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PIGMENT COMPENDIUM

A Dictionary of Historical Pigments

Nicholas Eastaugh • Valentine Walsh
Tracey Chaplin • Ruth Siddall

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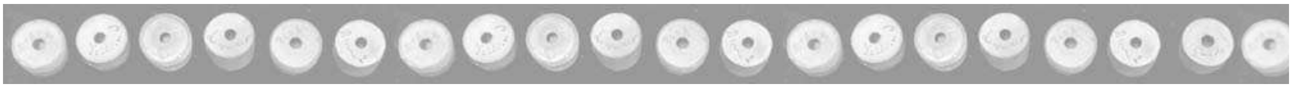

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INTRODUCTION

> ‘Artists have given to certain matters employed in the arts denominations which are more calculated to embarrass than to encourage amateurs … this is a real abuse of words, which habit preserves among our workmen, and which ought to be banished if we are desirous of rendering the language of the arts intelligible.’
>
> P.F. Tingry, *The Painter and Varnisher’s Guide*,
> First edition (1804), p. 374

Tingry’s lament is perhaps as true now as it was at the beginning of the nineteenth century. Moreover, it could be reasonably argued that the terms used for pigments have become no simpler in that time – rather, that situation has been made more complex by the need to relate past writings on pigments to a modern understanding of chemistry. This volume is, therefore, an attempt to bring a degree of order to a field that struggles, wittingly or unwittingly, to deal with the nature of pigments and what we call them.

The origins of this book lie with the companion volume on optical microscopy of pigments and a functional requirement for the authors to develop a resource that could lead the scientist, historian and conservator from those obscure but perhaps familiar terms to the science. At the outset of the project it was apparent though that three fundamental but interrelated questions needed to be addressed. First, what pigments have been used historically? Second, what terms have been used for them? Third, what should we call them now? The answers that came out of these (and difficulties in easily providing them) led to the realisation that there was a broader need for a more substantial volume addressing the issues of terminology and the composition of pigments. It also became clear from this research that as a field we have commonly been operating within too narrow a band of pigments and that there is a marked discrepancy between the materials described in past treatises and the reports of pigments found on artefacts. This book is consequently not intended to replace the number of excellent studies on individual pigments that exist, rather to complement them and provide an up-to-date reference that helps deal with the wider complexities and interrelationships.

A decision was taken to structure the microscopy book around what are called here ‘generic’ pigments – the building-block compounds that comprise the pigments found on artefacts. However, this required an index of some sort to guide users from terms of common application such as ‘lead white’ or ‘Brunswick green’, where there are multiple associated compounds, to the specifics of a lead carbonate hydroxide or a copper chloride hydroxide. The complete listing of pigment compounds that was developed can be found at the end of this book along with a more detailed description of the conventions used for naming them, while the index itself is, of course, the primary content of this dictionary.

The authors debated extensively the rationale for including particular compounds or terms and the reader deserves some explanation of reasons behind the choices that were made. In practice the broad criteria used were that the compound or term should have been mentioned in historical documents in a paint context, or in research papers dealing with the analysis of artefacts. Additionally, specific compounds with a clear relationship to these were added under the following circumstances:

- The corresponding natural or synthetic analogue.
- Other compounds that are perhaps isostructural, isomorphous, or otherwise closely related by virtue of their chemistry where a discussion of the group properties is relevant.

In addition to these cases a few minerals were added where an examination of the geology suggested that future identifications were likely to be forthcoming, such as where they are known to be in common association with other minerals already listed.

As a first step it was necessary to address the issue of how many distinct pigments might have been used historically. The authors felt strongly that the scope of the review should be as broad as possible since only in that manner can the true relationships of history and geography, evolution and trade, be properly traced. The decision was therefore taken to cover as wide a range of information sources as possible. Consequently not just those pigments found on Western European easel paintings are detailed (though there is an inevitable bias toward this, largely because much of the research has been conducted in this area), but also those from wall paintings, decorative paint and archaeological material, worldwide, without barrier of time or place. Compounds used only in ceramic glazes and glass have been excluded but those applied as an unfired decoration, or that also find use in a painted context, are included. It was also decided to include a few materials encountered as (human) body decoration. Dyestuffs, however, unless there was an explicit indication of use for painting rather than dyeing in the conventional sense, were omitted.

On a similar basis it was decided that the work should be inclusive rather than exclusive; where the evidence for the use of a compound was only partial, inclusion was none-the-less given (an example might be a mineral which was identified by X-ray diffraction, where it may actually be the synthetic analogue or an alteration product of another, more common, pigment). It also seemed appropriate to include some minerals which are rare and unlikely to have been used themselves as pigments but which are well characterised analogues of pigments (examples would be the rare mineral bayerite and the related aluminium hydroxide, or cuprorivaite and the related calcium copper silicate generally known as ‘Egyptian blue’). Third, the chemical literature was consulted to clarify what related forms and crystalline phases of a compound exist and might reasonably be stable under pigment conditions (though related compounds not directly described as pigments that are unstable under normal conditions were largely excluded unless they might represent transient phases of production). Finally, a number of compounds detailed in the historical literature were also added, even though they may have been experimental – Salter's 1869 edition of Field's *Chromatography*, for example, gives a large number of such compounds – the rationale here being that they *might* have been used or are of possible interest to historians, analysts and practitioners; these have also been cross-checked with the chemical and other technical literature in an effort to provide some indication of composition. It has also been necessary in reading the literature to decide whether a distinct pigment is involved, that a term refers to an established synonym or variant, or that the term is of indefinite or variable meaning. Finally, a number of terms were encountered which in practice refer to a multiplicity of compounds – 'clay' might be an obvious example, but more subtle cases were also encountered.

A number of naming conventions have been used, notably among the chemical terms. Further, specialist terms such as mineral, botanical and zoological names have been checked in a number of sources. Details of these may be found in the introduction to the generic compounds table later in this volume; the reader is strongly advised to read this. For common names and allied terms the principal form used in this dictionary has been chosen on the basis of that which appears to be most common; in some cases guidance was sought from the *Oxford English Dictionary* as to which spelling was used as the main word title. However, radically different spellings have sometimes been included as a separate entry where any alternate etymology (should it exist) is discussed or the topic simply referred to the main discussion. On the other hand this is not a translating dictionary and non-English terms have only been included under a very limited set of conditions. These are primarily where a term is of common English usage (such as 'Terre vert'), or of distinct meaning in the original language but relevant to discussions of English terminology (such as 'general' and 'genuli'), or provide a convenient umbrella under which to discuss certain issues (such as 'cimatura'). It was also felt appropriate to include some historical terms of importance to the understanding of, for example, classical texts, or to the etymology of other terms. Additionally, some excellent modern translations have brought treatises not originally in English to the general attention of the English-speaking world (for example, Veliz, 1986) making the inclusion of some of those terms both useful and appropriate. Lastly, contemporary analytical studies of the artefacts of other cultures require the use at some points of the original terminology, though these have not usually been included as a primary term. This dictionary also generally uses terms in translation, unless the English literature cited refers to a term in the non-English version, or that a confusion or lack of distinction could arise when the literature cited is referring to a term in another language.

Under each entry in the dictionary one of three broad categories has been given that indicates its relationship to other terms. Additionally, these categories are used to group related terms that appear at the foot of each entry. The 'Group' category (**bold** in the footer text) refers to groups of generic compounds that are linked by a common composition. This might be all aluminium compounds, or the aluminium oxides and hydroxides, or the anthraquinones. Second, specific compounds are given the 'Generic' designation (normal font in the footer text) where they are of specific composition and structure; these are the building-block compounds themselves, found individually or severally within the pigments of use. However, in addition to this the compound may be called a 'Generic variety' where, for example, a particular form of a mineral exists; such as alabaster, which is a variety of gypsum. Also within this category are the 'Common generic composites', a designation introduced to cover those materials composed of more than one generic compound but that are (almost) invariably used as a combined material. Obvious examples of these are the naturally derived materials such as dyestuffs or earth pigments. A number of borderline cases that might come under this heading were rejected and treated as common names, on the grounds that they were primarily characterised by one major component even though secondary phases were normally encountered. An example of this is Egyptian blue, which is here defined as calcium copper silicate.

The third category (*italics* in the footer text) covers the other relationships such as synonyms, manufacturing or source variant names, trade names and other related or associated terms. It is worth pointing out that when dealing with historical terminology it is generally necessary to consider a number of categories apart from the chemically specific and examine the relationships that exist between the 'generic' terms mentioned above and the common names, synonyms, varieties, and terms of variable, indefinite or unknown meaning that make up a substantial part of the discussion in the book. In practice the relationships between such common names and generic pigments are highly complex; on the one hand a single common name may refer overtly or covertly to a number of generics, while in other cases the reverse may be true and two or more common names may refer to a single generic. Only in rare cases is there a simple correspondence, the common name unambiguously referring to a single generic term. Awareness of the confusions engendered by these complex relationships made the clarification of such problems through systematic naming a principal objective of this publication.

A synonym, as in the usual meaning of the word, refers here to a term of direct equivalence, but one not to be considered as the primary common name. Various types of synonym might be discerned such as:

- Historical synonyms – terms of historical usage, now discontinued.
- Contemporary synonyms – terms of current usage or recent invention.
- Linguistic synonyms – either:
  - Equivalent terms in different languages or
  - Orthographic variants.
- Commercial synonyms – specific trade names applied by manufacturers or suppliers to essentially identical pigments.

What are called here 'variants' are pigments that have some distinct physical or chemical feature that significantly deviates from their prototypical form. Examples are shade variants and morphological variants; in the former the precise colour separates this pigment from another, in the latter it is the physical shape. Importantly, it should be noted that shade variants have not been taken into special account in the naming conventions described elsewhere in this volume, while morphological variants have. Such considerations led the authors to develop a series of categories which they hope are capable of reflecting some of these subtleties. Terms of variable, indefinite or unknown meaning are discussed wherever possible by relating the source(s), original context and subsequent interpretations. Many of these terms remain none-the-less obscure and they will surely provide a rich and fertile soil for future research.

An indication of the colour of the pigment is also provided, not solely for the purposes of describing this property of a compound or material, but also because a straightforward system was needed for electronic searching of the data (for example, 'find all yellow pigments'). A simplified series of *ad hoc* categories was therefore developed as the research for the dictionary progressed. Originally this category was intended to be a brief indication of the broad class of colour (blue, green, red and so forth). However, for a variety of reasons it seemed practicable to introduce broader ranges ('Red-Orange-Yellow') where this better suited the colours of a pigment, or special categories were required (such as pH sensitive dyestuffs that might range from red to blue). The complete list of colour classes used is as follows: Black, Black-Brown, Black-White, Blue, Blue-Green, Blue-Purple, Brown, Green, Green-Yellow, Grey, Orange, Pink, Purple, Red, Red-Blue, Red-Brown, Red-Orange, Red-Orange-Yellow, Red-Purple, White, Yellow, Yellow-Brown, Yellow-Orange, Metal, Variable (that is, outside the range of available descriptions) and Unknown. It should be stressed that this does not relate to any particular colour specification system; rather, it was a pragmatic solution to a problem of description.

The main body of each entry contains a range of information about the term, most of which is self-explanatory. For generics and generic groups this typically covers the chemical composition, the specific crystal or mineral form, the physical source and/or conditions under which it forms and any related species. Associated terminology (usually only the primary relationships) as well as the *Colour Index* constitution number may be included if relevant or the discussion redirected to an associated common name. In the entries for common names the discussion primarily covers the context under which the term is used, the associated terminology and historical methods of manufacture (unless that is superseded by a discussion under a related generic compound).

It was originally intended not to include comprehensive information on the geographical and temporal distribution of individual pigments and terms as it was apparent from an early stage that numerous compounds existed about which we know relatively little and in-depth studies of this nature were far outside the scope of this volume. Therefore there is no formal presentation of usage. It seemed reasonable, however, to broadly indicate some of what is known, especially where the data is more secure, or the occurrences so rare or specific that the context becomes important. Therefore, included in a number of the discussions are instances where particular pigments have been identified in analytical studies of artefacts; these are intended to be indicative of the types of physical context rather than complete listings. Depending on whether the identification is tied to a specific compound or a commonly used name, so the information is listed under the most appropriately specific entry. Additionally, where good reviews of the pigment exist, the listings in this volume instead provide data on alternate contexts or identifications that appeared only in the recent literature.

This book could not have been written without the 'giant's shoulders' of previous authors, the task of returning to all the primary sources being prohibitive in terms of the time which would be required. In practice a compromise has been sought whereby specialist surveys have been plundered, but wherever possible the original sources have also been hunted down and checked. In some cases this was not possible and in those situations both the original reference and the citing source are given (noted as 'cf.' in the text). Additionally, where modern editions of early sources have been referred to, the convention used gives the date of the original edition in the main text (since this is most relevant to understanding the historical context) while the full information on the specific edition of the work is then given in the reference at the end. Finally, mediaeval texts have been given a further reference number relating to the classification given by Mark Clarke in *The Art of All Colours*, Mediaeval Recipe Books for Painters and Illuminators (2001).

Additionally, a flexible approach to the integrity of the sources cited was taken since an intention was to present not only what a term *may* have meant historically, but also what people *thought* it meant. Therefore comments, views and opinions are truly the authors' own – the editorial process of preparing this dictionary was in part aimed at supplying the reader with as much original data as possible to follow lines of thought of their own while at the same time forming a balanced view. None-the-less, the sophisticated reader should make his or her own judgement about the veracity of particular sources.

Finally, two requests from the authors to the reader. First, this has been a long and complex project, one that has evolved substantially from the original concept of an augmented index. As the ideas have developed, so have the ways in which the information needed to be presented; some things may have been left behind. The dictionary was in fact written using a database specially designed by the authors so that highly formatted text could be entered, links developed, categories defined and so forth; the book was only generated at the very final stage of production, so that the latest information available to us could be included. Numerous checks were made in this process using software tools again developed by the project team, with the aim of ensuring a high level of integrity in the information. None-the-less, errors of both commission and omission are bound to have crept in and for these we sincerely apologise in advance. Second, the authors are also aware that an endeavour such as this should never be considered complete; knowledge is an evolutionary process, one that ought to be seen as a journey rather than a destination. We would therefore welcome contributions of new material, being not only acutely aware of the vast amounts of untapped sources of information relevant to the history of pigments, but also of the fascination this field holds for so many of our colleagues, and their diligence and scholarship.

Nicholas Eastaugh, Valentine Walsh,
Tracey Chaplin and Ruth Siddall
July 2003

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A

AAL
Red
Synonym, variant or common name

A common name for madder derived from various *Morinda* species (Rubiaceae) and used for printing on cotton in seventeenth century India. *Chiranjee* and *saranguy* were synonymous (Gittinger, 1982; cf. Schweppe and Winter, 1997).
See: madder.

Gittinger (1982); Schweppe & Winter (1997)

ACADEMY BLUE
Blue-Green
Synonym, variant or common name

According to Heaton (1928), academy blue was a compound colour said to be based on ultramarine (presumably the synthetic form) and the hydrated chromium oxide pigment viridian (*qq.v.*).

Ultramarine; *Viridian*
Heaton (1928) 379

ACCROIDES
Red-Orange-Yellow
Synonym, variant or common name

See: xanthorrhoea.

ACETATE GREEN
Green
Synonym, variant or common name

Term apparently associated with *Brunswick* and *chrome greens*, the former a pigment of variable composition, the latter typically based on a chromium-based yellow pigment and Prussian blue (*q.v.*).

Brunswick green; *Chrome green*; *Prussian blue*

ACETYLENE BLACK
Black
Synonym, variant or common name

Like the thermal black (*q.v.*) process, this was produced by incomplete combustion (thermal cracking) of a hydrocarbon source, in this case acetylene. The preparation of this pigment is dramatically described by Heaton (1928) as involving ‘exploding a mixture of acetylene and air under pressure’. Continuous processes of production were developed later (Buxbaum, 1998).

Carbon-based blacks group: Flame carbons sub-group; *Thermal black*
Buxbaum (1998) 159–160; Heaton (1928) 175

ACKERMANN’S WHITE
White
Synonym, variant or common name

According to Harley (1982), the English firm of colourmen Ackermann sold a silver-based pigment known as *light white*. De Massoul (1797), who provides a recipe for this, also lists *Ackermann’s white* under silver pigments and we must suppose that the two were wholly or largely identical in composition. Additionally, Harley, quoting de Massoul, states that zinc oxide (*q.v.*) was often mixed with a white precipitate of silver to make up for the lack of body for use as a watercolour. Harley further suggests that as Ackermann’s treatise (1801) is based on the work of de Massoul, Ackermann’s white was a mixture of zinc oxide and the white precipitate of silver.

Zinc oxide; *Light white*
Harley (1982) 174, 178; Massoul (1797)

ACKERMANN’S YELLOW
Yellow
Synonym, variant or common name

Harley (1982) encountered a reference to Ackermann’s yellow in a treatise on Ackermann’s watercolours dated 1801. From the description of the pigment she suggests that it is an early example of a quercitron (*q.v.*) lake (dye derived from *Quercus tinctoria* on an inorganic base).

Flavonoids group; Quercitron
Harley (1982) 115

ACTINOLITE
Green
Generic compound

Actinolite is a green fibrous amphibole group (*q.v.*) mineral of composition $Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$, sometimes known as nephrite jade. The name is derived from the Greek *aktinos* meaning ‘ray’, alluding to the fibrous habit of the mineral. Actinolite is found worldwide in certain metamorphosed rocks, particularly in green schists and talc schists and low- to medium-grade metamorphosed limestones. It is also sometimes found as a replacement for pyroxene in basic igneous rocks. Nephrite jade is the ornamental stone variety and is distinguishable by its greater compactness due to intergrown crystalline aggregates. Although actinolite is not considered to be a pigment in its own right, it may be present in natural green earth (*q.v.*) pigments which are often derived from the weathering of the rocks in which actinolite is found (Grissom, 1986; Kittel, 1960; Mitchell *et al*., 1971). The *Colour Index* (1971; CI 77718/Pigment White 26) also lists actinolite as a source mineral.

Amphibole group; Calcium group; Iron group; Magnesium group; Silicates group; Green earth
Colour Index (1971) 77718; Grissom (1986); Kittel (1960); Mitchell *et al*. (1971)

AEGIRINE
Green
Generic compound

Aegirine is a member of the pyroxene group (*q.v.*) of silicate minerals, often occurring in association with augite (*q.v.*); (Clark *et al*., 1969). It has composition $NaFe^{3+}Si_2O_6$ and is named after the Teutonic god of the sea. Aegirine is commonly found in alkali-rich igneous rocks such as syenites and alkali granites which usually occur in areas of continental extension (Rutley, 1988). Major occurrences of aegirine are its type locality in Kongsberg, Norway, as well as Magnet Cove (Arkansas, USA), Illimaussaq (Greenland) and Kola Peninsula (Russia). Although aegirine is not considered to have been used as a pigment in its own right, it is a possible relict mineral in green earths (*q.v.*), which are themselves derived from the erosion of alkali rocks in which aegirine may be present.

Iron group; Silicates group; Pyroxene group; Augite; Green earth
Clark *et al*. (1969); Rutley (1988)

AERINITE
Blue
Generic compound

Aerinite is a blue or blue-green calcium iron aluminosilicate mineral with approximate composition $Si_3Al_5O_{42}(Fe^{2+},Fe^{3+})_3.(Al,Mg)_2Ca_5(OH)_6.13H_2O$, in which about 1% sulfur is usually present (Cressey, pers. comm., 2003), although Azambre and Monchoux (1988) and Besteiro *et al.* (1982) give an ideal composition of $Ca_4(Al,Fe^{3+},Mg,Fe^{2+})_{10}Si_{12}O_{36}(CO_3).12H_2O$. Although first mentioned in the literature by Lasaulx in 1876, Dana (1892) later indicated that he thought aerinite might be a synthetic material 'perhaps owing its colour to artificial means'. Although purported by some sources to belong to the clay minerals group (*q.v.*), recent research has suggested that it has a very different structure to a clay, consisting instead of nanotubes, elongated along the fibres of the mineral, though the characterisation of aerinite is difficult due to the very small fibre-like crystals up to 0.1 micron wide which comprise each sample (Cressey, pers. comm., 2003).

The mineral name is derived from the Greek root *aer-* referring to the sky or atmosphere and thus the colour of the mineral. The intense blue colour is caused by delocalised electron transfer involving Fe^{2+} and Fe^{3+} in adjacent octahedral sites which form chains along the crystal fibres (Rius *et al*., 1998); the intensity of the colour may be modulated by the presence of aluminium or magnesium cations in intervening octahedral sites (Cressey). Lago and Pocovi (1980) and Amigo *et al.* (1982) describe the formation of aerinite in veins in brecciated volcanic rocks (dolerites) and this mineral has been found to occur in many localities worldwide in the same type of geological setting, such as the Huesca and Lerida provinces (northern Spain), at St Pandelon (Landes, France) and Morocco.

Aerinite has been reported to have been used in certain twelfth century Romanesque frescos of the Pyrenean region of Catalonia and in Andorra (Casas, 1991; Porta, 1990; Pradell *et al*., 1991). Casa and Llopis (1992) have also suggested using both natural and 'burnt' aerinite (the latter a green-blue) colour for restoration purposes.

Clay minerals group; Silicates group
Amigo *et al.* (1982); Azambre & Monchoux (1988); Besteiro *et al.* (1982); Casas (1991); Casas & Llopis (1992); Dana (1892); Lago & Pocovi (1980); Porta (1990); Pradell *et al*. (1991); Rius *et al*. (1998)

AERUGO
Green
Synonym, variant or common name

Aerugo (Pliny, 77 AD) or *aeruco* (Vitruvius, first century BC) occurs as a Latin term for various blue-green and green corrosion products of copper, its alloys and ores. It is stated in Pliny's *Naturalis Historia*, that '*Aeruginis quoque magnus usus est*' ('Great use is also made of verdigris'), though from his comment that *aerugo* can be scraped from natural copper ore (König, cf. Kühn, 1993a) it is clear that this refers to more than verdigris in the modern sense (that is, various copper acetates). However, *aerugo* (from the Latin *aes*, meaning brass or copper) might be used in classical and later Latin texts simply to mean any metallic corrosion product.

Copper acetate group; *Verdigris*
Kühn (1993a); Pliny (1st cent AD/Rackham, 1952) XXXIV.xxvi ff.; Vitruvius (1st cent BC/Grainger, 1934) VII.xii.1

AFRICAN COCHINEAL
Red
Synonym, variant or common name

Salter (1869) lists this, also giving the alternate term *Paille de Mil*. He is unspecific about the exact nature of it, unsure even that it derives from a cochineal-type insect.

Cochineal
Salter (1869) 170–171

AFRICAN GREEN
Green
Synonym, variant or common name

Proprietary name used by the English colour manufacturing firm of Berger to denote a form of Scheele's green (*q.v.*; Bristow, 1996b).

Copper arsenite group; *Scheele's green*
Bristow (1996b) 28

AKAGANÉITE
Yellow-Brown
Generic compound

Akaganéite is a brown, brown-orange or bright yellow iron hydroxide mineral with composition $Fe^{2+}(O,OH,Cl)$ (Mackay, 1962). It is derived from the weathering of iron-rich minerals and may occur in association with other iron hydroxides such as goethite and lepidocrocite (*qq.v.*). Akaganéite is rare and usually forms as a friable powder or as a more coherent massive crust, usually in chlorine-rich environments (especially in acid mine waters; Schwertmann and Cornell, 2000). It is named after its type locality at Akagané mine (Iwate Prefecture, Japan), where Nambu discovered it in 1961. Akaganéite can be synthesised by inorganic or bacterial oxidation (see Schwertmann and Cornell, 2000). The compound has not been recognised as a pigment, but has been identified on 'ancient iron implements' as an oxidation deposit in association with magnetite, goethite and lepidocrocite (Yabuki and Shima, 1979).

Iron group; Iron oxides and hydroxides group; Goethite; Lepidocrocite
Mackay (1962); Schwertmann & Cornell (2000); Yabuki & Shima (1979)

ALABASTER

White

Generic variety

Alabaster is a form of gypsum (hydrated calcium sulfate; *q.v.*), occurring as a fine-grained, massive mineral which is used as an ornamental stone. It can become coloured, a property dependent on associated minerals – for example, hematite (*q.v.*) will impart a red colour. 'Oriental alabaster' is a term for a stalagmitic variety of calcite (*q.v.*) characterised by well-marked banding; it should therefore not be confused with alabaster proper.

According to Veliz (1986) the Spanish term *de espejuelo* (which occurs in a discussion of preparing *gesso* grounds given in Pacheco's *Arte de la Pintura*, 1638) apparently signifies a recrystallised calcium sulfate derived from alabaster. There are also numerous examples of alabaster being added into paint formulations of quite diverse colour in the English manuscript by Fishwick (1795–1816).

Alabaster is also listed in the *Colour Index* (1971; CI 77231/ Pigment White 25) as a source of calcium sulfate.

Calcium group; Calcium sulfates group; Calcite; Calcium sulfate, gypsum type; Gypsum; Hematite; *De espejuelo*
Colour Index (1971) 77231; Fishwick (1795–1816) 58, 60–63, 76–77; Pacheco (1638) Bk 3, VII, 120; Veliz (1986) 209, n.106

ALACRANITE

Red-Orange-Yellow

Generic compound

Alacranite is an orange-red or yellow-orange monoclinic arsenic sulfide mineral with chemical composition, As_8S_9. It is the high temperature modified form of realgar (*q.v.*) and often occurs in association with it. Alacranite occurs as a volcanic sublimate (for example, at Vesuvius, Italy or Udon volcano at Kamchatka, Russia), as a deposit from hot springs (Steamboat Springs, Nevada) or in mineral veins (Tuscany, Italy). The type locality for alacranite is in Chile at Alacran, Pampa Larga, where it was discovered in hydrothermal mineral veins (Popova *et al*., 1986). A specimen from here examined by Clark (1970) was reported to be slightly paler and more yellowish in colour than realgar from the same deposit that in turn was a 'richer, redder orange than most realgar specimens'.

Although apparently rarely encountered in artefacts, FitzHugh (1997) mentions an identification of alacranite on an early colonial-era Mexican painted deerskin.

Arsenic group; Realgar
Clark (1970); FitzHugh (1997); Popova *et al*. (1986)

ALAMOSITE

White

Generic compound

Alamosite is a white fibrous lead silicate mineral with chemical composition $PbSiO_3$. Its mineralogical properties are poorly known. It is found in localities associated with regional metamorphism in which lead-rich hydrothermal fluids percolate through and alter the surrounding silicate-rich rocks. Alamosite is named after its type locality of Alamos, in Sonora, Mexico and has also been found in the Tsumeb Mine of Otavi, Namibia and in the Altai Mountains in Russia (Boucher and Peacor, 1968).

The synthetic form of alamosite, lead silicate has been described for use as a paint extender and is listed in the *Colour Index* (1971) as CI 77625/Pigment White 16.

Lead group; Lead silicates group
Boucher & Peacor (1968); *Colour Index* (1971) 77625

ALBÍN

Red-Brown

Synonym, variant or common name

A term used by the seventeenth-century Spanish author Pacheco in his *Arte de la Pintura*; it is, according to Veliz (1986), the name of a dark reddish-brown pigment used in fresco, likely to be an earth pigment.

Earth pigments group
Pacheco (1638) Bk 3, III, 51; Veliz (1986) 206, n.55

ALBITE

White

Generic compound

Albite is a white, grey, greenish-grey, or bluish-green sodium alumino-silicate mineral with chemical formula $NaAlSi_3O_8$ (Rutley, 1988). The name derives from the Latin *albus*, pertaining to its common white colour; it has also been known historically as clevelandite. It is a member of the feldspar group (*q.v.*) and a solid solution series exists between albite and anorthite ($CaAl_2Si_2O_8$), with albite being considered to have $<10\%$ of the anorthite (*q.v.*) component. Other members of the series are oligoclase, andesine, labradorite and bytownite (*qq.v.*) which contain increasing amounts of anorthite (Ferguson *et al*., 1958).

Feldspars commonly occur worldwide in all igneous rocks, as detrital grains in many terrigenous sedimentary rocks and as crystals in many metamorphic rocks. Albite is the most common plagioclase feldspar in spillite lavas and low-grade metamorphic schists, particularly at Amelia, Virigina, USA and Bourg d'Oisans and Isère, France. The occurrence of albite in pigments is likely to be by association only, as it breaks down easily in the presence of hydrothermal fluids to clay minerals such as montmorillonite and kaolinite (*qq.v.*). However, Duang *et al*. (1987) report albite as a component in the plasters of Buddhist temples in Dunhuang, China. It is also listed by Price *et al*. (1998) as occurring on paintings by Vincenzo Foppa (1427/30–1515/16).

Aluminium group; Feldspar group; Silicates group; Analcime; Andesine; Anorthite; Bytownite; Kaolinite; Labradorite; Montmorillonite; Oligoclase
Duang *et al*. (1987); Ferguson *et al*. (1958); Price *et al*. (1998); Rutley (1988) 422–425

ALEXANDRIAN BLUE

Blue

Synonym, variant or common name

Synonym for Egyptian blue (*q.v.*; Riederer, 1997).

Calcium copper silicate; *Egyptian blue*
Riederer (1997)

ALEXANDRIAN WHITE

White

Synonym, variant or common name

Andrea Cesalpino around 1500 relates tin white to Spain (Spanish?) white, furthermore naming Alexandrian white ('*biacca Allessandrina*') as a synonym. According to Seccaroni (1999a), tin white in this context would be tin(IV) oxide (*q.v.*) and the reference to Spain probably derives from the existence of a tin mine in Spain that had been in operation since antiquity.

Tin(IV) oxide; *Tin white*
Seccaroni (1999a)

ALEXANDRINE GREEN
Green
Synonym, variant or common name

See: green earth.

ALIZARIN
Orange
Generic compound

Strictly, 1,2-dihydroxy-9,10-anthracenedione (or: 1,2-dihydroxyanthraquinone). Alizarin is found as a major component in extracts of the roots of various member species of the Rubiaceae, Morinda, Gallium and Oldenlandia families; it is therefore a principal constituent of madder (*q.v.*) dyes. It may also be prepared synthetically: early methods were from 2-anthraquinonesulphonic acid (Caro *et al*., 1870; Perkin, 1876). There are historical reviews by Fieser (1930) and Schweppe and Winter (1997).

Alizarin has been, and continues to be, used as a dye in the preparation of lake pigments. It is catalogued by the *Colour Index* as CI 75330, CI Mordant Red 11 and CI Pigment Red 83.

The term 'alizarin' appears to have been used historically for a wide range of colours not within the normal range of alizarin-metal complexes (such as 'Alizarin blue' and 'Alizarin green'); these are probably instances of attempts to name pigments on the basis of a supposed chemical relationship or perhaps a colour or behavioural similarity only (Heaton, 1928).
See: madder.

Anthraquinones group; Madder
Caro *et al*. (1870); *Colour Index* (1971) 75330; Fieser (1930); Heaton (1928) 188; Perkin (1876); Schweppe & Winter (1997)

ALIZARIN BLUE
Blue
Synonym, variant or common name

A pigment of unknown composition listed in various sources (for example, Mayer, 1991). It is probably one of the synthetic dye-based pigments inaccurately called 'alizarin' (*q.v.*).

Alizarin
Mayer (1991) 35–36

ALIZARIN BROWN
Brown
Synonym, variant or common name

Mayer (1991) describes this as a 'rather dull but transparent brown', further noting that it may be produced as the result of 'an occasional off-color batch of red' (that is, of an alizarin (*q.v.*) lake).
See: madder brown.

Alizarin
Mayer (1991) 36

ALIZARIN CRIMSON
Red
Synonym, variant or common name

Synonym for, or shade variant of, an alizarin lake. Mayer (1991) also notes a variety of this pigment called 'golden alizarin crimson'.

Alizarin
Mayer (1991) 36

ALIZARIN GREEN
Green
Synonym, variant or common name

Carlyle (2001) found this listed in a Winsor & Newton catalogue of 1900. However, the precise composition is unknown and it is probably one of the synthetic dye-based pigments to which the term 'alizarin' (*q.v.*) was inaccurately applied historically. For example, Heaton (1928) lists Alizarine green (*sic*), stating that it was a 'derivative of alizarine'.

Alizarin
Carlyle (2001) 496; Heaton (1928)

ALIZARIN ORANGE
Orange
Synonym, variant or common name

Listed in a Winsor & Newton catalogue for 1900 (cf. Carlyle, 2001). The composition is unknown, but could be either a shade variant of an alizarin lake or one of the inaccurately termed 'alizarin' pigments based on a synthetic dyestuff other than alizarin (*q.v.*).

Alizarin
Carlyle (2001) 501

ALIZARIN RED
Red
Synonym, variant or common name

Heaton (1928) lists Alizarine red (*sic*), stating that it was a 'derivative of alizarine'. Alizarin red S, a sulfonated alizarin, is a red anionic anthraquinone dye. Gurr (1971) reports that it was used for the preparation of lake pigments.

Alizarin
Gurr (1971) 234–235; Heaton (1928) 379

ALIZARIN SCARLET
Red
Synonym, variant or common name

A form of alizarin lake.
See: alizarin.

ALIZARIN VIOLET
Purple
Synonym, variant or common name

According to Mayer (1991), this is produced from synthetic purpurin (*q.v.*) in the same manner as an alizarin (*q.v.*) lake. Heaton (1928) lists Alizarine purple (*sic*), stating that it was a 'derivative of alizarine'.

Alizarin; Purpurin; *Violet madder lake*
Heaton (1928) 379; Mayer (1991) 36

ALIZARIN YELLOW
Yellow
Synonym, variant or common name

Mayer (1991) describes this as a 'dull, rather brownish, but transparent yellow' without giving information on the composition. However, Heaton (1928) lists Alizarine yellow (*sic*), stating that it was a 'derivative of alizarine'.

Alizarin
Heaton (1928) 379; Mayer (1991) 36

ALIZARIN, 2-METHYL ETHER

Orange
Generic compound

Methyl derivative of alizarin (*q.v.*) also found in the naturally derived dyestuff madder (*q.v.*; extract of *Rubia* roots and other related Rubiaceae species).

Anthraquinones group; Quinones group; Alizarin; Madder

ALKANET

Red-Blue
Generic compound

Common name for a dye derived from the roots of *Alkanna lehmannii* Tineo (formerly known as *Alkanna tinctoria* Tausch., *A. tuberculata* and, in older literature, *Anchusa tinctoria* Lamm.), a member of the Boriginaceae family. The plant is found in Asia Minor, Hungary, Greece and the Mediterranean region. *Pentaglottis sempervirens* (L.) L. Bailey (Boriginaceae; found in south-western Europe) is also known as *alkanet*, while *Lithospermum arvense* L. (Boriginaceae; Eurasian distribution) is known as 'bastard alkanet'; use of these species as dye/pigment plants is uncertain. The principal colouring constituent in Alkanna is alkannin along with alkannan (*qq.v.*) and in Lithospermum it is shikonin. It can give red (acid conditions) or blue-green (alkaline conditions) colours (*Merck Index*, 1996; Schweppe, 1992).

Other terms for alkanet include alkanna, orcanette, dyer's alkanet, anchusa or orkanet.

The third edition of Tingry (1830) lists alkanet as a dye used to colour lacquers, while in 1860 Ure (giving the species as *Anchusa tinctoria*) states that it is grown in Montpellier, France and in the Levant. Salter (1869) describes it as the basis of what he calls violet carmine (*q.v.*) and Schweppe (1992) identified a sample from the Deutsches Museum in Münich labelled 'Karmineviolett' as aluminium lake of alkanna.

Naphthoquinones group; Alkannan; Alkannin; *Violet carmine*
Merck Index (1996); Salter (1869) 302; Schweppe (1992) 196; Tingry (1830); Ure (1860)

ALKANNAN

Red
Generic compound

A naphthoquinone dyestuff which is the secondary colouring matter derived from the roots of the plant *Alkanna lehmannii* Tineo (formerly known as *Alkanna tinctoria* Tausch. and commonly *Alkanet*, *q.v.*) (Schweppe, 1992). It is catalogued by the *Colour Index* (1971) as CI 75520.

Naphthoquinones group; Alkanet
Colour Index (1971) 75520; Schweppe (1992) 191

ALKANNIN

Red-Brown
Generic compound

A naphthoquinone dyestuff which is the principal colouring matter derived from the roots of the plant *Alkanna lehmannii* Tineo ('Alkanet'; *q.v.*). Chemically this is (S)-5,8-dihydroxy-2-(1-hydroxy-4-methyl-3-pentenyl)-1,4-naphthalenedione (or: (1-hydroxy-3-isohexenyl)naphthazarine). It is soluble in organic solvents, but only sparingly soluble in water. The colour varies according to pH; buffered aqueous solutions are red at pH 6.1, purple at pH 8.8 and blue at pH 10.0 (*Merck Index*, 1996, Mills and White, 1994). It is catalogued by the *Colour Index* as CI 75530.

Naphthoquinones group; Alkanet
Colour Index (1971) 75530; *Merck Index* (1996) 253; Mills & White (1994) 144

ALMAGRA

Red
Synonym, variant or common name

According to Harley (1982) and Veliz (1986), *almagra* was originally a Spanish term for a red iron oxide pigment which Field (1835) states is found in Andalusia and is also called *Terra Sinoptica*. Other variants include *almagre*, *almaigre* and *almagro*. Harley also specifically notes letters patent granted in 1626 covering the Forest of Dean, Gloucestershire, England, that gave control over 'grinding and makeing that Redocker or Red Earth called Almagro and of refining, washing, deviding from gravell or sande the burnte Ocker digged in the fforeste of Deane called Spanish Browne'.

Carrillo, writing about the New Mexico painters known as santeros ('saint makers'), states that: 'Oral history from the Questa Valley as well as from Taos Pueblo details the collection of a red oxide known locally as almaigre (almagre) from a cave above the village of Questa. An examination by the author of the red-oxide mine reveals that the site was mined in prehistoric times' (Carillo, 1998).
See: bole.

Iron oxides and hydroxides group; *Colorado*; *Spanish brown*
Carrillo (1998); Field (1835) 95; Harley (1982) 119; Veliz (1986) xvii

ALMAZARRÓN

Red
Synonym, variant or common name

A term used in the treatise by the eighteenth century Spanish author Palomino, *El museo pictórico y la escala óptica*; Veliz (1986) gives this as a variety of red earth.

Iron oxides and hydroxides group
Palomino (1715–24); Veliz (1986) 213, n.9

ALOE

Yellow-Brown
Common generic composite

Aloes form a genus of succulent plants of the Liliaceae; they have triangular, spear-like leaves and thorny ridges. Their original habitat is in Africa, southern Arabia and Madagascar but they have become naturalised in various other locations, notably the West Indies, central and southern USA and Asia. Although widely known for medicinal properties, several species yield a coloured juice on cutting the leaves which, when allowed to evaporate and the residue ground to a powder, can be used as a pigment for the production of a glaze or tinted varnish. It has a yellow-brown colour. The main species which produce the better grades are *Aloe barbadensis* Miller (also known as *A. vera* Linné, Curaçao aloe or Barbados aloe) and *A. ferox* and *A. perryi* from South Africa (Mills and White, 1994). The latex contains varying amounts of aloin (barbaloin), aloe-emodin, chrysophanol, volatile oil and resins. The principal dye components of these plants are the anthraquinones aloe-emodin and chrysophanol (*qq.v.*; *Merck Index*, 1996; Thomson, 1971).

The Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849) mentions 'soccotrine' aloes distempered in water as a yellow pigment, and Leonardo da Vinci (c. 1480) recommends the addition of Caballine aloe to verdigris to improve its colour stating, that saffron would be better were it not so fugitive. This indicates that it was a yellow colour. He suggests that the 'goodness of this aloe will be proved by dissolving it in warm brandy … this aloe may be ground also in oil by itself'. Several mediaeval German manuscripts (Oltrogge, 2003) refer to the use of aloe; however, this is generally as an additive in yellow foundations for gilding in illuminated manuscripts. These texts variously use the terms *aleopaticum*, *aloe epaticum* and *aloepaticum*, and therefore probably have as a source hepatic aloes. Boltz (1549) gives a list of gums for gold grounds among which are '*Calbanum*' and '*Alepaticum*'. It should be noted that according to Thompson (1956) they were also used as a glaze over powdered silver or tin to imitate gold.

Anthraquinones group; Aloe-emodin; Aloin; Chrysophanol
Boltz von Ruffach (1549/Benziger 1913) 59–61; da Vinci (c. 1480/trans. McMahon, 1956) 128–129; *Merck Index* (1996) 312; Merrifield (1849) II, 694; Mills & White (1994) 149; Oltrogge (2003); Thompson (1956) 184; Thomson (1971) 399–402

ALOE-EMODIN

Yellow-Orange
Generic compound

Aloe-emodin – 1,8-dihydroxy-3-(hydroxymethyl)-9,10-anthracenedione – is a component found in the latex of various species of aloe (*q.v.*) used to prepare the pigment known as aloe brown. It is also found in the roots of various Rehum species as well as in the stamens of Cassia species (*Merck Index*, 1996).
See: aloe, rhubarb and *Cassia fistula*.

Anthraquinones group; Aloe; Rhubarb
Merck Index (1996) 313

ALOIN

Yellow
Generic compound

Aloin ('barbaloin') is an anthraquinone component found in the latex of various species of aloe used to prepare the pigment known as *aloe brown*. The molecule, 10-glucopyranosyl-1, 8-dihydroxy-3-(hydroxymethyl)-9(10H)-anthracenone, is built from aloe-emodin (*q.v.*; *Merck Index*, 1996)

Anthraquinones group; Aloe; Aloe-emodin
Merck Index (1996) 314

ALUMEN

White
Synonym, variant or common name

According to references in the treatise ascribed to Heraclius, alumen appears to have been *allume scagliuola*, a kind of stone resembling talc, of which when calcined, is made the 'gesso da oro', or gesso of the gilders, and which is also used for the grounds of pictures. It was prepared for painting by grinding with gum and water, and was distempered when required with egg white (Heraclius; cf. Merrifield, 1849).

Merrifield (1849) clii, 232, 245

ALUMINA

White
Synonym, variant or common name

Widely used synonym for aluminium oxide.
See: aluminium oxides and hydroxides group.

ALUMINA BLANC FIXE

White
Synonym, variant or common name

Listed by the *Colour Index* (1971; CI 77122/Pigment White 23) where it is described as a co-precipitate of approximately 25% aluminium hydroxide and 75% barium sulfate (*qq.v.*). Prepared by co-precipitation from sodium carbonate, aluminium sulfate and barium chloride.

Aluminium oxides and hydroxides group; Aluminium hydroxide; Barium sulfate
Colour Index (1971) 77122

ALUMINA BLUE

Blue
Synonym, variant or common name

The German author Rose (1916) writes of *tonerdeblau* ('alumina blue') as being a synonym for cobalt blue – cobalt aluminium oxide (*qq.v.*). The term, usually qualified as in 'cobalt tin alumina blue', appears to be still in limited current use in the ceramics industry.

Cobalt aluminium oxide; *Cobalt blue*
Rose (1916) 288

ALUMINE ZUCCARINO

White
Synonym, variant or common name

Merrifield (1849) describes how *alumine zuccarino* was alum (potassium/aluminium sulfates) ground and heated with rose water, sugar and white of egg and allowed to harden by cooling. It was used as a base for lake pigments and in the preparation of verdigris (*qq.v.*).

Lake pigments; *Verdigris*
Merrifield (1849) 62, 66

ALUMINIUM

Metal
Generic compound

Aluminium powder has been used as a metallic flake pigment. The term 'aluminium bronze powder' (*q.v.*) also seems to refer to this.

According to Gettens and Stout (1966), although aluminium powder was probably available from the mid-nineteenth century, it was not until after the introduction of the Hall process for aluminium production in 1886 that this became readily available. Moreover, Edwards (1927) indicates that aluminium powder as a commercial paint was not widely used until after 1920.

The earlier history of aluminium pigments is given by Edwards and Gettens and Stout. Modern reviews include those by Smith (1983a,b).

Aluminium group; *Aluminium bronze powder*
Edwards (1927); Gettens & Stout (1966) 92; Smith (1983a, b)

ALUMINIUM BRONZE POWDER

Metal
Synonym, variant or common name

Synonym for a pigment produced from aluminium (*q.v.*) powder (Edwards, 1927). The use of the word 'bronze' in this context is probably by association with powders produced from copper alloys (Gettens and Stout, 1966).

Aluminium
Edwards (1927); Gettens & Stout (1966)

ALUMINIUM GROUP

Variable
Group term

After oxygen and silicon, aluminium is the third most abundant element in the earth's crust. Therefore, it is not surprising to discover that it is a component of a great many minerals, organic and inorganic compounds from which pigments have been derived. The following aluminium compounds are known to have been used as pigments or are closely associated with them:

Aluminium: metallic aluminium (Al)
Oxides and hydroxides: aluminium oxide (Al_2O_3) and corundum (Al_2O_3); the minerals and synthetic analogues of bayerite ($Al[OH]_3$), gibbsite ($Al[OH]_3$), nordstrandite ($Al[OH]_3$), doyleite ($Al[OH]_3$), diaspore and boehmite ($AlO(OH)$).
Aluminates: calcium aluminate ($CaAl_2O_4$), cobalt aluminate ($CoAl_2O_4$), lead aluminate ($PbAl_2O_4$) and hercynite (iron aluminate, $Fe^{2+}Al_2O_4$).
Phosphates: aluminium phosphate ($AlPO_4$).
Sulfates: aluminium sulfate ($Al_2[SO_4]_3$), alum ($Al_2[SO_4]_3$), alunite ($KAl_3[SO_4]_2[OH]_6$) and alunogen ($Al_2[SO_4]_2.18H_2O$).
Silicates: the amphibole group, the chlorite group, the clay minerals, the feldspar group, the mica group and the sheet silicates group.

Additionally, aluminium is found widely in other compounds used as pigments but classed here under different headings; an example is ultramarine where 'ultramarine' and 'lazurite' are listed as aluminium silicates.

Aluminium oxides and hydroxides group; Aluminium phosphates group; Aluminium silicates group; Aluminium sulfates group; Chlorite group; Clay minerals group; Cobalt group; Feldspar group; Metal pigments; Mica group; Aluminium; Aluminium hydroxide, bayerite type; Aluminium hydroxide, nordstrandite type; Aluminium oxide, amorphous type; Aluminium oxide, corundum type; Alunite; Alunogen; Bayerite; Boehmite; Calcium aluminium oxide; Chromium aluminium cobalt oxide; Cobalt aluminium phosphate; Corundum; Doyleite; Epidote; Hematite; Hercynite; Kaolinite; Lazurite; Lead aluminium oxide; Maya blue; Nacrite; Nontronite; Nordstrandite; Ochre; Palygorskite; Pyrophyllite; Ultramarine; *Alumina blanc fixe*; *Alumina blue*; *Alumine zuccarino*; *Aluminium bronze powder*; *Cobalt blue*; *Emery*; *Gloss white*; *Satin white*; *Spinel pigments*; *Turkish green*

ALUMINIUM HYDRATE

White
Synonym, variant or common name

Synonym for aluminium hydroxide (*q.v.*).
See: aluminium oxides and hydroxides group.

ALUMINIUM HYDROXIDE

White
Synonym, variant or common name

Commonly used term which may refer to one of a number of compounds that may be encountered as pigments, notably the following minerals and/or their synthetic analogues: bayerite, doyleite, gibbsite (or *hydrargillite*) and nordstrandite as forms of $Al(OH)_3$; diaspore and boehmite as forms of $AlO(OH)$ (Fricke, 1928; Hansen and Brownmiller, 1928; Winchell, 1931).

For a fuller discussion of aluminium oxides and hydroxides and their interrelationship, see the entry for aluminium oxides and hydroxides group.

Aluminium oxides and hydroxides group; Bayerite; Boehmite; Diaspore; Doyleite; Gibbsite; Nordstrandite; *Transparent white*
Fricke (1928); Hansen & Brownmiller (1928); Winchell (1931)

ALUMINIUM HYDROXIDE, BAYERITE TYPE

White
Generic compound

Synthetic form of bayerite (*q.v.*), an aluminium hydroxide mineral ($Al(OH)_3$, though older sources, including Winchell (1931), may give the seemingly equivalent but structurally inaccurate $Al_2O_3.3H_2O$) which is classed crystallographically among the water-bearing hydroxides and oxide hydrates. Aluminium hydroxide may in fact take on a number of crystalline forms, notably as the minerals and synthetic analogues of bayerite, doyleite, gibbsite and nordstrandite (*qq.v.*; Chao *et al.*, 1985).

Bayerite is generally only encountered as an artificial compound, being formed as part of the Bayer process of purifying the rock bauxite, a common commercial source of aluminium. According to Winchell (1931), this compound is produced by precipitating aluminium hydroxide from solution; as such, it is the form likely to be produced during preparation of lake pigments where a dyestuff is co-precipitated. In the context of pigments it therefore typically occurs as a lake substrate and also as a filler.
See: aluminium oxides and hydroxides group.

Aluminium oxides and hydroxides group; Bayerite; Doyleite; Gibbsite; Nordstrandite
Chao *et al.* (1985); Winchell (1931)

ALUMINIUM HYDROXIDE, BOEHMITE TYPE

White
Generic compound

See: aluminium oxides and hydroxides group.

ALUMINIUM HYDROXIDE, DIASPORE TYPE

White
Generic compound

See: aluminium oxides and hydroxides group.

ALUMINIUM HYDROXIDE, DOYLEITE TYPE

White
Generic compound

See: aluminium oxides and hydroxides group.

ALUMINIUM HYDROXIDE, GIBBSITE TYPE

White
Generic compound

See: aluminium oxides and hydroxides group.

ALUMINIUM HYDROXIDE, NORDSTRANDITE TYPE

White
Generic compound

Synthetic form of nordstrandite (*q.v.*), an aluminium hydroxide mineral ($Al(OH)_3$, though older sources, including Winchell (1931), may give the seemingly equivalent, but structurally inaccurate formula $Al_2O_3.3H_2O$) which is classed crystallographically among the water-bearing hydroxides and oxide hydrates; first identified by Nordstrand (Nordstrand *et al.*, 1956).

Aluminium hydroxide may in fact take on a number of crystalline forms, notably as the minerals and synthetic analogues of bayerite, doyleite, gibbsite and nordstrandite (*qq.v.*).

See the entry for Aluminium oxides and hydroxides group for a fuller discussion of the various compounds of this form which may be encountered and the conditions under which they are likely to occur.

Aluminium oxides and hydroxides group; Bayerite; Doyleite; Gibbsite; Nordstrandite
Nordstrand *et al.* (1956); Winchell (1931)

ALUMINIUM OXIDE

White
Synonym, variant or common name

Commonly used term that may denote one of several aluminium oxides which may be encountered as pigments. Of these the mineral corundum and its synthetic analogue, as well as an unnamed cubic form of Al_2O_3 may occur. Aluminium oxide is also commonly known as 'alumina'.

For a fuller discussion of aluminium oxides and hydroxides and their interrelationship, see the entry Aluminium oxides and hydroxides group.

Aluminium oxides and hydroxides group; Corundum

ALUMINIUM OXIDE, AMORPHOUS TYPE

White
Generic compound

Winchell (1931) gives a preparation method for an amorphous form of aluminium oxide, the conditions being stated as calcination of an aluminium hydroxide at 925°C 'for some hours'. At 1000–1200°C for 1 hour this compound converts to corundum (*q.v.*), so samples may have mixed phases. Heaton (1928) notes that synthetic aluminium oxide has been used as a substrate for lake pigments.

Aluminium oxides and hydroxides group; Corundum
Heaton (1928) 109, 193; Winchell (1931)

ALUMINIUM OXIDE, CORUNDUM TYPE

White
Generic compound

Synthetic analogue of the mineral corundum (*q.v.*), an aluminium oxide (α-Al_2O_3; rhombohedral crystal structure). It is prepared industrially by thermal conversion of an aluminium hydroxide ($Al(OH)_3$ or $AlO(OH)$) at temperatures in the region of 1200°C or by combustion of aluminium or calcination of aluminium salts (Greenwood and Earnshaw, 1999). Heaton (1928) notes that synthetic aluminium oxide has been used as a substrate for lake pigments.

Aluminium group; Aluminium oxides and hydroxides group; Corundum
Greenwood & Earnshaw (1999) 242; Heaton (1928) 109, 193

ALUMINIUM OXIDES AND HYDROXIDES GROUP

White
Group term

The structural relationships between the various aluminium oxides and hydroxides are extremely complicated. The main crystal forms among the simple aluminium oxides and hydroxides are:

Corundum and aluminium oxide (alumina), Al_2O_3
Synthetic analogue of bayerite, $Al(OH)_3$
Gibbsite and its synthetic analogue, $Al(OH)_3$
Nordstrandite and its synthetic analogue, $Al(OH)_3$
Doyleite and its synthetic analogue, $Al(OH)_3$
Diaspore and boehmite, $AlO(OH)$

Other oxides and hydroxides (including natural and synthetic analogues of the above where not mentioned) are known but have not apparently been identified among pigments.

Among the oxides, corundum and its synthetic analogue (α-Al_2O_3) are the forms most likely to be encountered. In natural material corundum occurs as a secondary phase in mineral aggregates, while in synthetic material corundum may be the primary phase. Heaton (1928) for example notes that while aluminium oxide is rarely used by itself as pigment, it does find wide application as a lake substrate. The preparation he describes is to strongly heat aluminium hydroxide (which is generally given as a preparation method for corundum), with temperatures typically in excess of 1000° for conversion of hydroxides. In addition to this primary form there is also lower temperature conversion to α-Al_2O_3 giving a compound with a so-called 'defect spinel' structure, while Winchell (1931) further lists an 'amorphous' form (which may rather be cryptocrystalline). It might additionally be noted that emery is a granular form of corundum, while aluminium commonly substitutes into the iron oxide hematite leading to an expectation of corundum in ochre pigments.

As a substrate for lake pigments it is generally formed by a process of aqueous precipitation. When formed in this manner, aluminium hydroxide might take on one or more of several crystalline states according to temperature, time, concentration of reactants and pH. For example, formation of the bayerite structure requires rapid precipitation from cold alkaline solutions, whereas with warm alkaline solutions the gibbsite structure can occur (Greenwood and Earnshaw, 1999). Gibbsite also has a more stable structure and is therefore much more widely found as a mineral in nature than bayerite. None-the-less, gibbsite can also be dehydrated to the boehmite structure (γ-$AlO(OH)$) at 100°C, and to anhydrous γ-Al_2O_3 at 150°C. Thermal treatment of these compounds, as in calcined lakes, will clearly also have the potential to change the hydration states of any lake substrate encountered.

Also included here are the secondary oxides (aluminates) calcium aluminate ($CaAl_2O_4$), cobalt aluminate ($CoAl_2O_4$), lead aluminate ($PbAl_2O_4$) and hercynite (iron aluminate, $Fe^{2+}Al_2O_4$). Calcium aluminate (calcium aluminium oxide) may be a component of the pigment known as *Satin white*. Cobalt aluminate (cobalt aluminium oxide) is the pigment *Cobalt blue*. Lead aluminate is listed by the *Colour Index* (1971) under CI 77585. Hercynite has been identified on Minoan painted pottery by Stos-Fertner *et al.* (1979). Chromium aluminium cobalt oxide is Turkish Green.

Aluminium group; Aluminium hydroxide, bayerite type; Aluminium hydroxide, nordstrandite type; Aluminium oxide, amorphous type; Aluminium oxide, corundum type; Bayerite; Boehmite; Calcium aluminium oxide; Chromium aluminium cobalt oxide; Cobalt aluminium oxide; Corundum; Diaspore; Gibbsite; Hercynite; Lead aluminium oxide; Nordstrandite; Ochre; *Cobalt blue*; *Emery*; *Satin white*; *Spinel pigments*; *Turkish green*
Colour Index (1971) 77585; Greenwood & Earnshaw (1999) 242–245; Heaton (1928) 109, 193; Stos-Fertner *et al.* (1979); Winchell (1931)

ALUMINIUM PHOSPHATE

White
Generic compound

See: aluminium phosphates group.

ALUMINIUM PHOSPHATES GROUP

White

Group term

Aluminium phosphate (‘aluminium orthophosphate’; $AlPO_4$) occurs in nature as various minerals such as angelite, but may be prepared synthetically from $NaAlO_2$ and H_3PO_4 (Brauer, 1963). There are sesqui-, di- and tri-hydrates. On heating it passes through a number of phases, from α- and β-$AlPO_4$ through berlinite-, tridymite- and cristobalite-like structures until it melts at >1600°C. Aqueous synthesis is also known to lead to zeolite-like cage structures which are used as molecular sieves. Two other phosphates might be encountered – $AlH_3(PO_4)_2$ and $Al(H_2PO_4)_3$ – though there are various additional compounds given in the chemical literature.

According to Church (1901), aluminium phosphate was used as a lake substrate; it is unclear what form is likely to be encountered.

Aluminium group

Brauer (1963) I, 831; Church (1901) 173

ALUMINIUM SILICATES GROUP

White

Group term

The principal members of the naturally occurring groups of aluminium silicates are the feldspars, micas and clay minerals. These are further discussed under the relevant group entries. The individual minerals are far too numerous to mention here. Most important as pigments are the clay minerals kaolinite ($Al_4[Si_4.O_{10}](OH)_8$), dickite ($(Al_2Si_2O_5(OH)_4$, halloysite ($Al_2Si_2O_5.(OH)_4.2H_2O$), palygorskite ($[Mg,Al]_2[Si_4O_{10}][OH].4H_2O$) and nacrite ($Al_2Si_2O_5(OH)_4$). The term ‘aluminium silicate’ is also sometimes used to refer to kaolin (*q.v.*). Palygorskite (formerly attapulgite) is used in the pigment Maya blue (*q.v.*).

The following silicate and sheet silicate mineral groups also contain aluminium: the amphiboles, the chlorites, the feldspars and the micas. It is also worth adding the following pigment-related minerals to this list: aerinite ($Si_3Al_5O_{42}(Fe^{2+},Fe^{3+})_3(Al,Mg)_2Ca_5(OH)_6.13H_2O$) and lazurite ($(Na,Ca)_8[(Al,Si)_{12}O_{24}].(S,SO_4)$). Lazurite or its synthetic analogue is the basis of the pigment ultramarine.

An ‘alumino-silicate’ product known as Charlton white is also documented (Carlyle, 2001).

Aluminium group; Chlorite group; Clay minerals group; Feldspar group; Mica group; Sheet silicates group; Silicates group; Dickite; Epidote; Halloysite; Hornblende; Kaolinite; Lazurite; Nacrite; Palygorskite; Pyrophyllite; Ultramarine; *Charlton white*; *Kaolin*

Carlyle (2001) 518

ALUMINIUM SULFATES GROUP

White

Group term

Various aluminium sulfates are described in the chemical and pigment literature: aluminium sulfate ($Al_2[SO_4]_3$); alunite ($KAl_3[SO_4]_2[OH]_6$); alunogen ($Al_2[SO_4]_2.18H_2O$); alum ($Al_2.[SO_4]_3$); ettringite ($Ca_6Al_2[SO_4]_3[OH]_{12}.26H_2O$).

The first of these, $Al_2(SO_4)_3$, is commercially supplied as the octadecahydrate, though it typically contains 5–10% less water than it theoretically should (*Merck Index*, 1996). Patton (1973i) also lists light alumina hydrate as ‘a basic aluminium sulfate prepared as a precipitate from solutions of aluminium sulfate and sodium carbonate’; he adds that no precise formula exists although he gives both $Al_2O_3.O_3.SO_3.3H_2O$ and $5Al_2O_3.2SO_3.xH_2O$ as approximations. Stated synonyms include lake white and transparent white. Additionally, the *Colour Index* (1971) gives CI 77002/Pigment White 24 as ‘aluminium hydroxide with varying amounts of basic aluminium sulfate’.

Naturally occurring alum or rock alum is an important ore of aluminium and is used in numerous manufacturing processes. It is also used as a mordant in the dye industry. Commercial aluminium sulfate is also known as cake alum or patent alum. There is also an aluminium sulfate mineral, alunogen. Ettringite forms primarily as a component of hydraulic lime plasters. It is also listed as calcium sulphoaluminate in the *Colour Index* as CI 77235/Pigment White 33.

Aluminium group; Alunite; Alunogen; Ettringite; *Lake white*; *Transparent white*

Colour Index (1971) 77002, 77235; *Merck Index* (1996) 381; Patton (1973i)

ALUNITE

White

Generic compound

Alunite, $KAl_3(SO_4)_2(OH)_6$, is a mineral formed from acid-sulfate leaching of orthoclase feldspar-rich rocks. In such settings, it is likely to be found in association with kaolinite and other clay group minerals and silica (quartz; *qq.v.*). The name is derived from the Latin *alunit*, meaning alum. Alunite is synonymous with aluminilite.

Alunite has been found by Newman *et al.* (1980) with Prussian blue (*q.v.*) in a watercolour pan produced by the English firm of Winsor & Newton and used by Winslow Homer; it was presumed to be an extender. Watchman *et al.* (in press) have made a tentative identification of alunite in rock art at Wardaman, Australia. McNulty (2000) has experimented with kaolinite-alunite-silica mixtures from the Aegean Island of Melos regarding their properties as pigments and believes that this mixture may be the ‘Melian earth’ (*Melian white*, *q.v.*) or *Melinum* of the Roman authors.

Aluminium group; Aluminium sulfates group; Clay minerals group; *Kaolinite*; *Melian white*; *Prussian blue*; *Quartz*

McNulty (2000); Newman *et al.* (1980)

ALUNOGEN

White

Generic compound

Alunogen is a hydrated aluminium sulfate mineral with chemical composition $Al_2(SO_4)_2.18H_2O$. It is generally white in colour although it may occasionally be yellowish or reddish. It occurs principally in volcanic regions as a white fibrous crust but may also be found in aluminium-rich shales where pyrite (*q.v.*) is breaking down. It is a relatively common mineral and occurs in areas such as Monte Somma (Italy), Cornwall (England), Attica (Greece) and Chiwachi (Colombia) (Rutley, 1988).

Aluminium group; Aluminium sulfates group; Pyrite

Rutley (1988) 329

AMATITO

Red

Synonym, variant or common name

Merrifield (1846) gives a convincing argument that this term refers not to mineral cinnabar (although both Cennini and Borghini relate it to cinnabar) but to hematite (*qq.v.*). Merrifield cites several authors who use this term describing it as a red mineral colour used in fresco painting. She believes that it ceased to be used in Italy and France by the end of the sixteenth century, but carried on in Spain at least until the beginning of the eighteenth century. Other terms for this are *lapis amatito*, *lapis matita* and *matita* in Italian (Baldinucci, 1681), and *albin* (*q.v.*) in Spanish (Pacheco, 1638).

Albin; Cinnabar; Hematite
Baldinucci (1681) 34; Borghini (1584/edition of 1787) 254; Cennini (c. 1400/Thompson 1960) ch. 42; Merrifield (1846) xii–xxii, 67; Pacheco (1638) 3, III, 51

AMBER

Yellow
Generic compound

Amber is fossilised resin, exuded from trees, mainly from the families Araucariaceae and Pinaceae. It is described as an amorphous, polymeric glass composed of polymerised terpenoids. Terpenes are the main constituents of essential oils derived from plants. They are based on isoprene (C_5H_8), have a general formula $(C_5H_8)_n$ and are classified based on the number of isoprene units present. Thermal alteration over the geological timescale (maturation) results in polymerisation of monoterpenes such as pinene ($C_{10}H_{16}$, exuded as pine resin) which results in sesqui-, di-, tri- and tetraterpenes (with three, four, six and eight isoprene units respectively) and terpenoids including alcohols and acids, particularly succinic acid. Compounds typically contain between 6 and 31 carbon atoms (Crelling and Krugge, 1998; Stout *et al.*, 2000). The typical elemental composition is 79% carbon, 10% hydrogen and 11% oxygen with trace sulfur (Ross, 1998). The only living trees believed capable of producing resins stable enough to become fossilised to amber are the New Zealand kauri pine (*Agathis australis*) and the legume tree *Hymenaea courbaril* found in Central America (Ross, 1998). Many trees produce resins that harden to a superficially similar material, copal. Copal, however, is *not* a fossilised product and fuses at temperatures below 150°C, unlike amber which melts between 200 and 380°C.

The maturation of amber takes several million years. The oldest ambers known are of the Carboniferous age (c. 350 Ma) and the youngest are the late Miocene ambers of Borneo (c. 5 Ma). The world's main deposits are of the Baltic amber succinite and deposits in the Dominican Republic. *Pinus* species-derived Baltic ambers (Eocene-Oligocene; c. 35 Ma) are the most widely used for carving and the production of varnishes. Other deposits are known from south-east Asia, Mexico, USA, Canada, Romania, Germany and a few localities in the Mediterranean.

Two main organic chemical fractions make up the material; an insoluble fraction and a soluble fraction. Usually, only 18–26% of the amber is soluble in organic solvents (Gold *et al.*, 1999; Thickett, 1993). Tingry (1804) in his Treatise on varnishes says that amber was derived from Prussia and was 'similar to copal'. He goes on to say that amber 'forms the base of … beautiful varnishes … Must be pure, transparent, and without any mixture of foreign bodies'. When heated to 280°C, according to Church (1901), it 'Gives off water, succinic acid, marsh gas, a mixture of liquid hydrocarbons (oil of amber) and finally at very high temperature, a yellow substance having a wax-like constituency.'

Amber, ground and used as a pigment, has been tentatively detected by Cabrera Garrido (1978) in the Palaeolithic cave paintings at Altamira, northern Spain. Amber recipes are also found in some mediaeval manuscripts for making pigments. For example, the fifteenth century German manuscript, Clarke MS 2200, states that to make a gold colour amber is ground with linseed oil and egg white in a 50:50 ratio and cooked until well mixed ('nÿm achstein rerreiben in leinöl vnd ein aÿr clar payde gleich vnd lass seiden pis sich ains vnder das ander vol mengt'; cf. Oltrogge, 2003). According to Carlyle (2001) amber varnishes were used as a medium for tube paints supplied by Roberson. However, Leonard *et al.* (2001) warn against the confusions between historical and modern uses of the term copal and amber and suggest that in many cases it was actually copal that was used as a varnish and that this material would not leave a solid residue. Burnt, ground kauri copal ('gum') is used as a pigment for tattoos and other art by the Maori in New Zealand.

The name 'amber' is derived from the Arabic *anbar*. Tingry (1804) lists the following terms for amber: karabé, yellow amber and electrum. Karabé (or carabé) is from the Persian meaning 'attractor of straws'. Church (1901) additionally gives succinum and lyncurium. He also gives the mediaeval *vernix* and *glas* or *glassa* in use in the fifteenth century. Specific varieties of amber are named after their sources; for example, rumanite from Romania and burmite from Burma. Simetite is Sicilian amber. Resinite (a maceral of the liptinite group; see: *Coal*) is a form of amber commonly occurring in bituminous coals as globules and in veinlets. It occasionally occurs in macroscopic accumulations. The occurrence and composition of resinite is described by Crelling and Krugge (1998). Retinites are ambers that contain minor amounts of succinic acid. Mexican ambers and some Dominican ambers are retinites. They are derived from legumes rather than pines (*Hymenaea protera*). Succinites and retinites may be easily distinguished by Fourier-transform infrared spectroscopy (Ross, 1998).

Hydrocarbons group; Coal
Cabrera Garrido (1978); Carlyle (2001) 66–68; Church (1901); Crelling & Krugge (1998); Gold *et al.* (1999); Leonard *et al.* (2001); Oltrogge (2003); Ross (1998); Stout *et al.* (2000); Thickett (1993); Tingry (1804) 27

AMBERG YELLOW

Yellow
Synonym, variant or common name

Apparently a German variety of yellow ochre (*q.v.*) used for fresco and architectural painting. Cramer (1985) discusses it as a yellow pigment for painting exterior and interior timber frames during the late sixteenth to the early nineteenth centuries.

Yellow ochre
Cramer (1985)

AMERICAN BLUE

Blue
Synonym, variant or common name

Synonym for Prussian blue (*q.v.*; Gardner *et al.*, 1978; cf. Berrie, 1997).

Hexacyanoferrate group; *Prussian blue*
Berrie (1997); Gardner *et al.* (1978)

AMERICAN CHROME YELLOW

Yellow
Synonym, variant or common name

According to Zerr and Rübencamp (1906), this was one of the forms of chrome yellow which contained white adjuncts (such as baryte, china clay, diatomaceous earth and gypsum, *qq.v.*). Other related products were called new yellow, Paris yellow and Baltimore chrome yellow (*qq.v.*). Kühn and Curran (1986), citing Hurst, also state that this was a form of lead chromate (*q.v.*) which contained alum (hydrous potassium aluminium sulfate, $KAl[SO_4]_2.12H_2O$).

Chromates group; Lead chromates group; Baryte; Gypsum; Lead chromate(VI); *Baltimore chrome yellow*; *China clay*; *Chrome yellow*; *Diatomaceous earth*
Hurst (1913) 133; Kühn & Curran (1986); Zerr & Rübencamp (1906/1908) 149

AMERICAN VERMILION
Red
Synonym, variant or common name

A term used for *chrome red* or *orange* (*qq.v.*) as recorded, for example, by Heaton (1928), Schiek (1973) and Kühn and Curran (1986). It was also applied to a 'heavy, opaque lake pigment, usually made from eosine or scarlet dye on a red lead, orange mineral, or chrome red [*qq.v.*] base' (Gettens *et al*., 1972).

Eosin; *Chrome orange*; *Chrome red*; *Orange mineral*; *Red lead*
Gettens *et al*. (1972); Heaton (1928) 134; Kühn & Curran (1986); Schiek (1973)

AMERICAN YELLOW
Yellow
Synonym, variant or common name

See: American chrome yellow.

AMETHYST
Purple
Generic compound

Amethyst is a purple semi-precious variety of quartz (*q.v.*). Its empirical chemical formula is therefore SiO_2, with the purple colour attributable to impurities of iron.

Listed by Montagna (1993), who in turn cites Cennini (c. 1400, Clarke MS 590) and Ronchetti (1955) as sources for the use of this material. However, this is based on a misreading of Cennini: Thompson's etymology makes it clear that 'amatisto, over amatito' refers to hematite (*q.v.*). It is highly unlikely that amethyst was ever ground and used as a pigment (since all colour would be lost) and the original reference may in fact be to another mineral of amethystine hue such as strongly coloured fluorite (*q.v.*).

Silicates group; Fluorite; Quartz
Cennini (c. 1400/Thompson 1960) 25; Montagna (1993); Ronchetti (1955)

AMMONIA-PERCHLORIDE OF PALLADIUM
Red
Synonym, variant or common name

See: palladium red.

AMMONIUM PRUSSIAN BLUE
Blue
Synonym, variant or common name

The original preparation of this pigment was by Monthiers (hence the synonymous *Monthier's blue*, *q.v.*) where 'ordinary' Prussian blue (*q.v.*) was treated with ammonia. Gardner *et al*. (1978) describe the preparation as by oxidation of the precipitate formed through the action of ammoniacal ferrous chloride on potassium ferrocyanide. Riffault *et al*. (1874) also describe the process: pure hydrochloric acid saturated with iron is mixed with excess aqueous ammonia; this is then filtered and added to a potassium ferrocyanide solution. A white precipitate is formed which is collected on a filter and exposed to air, when it turns blue. The resulting material is finally washed with ammonium tartrate to dissolve excess iron oxide.

There is no scientific evidence that an ammonium-substituted form of the iron(III) hexacyanoferrate(II) structure exists and the precise nature of the modifications induced is uncertain (Berrie, 1997). See Hexacyanoferrate group for a fuller discussion.

Hexacyanoferrate group; *Monthiers blue*; *Prussian blue*
Berrie (1997); Gardner *et al*. (1978); Monthiers (1846); Riffault *et al*. (1874) 253

AMOR GREEN
Green
Synonym, variant or common name

Term used for a phthalocyanine green by the French firm of Lefranc et Bourgeois, late 1980s.
See: phthalocyanines group

Phthalocyanine group

AMOSITE
White
Generic compound

See: asbestos.

AMPHIBOLE GROUP
Variable
Group term

The amphibole group comprises a suite of silicate minerals with the general chemical formula $AX_2Y_5Z_8O_{22}(OH,F)_2$, where A = Na, K and Ca, X = Na, Ca, Mg, Mn and Fe, Y = commonly Mg, Fe and Al, and Z = Si and Al; minor amounts of elements such as Mn, Zr, Cr, Ti and Li may also be present. The members of the amphibole group have a characteristic structure (consisting of double chains of SiO_4 tetrahedra extending through the crystal) and a degree of hydration which distinguishes them from the members of the pyroxene group. The amphiboles usually occur as acicular or bladed prismatic crystals, with fibrous varieties also known. They show significant variation in colour, with the common members being dark green or brown, although red-brown, yellow, blue, blue-green and white members are known. Amphiboles occur widely in many metamorphic rocks and igneous rocks worldwide, with the members forming in particular geological settings. They are subject to alteration in the presence of water, breaking down to form minerals such as talc and members of the chlorite group (*q.v.*). The amphibole group is subdivided by composition into three broad categories: the calcium-poor, calcium-rich and the alkali amphiboles. The calcium-poor (or ferromagnesian-rich) amphiboles have the general formula $(Mg,Fe)_7Si_8O_{22}(OH,F)_2$ (that is, no A cation present). They are commonly brown and occur only in metamorphic rocks. The members of this sub-group considered here are the monoclinic and orthorhombic magnesium-rich members cummingtonite and anthophyllite (*qq.v.*), which form solid-solution series with the iron-rich varieties grunerite (Klein, 1964) and gedrite (which also contains Al; Robinson *et al*., 1971). The calcium-rich amphiboles, in which Ca > Na, have A = Na in some cases, X = Ca, with Y and Z as listed for the main group. The subdivision includes the tremolite-actinolite-ferroactinolite series based on $Ca_2(Mg,Fe)_5Si_8O_{22}(OH,F)_2$ which has increasing iron content. Tremolite is white, actinolite (*qq.v.*) and ferroactinolite are green-brown; they often occur as fibrous crystals and occur in many metamorphic rocks. The hornblende series is also included in this subdivision, which contains significantly more Al and Na than the tremolite series, and includes the four end-members as tschermakite, edenite, pargasite and hastingsite. The hornblendes are black or dark green and occur in a wide range of igneous and metamorphic rocks, but are most common in intermediate igneous rocks. The alkali amphiboles have a high sodium content (with $Na > Ca$) and low aluminium content, described by A = Na and K, X = Na and Ca, Y = Mg, Fe, Al and Z = Si. The main members of this subdivision included here are glaucophane and riebeckite (*qq.v.*), which occur in metamorphic rocks; other members include crossite richterite, katophonite, kaersutite, taramite, eckermannite, aenigmatite and arfvedsonite. The alkali amphiboles show a wider variety of colours, often being blue or blue-green but also red, brown, yellow and green. Fibrous varieties of amphibole include asbestos, amosite and crocidolite which are fibrous forms of actinolite, anthophyllite and riebeckite, respectively (Deer *et al*., 1992; Rutley, 1988).

Amphibole has been cited by Kittel (1960) as a source for green earth (*q.v.*) at Heiger (Germany), and Grissom (1986) also reports amphibole as a source of green earth. Riederer (1997) has reported the use of glaucophane and riebeckite mixed with Egyptian blue (*q.v.*) at several sites in Greece (Profi *et al*., 1976; Cameron *et al*., 1977; Filippakis *et al*., 1976). Patton (1973e) states that tremolite is commonly associated with pigmentary talc.

Chlorite group; Silicates group; Actinolite; Anthophyllite; Glaucophane; Green earth; Hornblende; Riebeckite; Tremolite; *Egyptian blue*
Cameron *et al*. (1977); Deer *et al*. (1992) 223–275; Filippakis *et al*. (1976); Grissom (1986); Kittel (1960); Klein (1964); Patton (1973e); Profi *et al*. (1976); Riederer (1997); Robinson *et al*. (1971); Rutley (1988) 386–387

ANATASE
Variable
Generic compound

Anatase is a yellow, brown, reddish brown, green, blue or black titanium oxide mineral of composition TiO_2. It commonly occurs as elongated bipyramidal crystals or octahedra (Dana, 1944) and hence it is also known as octahedrite. Anatase is the low temperature tetragonal polymorph of the other titanium oxide minerals, rutile (Legrand and Deville, 1953) and brookite (*qq.v.*), and its occurrence is restricted to areas which have been subjected to hydrothermal activity associated with acid volcanism, or metamorphism, where it forms in veins and cavities (such as Minas Geraes, Brazil). It is a frequent alteration product of other titanium-containing minerals such as sphene and ilmenite (*q.v.*).

Zuo *et al*. (1999) reported the use of anatase as a white pigment on ancient (c. 4300–2800 BC) painted pottery from Xishan (Henan, China), applied as a coating after firing of the pottery. However, there is currently little other direct evidence of the use of natural anatase as a pigment in its own right, though the white synthetic analogue, manufactured since the earlier twentieth century, has been used (Buxbaum, 1988).

Titanium group; Titanium oxides and hydroxides group; Brookite; Ilmenite; Rutile; Titanium(IV) oxide, anatase type; *Permanent white*; *Titanium dioxide white*; *Titanium white*; *Titanox*
Buxbaum (1998) 48; Dana (1944) 583; Legrand & Deville (1953); Zuo *et al*. (1999)

ANCORCA
Yellow
Synonym, variant or common name

A Spanish term described by Veliz (1986) as ‘a yellow pigment of variable or indefinite meaning used primarily for glazing or to be mixed with blue to give greens’. The earliest reference to this pigment found by Veliz was in Carducho’s *Diálogos* of 1633, though she points out that there was widespread use of another term, *tierra santa*, in a similar context, in many other sources of the period and that the terms were therefore probably related. *Tierra santa* is seemingly equivalent to the Italian *giallo santo*, which Merrifield (1849) defines as an organic yellow (that is, a ‘lake’ pigment). However, Veliz points out that the term is ill defined and has been given a bewildering array of definitions: ‘a yellow colour composed of matte gesso and a tincture obtained from the weld plant’ (Palomino, 1715–24); ‘*Dutch earth*’; ‘*Venetian earth*’; ‘*grana de Aviñon*’ (equivalent to *Avignon berries* or *Yellow berries*, that is, from Rhamnaceae), ‘a fine yellow earth for painting’; and ‘lead oxide’. Merrifield links the term to the *arzica* mentioned by Cennini in the *Il libro dell’arte* (c. 1400, Clarke MS 590*)* and in the Bolognese manuscript (fifteenth century, Clarke MS 160).

Summarising, Veliz suggests that in the sixteenth century there was a particularly fine, transparent and stable yellow pigment which was increasingly replaced from the early seventeenth century by ‘an artificially prepared organic or inorganic pigment of varying color and quality that was called *ancorca* and was obtained by striking a yellow dye on alum, chalk, or, as one recipe suggests, white lead’. This was probably the pigment made from weld (*q.v.*). See: terra merita.

Rhamnus; Weld; *Avignon berries*; *Dutch earth*; *French berries*; *French pink*; *Giallo santo*; *Tierra santa*; *Venetian earth*; *Yellow berries*
Carducho (1633); Cennini (c. 1400/Thompson 1960) 30; Merrifield (1849) cliii, clxiv; Palomino (1715–24); Veliz (1986) 196–197

ANDESINE
White
Generic compound

Andesine is a mid-range member of the feldspar group (*q.v.*) of silicates, lying between albite and anorthite (*qq.v.*) in the plagioclase feldspar series. It is thus a sodium-calcium aluminosilicate mineral, with composition $(Na_{0.7-0.5}Ca_{0.3-0.5})(Al,Si)_4O_8$, and is described as containing 30–50% anorthite (Rutley, 1988). Andesine is minor constituent in most granites and syenites worldwide, but is the dominant feldspar in certain intermediate igneous rocks called, appropriately, andesites; it also occurs as a minor constituent in some higher grade metamorphic rocks (granulite facies). As with all plagioclase feldspars, andesine readily degrades to clay group (*q.v.*) and zeolite minerals and may therefore occur as a relict mineral in material derived in turn from these (Horst *et al*., 1981).

Clay minerals group; Feldspar group; Silicates group; Albite; Amorthite
Horst *et al*. (1981); Rutley (1988) 422–425

ANGLESITE
White
Generic compound

Anglesite, also known as lead vitriol, is a white lead sulfate mineral with chemical composition $PbSO_4$. It is a secondary mineral and forms from the decomposition of galena (*q.v.*) under acid conditions in the upper levels of lead veins. Anglesite is named after its type locality in Anglesey, Wales (at the Parys Mine), but occurs in lead deposits worldwide which form under hydrothermal conditions associated with igneous activity (such as the Peak District, England; Broken Hill, Australia; Tsumeb, Namibia) (Beudant, 1832; Dana, 1932; Rutley, 1988).

Ponsot *et al.* (1998) have demonstrated that anglesite forms with lanarkite (*q.v.*), during heating and oxidation of galena at 400–600°C, forming a blue sheen on the galena surface. Ponsot *et al.* also report that traditional North African recipes for the use of galena in eye cosmetics (kohl) indicate that it was processed prior to application, particularly by heating. Thus anglesite and lanarkite may be found in such materials or in other forms of processed galena. Specific occurrences of anglesite as a pigment are otherwise unknown although other synthetic forms of lead sulfate are known to have been used.
See: lead sulfates group.

Lead group; Lead sulfates group; Galena; Lanarkite; Lead sulfate
Beudant (1832); Dana (1932) 751; Ponsot *et al.* (1998) ; Rutley (1988) 319

ANHYDRITE

White
Generic compound

Anhydrite is a white or colourless sulfate mineral with chemical formula $CaSO_4$. It commonly occurs as prismatic, tabular or fibrous crystals, or as aggregate masses and may be tinted grey, blue or pink (Rutley, 1988). The name is derived from the Greek *anhydros*, meaning 'waterless', as it contrasts with the hydrated form of calcium sulfate, gypsum (*q.v.*), to which it may alter. The term is also applied to the synthetic analogue (see: calcium sulfate, anhydrite type). Anhydrite may form as a primary mineral due to the evaporation of highly saline waters often in association with halite (*q.v.*), or it may form by the dehydration of gypsum. Anhydrite is found worldwide where marine evaporite deposits occur, such as Eskdale (Yorkshire, England), Stassfurt (Germany), Naica (Mexico) and Jordan and Cyprus.

The use of anhydrous calcium sulfate in the ground structure of Italian paintings has been discussed by Gettens and Mrose (1954) and Martin *et al.* (1992). Richter (1988) notes the use of anhydrite, which he attributes to the use of burnt gypsum, in German painting and sculpture of the eleventh to fourteenth centuries.

Calcium sulfates group; Calcium sulfate, anhydrite type; Gypsum; Halite
Gettens & Mrose (1954); Martin *et al.* (1992); Richter (1988); Rutley (1988) 320

ANIL

Blue
Synonym, variant or common name

According to Ploss (1962), this was derived from the old Indian word for dark blue, *nilah*, then adopted by the Persians as *nilä* and then by the Arabs who added the definite article *al-nil*. The Portuguese took the term up from North Africa and from the seventeenth century *anil* became the French and Portuguese term for indigo. Guicciardini (1567) mentions that 'il colore Indico detto da Portogallesi anil' ('the colour indigo, called by the Portugese anil') was among East-Indian goods imported into Antwerp (cf. Eikema Hommes, 2002). Harley (1982) also found the term, or the abbreviation *nil*, in early seventeenth century British documentary sources; she indicates that it was used by traders rather than painters, however. French sources on dyeing from the eighteenth century also use the term synonymously with *indigofera tinctoria* (Rondot, 1858). According to Ploss this is the root of the term aniline.

Indigoid group; Indigo
Eikema Hommes (2002) 113; Guicciardini (1567) 119; Harley (1982) 67; Ploss (1962) 60–61; Rondot (1858) 24

ANILINE BLACK

Black
Synonym, variant or common name

Aniline black (CI 50440/Pigment Black 1), an indazine derivative, was first developed as a dye by Lightfoot around 1860–63. The process involved using aniline, aniline hydrochloride and sodium chlorate in the presence of an oxidation catalyst; the compound was then 'developed' at 60–100°C and oxidised further with sodium chromate. However, Perkin had already synthesised a compound that he called aniline black around 1856; oxidising aniline containing toluidine with potassium dichromate, aniline violet was then separated from the resulting mixture (the aniline black). Aniline black continues to be used in a variety of media where carbon-based blacks are inappropriate (Herbst and Hunger, 1997).

Also known as chrome black (Riffault *et al.*, 1874).

Colour Index (1971) 50440; Herbst & Hunger (1997) 578–579; Riffault *et al.* (1874) 524–525

ANILINE BLUE

Blue
Synonym, variant or common name

Mierzinski (1881) provides several recipes for this pigment, based on the compound rosanaline (more commonly known now under the names fuchsin(e) and magenta).

Mierzinski (1881) 8–9

ANILINE COLOURS

Variable
Synonym, variant or common name

See: coal tar colours.

ANILINE PURPLE

Purple
Synonym, variant or common name

See: mauve.

ANIMAL BLACK

Black
Synonym, variant or common name

Documentary sources indicate that animal black referred to a black pigment made by calcination of bone (*q.v.*), presumably from the use of animal bones as a starting material (Winter, 1983). Mutton (sheep) bones as well as those from pigs appear to have been used.

For a fuller discussion of black pigments based on bone chars, see: carbon-based blacks group: cokes sub-group.

Carbon-based blacks group: Cokes sub-group; Bone; Bone, calcined
Winter (1983)

ANKERITE

White
Generic compound

Ankerite is a white or yellowish carbonate mineral with chemical composition $Ca(MgFe)(CO_3)_2$. It is chemically and structurally similar to dolomite (*q.v.*), but contains iron in the crystal structure. Ankerite commonly occurs as rhombohedral crystals and forms as veins or concretions in iron-rich sediments, usually containing siderite (*q.v.*) and iron oxides, as a result of hydrothermal and low temperature metasomatism. It may also occur in high-grade metamorphic schists (e.g. Lewisian, Scotland) and in ore zones (e.g. northern Pennine orefield, England) in association with minerals such as fluorite, galena and sphalerite (*qq.v.*; Rutley, 1988). Ankerite is named after the Austrian mineralogist, M.J. Anker (1771–1843). Synonyms for ankerite include brown spar, braunspat, eisendolomit, ferrodolomite, paratomes-kalkhaloid, perlspath, rohwand, spathperle, tautoclin and wandstein.

Reported as a minor component in a whewellite (*q.v.*) alteration crust on Western Australian rock art by Ford *et al.* (1994).

Calcium group; Iron group; Magnesium group; Fluorite; Galena; Siderite; Sphalerite; Whewellite
Ford *et al.* (1994); Rutley (1988) 303

ANNALINE

White
Generic variety

Described in the *Colour Index* (1971) as being ‘a strongly calcined gypsum’, it presumably forms anhydrous calcium sulfate (synthetic analogue of anhydrite) and is therefore also equivalent to ‘burnt’ gypsum. Likely to retain some morphological features of gypsum during processing.

Calcium sulfate, anhydrite type; Gypsum; Gypsum, burnt
Colour Index (1971)

ANNATTO

Orange
Synonym, variant or common name

See: bixa.

ANORTHITE

White
Generic compound

Anorthite is a calcium aluminosilicate mineral with composition $CaAl_2Si_2O_8$. It is one of the rarer members of the feldspar group (*q.v.*), being an end-member of the albite-anorthite (*q.v.*) plagioclase feldspar series (Kempster *et al.*, 1962). Anorthite occurs in many igneous and higher grade metamorphic rocks and is notably found in Lake County, California and Franklin, New Jersey (USA) and Monte Somma and Valle di Fassa (Italy).

The plagioclase feldspar minerals break down easily into clay minerals and can therefore occur as relict minerals in artists’ materials which are clay based; however, no specific identifications currently known.

Clay minerals group; Feldspar group; Albite
Kempster *et al.* (1962)

ANORTHOCLASE

White
Generic compound

Anorthoclase is a white member of the alkali feldspar group (*q.v.*) of silicates, with composition $(Na,K)AlSi_3O_8$ (Pieri and Quareni, 1973). Anorthoclase is found in sodic-rich volcanic rocks, such as soda rhyolites, and also in acid volcanic rocks such as trachytes and scoria. It is a comparatively rare mineral which is documented to occur in places such as Pantelleria (SW Sicily), Grande Caldeira (Azores) and the volcanic provinces in Mexico and Scotland.

The alkali feldpars are known to weather easily to clay group (*q.v.*) minerals and can therefore occur as relict minerals in artists’ materials which are clay based.

Clay minerals group; Feldspar group
Pieri & Quareni (1973)

ANTHONYITE

Green
Generic compound

Anthonyite is a green or blue monoclinic hydrated copper chloride mineral, with chemical composition $Cu(OH,Cl)_2.3H_2O$. Named after the mineralogist J.W. Anthony (1920–92), anthonyite is chemically very similar to calumetite (*q.v.*) which has been identified on paintings on canvas and in fresco. Calumetite contains less water in its structure and is usually bluer in colour. Both of these minerals are known from their type locality at the Centennial mine, Calumet (Michigan, USA). They are secondary copper minerals which form in the weathered zones of copper deposits (Williams, 1963).

The related calumetite has been identified in a painting context, but not apparently anthonyite (Scott, 2002).

Copper group; Copper halides group; Calumetite
Scott (2002); Williams (1963)

ANTHOPHYLLITE

Green
Generic compound

Anthophyllite is a dark green amphibole group (*q.v.*) mineral with composition $(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$. Its name is derived from the Latin *anthophyllum*, which means ‘clove’, referring to its body colour. Anthophyllite is found in schistose rocks in areas of contact and regional metamorphism, such as Bodenmais (Germany) and Montana (USA). It is the major constituent of mass-fibre asbestos and is also found as a secondary mineral in peridotites and dunites (Warren and Modell, 1930).

Documentary sources suggest that asbestos materials were used as additives in paint formulations (for example, Heaton, 1928); anthophyllite might therefore be encountered although no identifications are thus far known. Stated by Patton (1973e) to be a mineral commonly associated with pigmentary talc (*q.v.*).

Amphibole group; Iron group; Magnesium group; Silicates group; *Asbestos*; *Talc*
Heaton (1928); Patton (1973e); Warren & Modell (1930)

ANTHRACITE

Black
Generic compound

Anthracite, a form of coal (*q.v.*), contains from 90 to 95% carbon with low oxygen and hydrogen content. It is black with a sub-metallic lustre, conchoidal fracture, banded structure and does not mark the hands when handled. Anthracite is formed when coal-bearing beds are subject to low-grade metamorphism, so, for instance, in the South Wales coalfield transitions from bituminous coal to anthracite can be seen. In North America seams of bituminous coal can be traced into the Appalachian fold belt where they become anthracite.

The British anthracite from north Devon forms the pigment called *Bideford black*, which was widely used during the eighteenth and nineteenth centuries as an industrial exterior paint, primarily used for ship painting (Bristow, 1996b).

Hydrocarbons group; Coal; *Bideford black*
Bristow (1996b)

ANTHRAGALLOL

Orange
Generic compound

Anthragallol, 1,2,3-trihydroxyanthraquinone, is found as a major dye component in roots *Rubia tinctorum* L. and is therefore a principal constituent of madder dyes. It is designated by the *Colour Index* (1971) as CI 58200. Synthesis is from gallic acid and benzoic acid with sulfuric acid at 125°C or from phthalic anhydride and pyrogallol with sulfuric acid at 160°C (Seuberlich, 1877; cf. *Merck Index*, 1996). It is found in the following forms:

Anthragallol-2-methyl ether is extracted from *Coprosma lucida* Forst, *C. acerosa* Cunn. and *C. linarifolia* Hook.
Anthragallol-3-methyl ether is extracted from the roots of *Rubia tinctorum* L.
Anthragallol-1,2-dimethyl ether is extracted from the roots of *Oldenlandia umbellata* L., the bark of *Coprosma lucida* Forst., *C. acerosa* A. Cunn., the root-bark of *C. rhamnoides* A. Cunn. and the roots of *Morinda citrifolia L.* and all other *Rubia* species.
Anthragallol-1,3-dimethyl ether is extracted from the whole plant of *Oldenlandia umbellata* L. and the bark of *Coprosma linariifolia* Hook.
Anthragallol-2,3-dimethyl ether is extracted from the seed of *Morinda citrifolia* L. and the roots of *Rubia tinctorum* L.
Anthragalloltrimethyl ether extracted from the whole plant of *Oldenlandia umbellata* L. (Schweppe, 1992).

See: madder.

Anthraquinones group; Madder
Colour Index (1971) 58200; *Merck Index* (1996) 72; Schweppe (1992) 206

ANTHRAQUINONES GROUP*

Variable
Group term

A large group of natural and synthetic dyestuffs based on the anthraquinone structure have found use in the formation of lake and other pigments.

The anthraquinone secondary metabolite alizarin is derived from the madder plant. It was exploited as a colorant by man long before the structure was elucidated by Graebe and Liebermann in the 1860s. The anthraquinonoid colourants form the basis of many of the modern synthetic dyes and, after the azo class, they form the second most important group of organic colourants listed in the *Colour Index* (1971) today. Anthraquinone dyes tend to predominate in the violet, blue and green hue sectors in the disperse, vat, and acid application classes of dyes, although they have also made important contributions to mordant, solvent and reactive dyes and also to pigments. The following plant- and insect-based anthraquinones have been found in pigments:

Carminic acid in ‘Cochineal’ from insect species such as *Dactylopius coccus*, *D. confusus*; *Porphyrophora polonica* L. and *P. hamelii*.
Kermesic acid in ‘Kermes’ from insect species such as *Kermes vermilio* Planchon. and *Kermococcus illicis*.
Laccaic acids A–E in ‘Lac’ from insect species such as *Kerria (Kerria) lacca lacca* (Kerr) (formerly known as *Coccus laccae and Kerria lacca Kerr*) and *Kerria (Kerria) chinensis chinensis* (Mahdihassan).
Aloe-emodin and *Aloin* in ‘Aloe-brown’ from plant species such as *Aloe barbadensis* Miller (also known as *A. vera* Linné), *A. ferox* and *A. perryi*.
Alizarin, *Pseudopurpurin*, *Purpurin* as well as *Lucidin*, *Morindone*, *Munjistin* and *Rubiadin* in ‘Madder’ and other closely related dyestuffs of natural origin from plant species such as *Rubia tinctorum* L. and other *R.* species, *Odenlandia* species, *Morinda* species and *Galium* species.
Rhein is found in various *Cassia* and *Rheum* species.
Emodin is found mostly as a rhamnoside in various *Rhamnus*, *Rheum* and *Cassia* species.
Chrysophanol (‘chrysophanic acid’) is present in *Aloe* and *Rheum* species.
Frangulin A and B occur in *Rhamnus* species.

Studies are also being made of the production of important anthraquinones derived from fungi using biotechnology methods (Hobson and Wales, 1998).

Quinones group; Alizarin; Aloe; Aloe-emodin; Aloin; Carminic acid; Chrysophanol; Cochineal; Emodin; Frangulin; Kermes; Kermesic acid; Lac; Laccaic acid; Lucidin; Madder; Morindone; Munjistin; Pseudopurpurin; Purpurin; Rhein; Rubiadin
Colour Index (1971); Hobson & Wales (1998) 42–44

*For structure, see Quinones group entry.

ANTHRAX

Variable
Synonym, variant or common name

According to Theophrastus (c. 315 BC), *anthrax* was a term for ruby or ruby spinel (Hey, 1993 under ‘corundum’). However, Schweppe (1997) points out that in the third century AD *Papyrus Graecus Holmiensis* (cf. Lagerkrantz, 1913; Reinking, 1925), the harvested, crushed and dried woad (*q.v.*), was called anthrax.

Corundum; *Woad*
Hey (1993); Lagerkrantz (1913); Reinking (1925); Schweppe (1997); Theophrastus (c. 315 BC/Caley & Richards, 1956) 18

ANTIGORITE

Variable
Generic compound

Antigorite is a green, blue or white magnesium silicate mineral with approximate composition $Mg_3Si_2O_5(OH)_4$. It belongs to the serpentine group (*q.v.*) of minerals and commonly forms by retrograde hydrothermal alteration of ultrabasic igneous rocks such as dunites and peridotites. Its type locality from which it is named is the Valle di Antigorio, Domodossola, Italy. There are many synonyms for this in the mineral literature, for example: Blatterserpentin, Bowenite, Cyphoite, Fasernephrite, Hampdenite, Jenkinsite, Nephritoid (Barsanov), Picroline, Picrolite, Picrosmine, Pikrosmin Pikrolith, Rochlandite, Rochlaudite, Rocklandite, *Sang-i-yashm*, Septeantigorite, Tangawaite, Tangiwait, Tangiwaite, Thermophyllite, Vorhauserite, Williamsite, Williamsonite and Zermattite (Schweizer, 1840).

Antigorite has been identified in rock art pigments from the Kimberley region of Western Australia by Ford *et al.* (1994).

Magnesium group; Serpentine group; Silicates group
Ford *et al.* (1994); Schweizer (1840)

ANTIMONIAL SAFFRON
Red-Orange-Yellow
Synonym, variant or common name

Historical synonym for the so-called antimony(V) sulfide (*q.v.*; *Merck Index*, 1996).

Antimony(V) sulfide
Merck Index (1996) 738

ANTIMONITE
Grey
Synonym, variant or common name

See: stibnite.

ANTIMONY
Black
Generic compound

According to the *Colour Index* (1971, CI 77050) an aqueous precipitate of antimony was used as a black pigment under the terms antimony black and iron black (*qq.v.*). Stibnite ((*q.v.*); or antimonite) was called antimony in the sixteenth century and references to antimony as a pigment may therefore refer to this mineral.

Antimony group; Stibnite; *Antimony black*; *Iron black*
Colour Index (1971) 77050

ANTIMONY BLACK
Black
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77050), by treating an acid solution of an antimony salt it is possible to precipitate a fine black powder known as antimony black or iron black. It is said to be used to 'impart the appearance of polished steel to papier mache and plaster of Paris'.

Iron black
Colour Index (1971) 77050

ANTIMONY BLUE
Blue
Synonym, variant or common name

Listed in the *Colour Index* (1971; CI 77510), antimony blue is formed 'by adding dilute aqueous potassium ferrocyanide to a clear solution of antimony in aqua regia'. The precise composition seems to be unknown, but is likely to belong to the hexacyanoferrate(II) group of pigments (*q.v.*). Bersch (1901) additionally remarks that: 'According to Krauss, it contains no antimony as colouring principle, but is a Prussian blue (*q.v.*) obtained from the ferrocyanide, which is decomposed by the strong acid, with evolution of hydrocyanic acid.'

Hexacyanoferrate group; *Prussian blue*
Bersch (1901) 179; *Colour Index* (1971) 77510

ANTIMONY(III) CHLORIDE
White
Generic compound

Antimony(III) chloride is an orthorhombic compound of composition Cl_3Sb. Preparation has been given by Schenk (1963). The *Colour Index* (1971) designation is CI 77056; it has also been known historically as butter of antimony. Use as a pigment is unlikely, but it was employed as a mordant and for making other antimony compounds.

Antimony group; Antimony halides group; *Butter of antimony*
Colour Index (1971) 77056; Schenk (1963) 608

ANTIMONY CHLORIDE OXIDE
White
Generic compound

Antimony chloride oxide (ClOSb) is a white compound whose extent of use as a historical pigment is unknown. Preparation has been discussed by Schenk (1963). The *Colour Index* (1971) designation is CI 77055. It is also known as powder of Algaroth or Algarotti white after its inventor Vittorio Algarotti, who developed it as an emetic (Lavoisier, 1790).

Antimony group; *Mercurius vitae*; *Powder of Algaroth*
Colour Index (1971) 77055; Lavoisier (1790); Schenk (1963)

ANTIMONY GLANCE
Grey
Synonym, variant or common name

Antimony glance is synonymous with stibnite (*q.v.*), an antimony sulfide mineral with composition Sb_2S_3.

Stibnite

ANTIMONY GROUP
Variable
Group term

The following compounds containing antimony are considered to have been, or are closely related to, compounds which are used as pigments:

Elemental antimony (Sb)
Halides: antimony chloride oxide (ClOSb).
Oxides and hydroxides: senarmontite, valentinite and their synthetic analogues (Sb_2O_3); antimony ochre (stibiconite, $Sb_2O_3.(OH)_2$); bindheimite and synthetic analogues ($Pb_2Sb_2O_6.[O,OH]$).
Sulfides: stibnite and its synthetic analogue (Sb_2S_3); kermesite (Sb_2S_2O); antimony oxide sulfide (variable composition); antimony(V) sulfide (Sb_2S_3).

Antimony chloride oxide (powder of Algaroth) is a white pigment; the extent of its use is unknown. Several forms of lead antimony oxide (bindheimite type) are important yellow pigments (lead antimonate or 'Naples yellow'). Antimony oxide sulfides (*q.v.*) form the basis of many red and orange pigments (for example, 'antimony orange'). Antimony(V) sulfide (*q.v.*) is not a stoichiometric compound (Cotton *et al.*, 1999) although it is said to form several yellow pigments.

In addition, various other pigments contain antimony, but are classed here under different headings.

Antimony oxides and hydroxides group; Antimony sulfides group; Antimony; Antimony chloride oxide; Antimony hexacyanoferrate(II);

Antimony oxide sulfide; Antimony trioxide; Antimony(III) chloride; Antimony(III) oxide; Antimony(III) sulfide; Antimony(V) sulfide; Bindheimite; Kermesite; Lead antimoniate; Lead antimonite; Lead antimony oxide, bindheimite type; Lead antimony oxide, rosiaite type; Lead antimony tin oxide; Lead antimony zinc oxide; Ochre; Rosiaite; Senarmontite; Stibnite; Valentinite; *Antimonial saffron*; *Antimony black*; *Antimony blue*; *Antimony glance*; *Antimony orange*; *Antimony red*; *Antimony vermilion*; *Antimony white*; *Antimony yellow*; *Antimony-tin yellow*; *Baryta red*; *Butter of antimony*; *Crimson antimony*; *Golden sulfur of antimony*; *Golden yellow*; *Iron black*; *Mercurius Vitae*; *Mérimée's yellow*; *Naples yellow*; *Nickel rutile yellow*; *Powder of Algaroth*; *Solid yellow*; *Timonox*
Cotton *et al.* (1999)

ANTIMONY HALIDES GROUP

Variable
Group term

See: antimony chloride oxide.

ANTIMONY ORANGE

Orange
Synonym, variant or common name

Mentioned by various nineteenth century authors such as Field (1835), and his later editors Salter (1869) and Scott Taylor (1885), this was also called golden sulfur of antimony or golden yellow. It is described as being a 'hydro-sulfuret of antimony' (that is, some form of antimony sulfide hydrate). Riffault *et al.* (1874) describe a preparation technique whereby a hydrated or, more probably, the oxide sulfide form of antimony sulfide occurs. Heaton (1928) also lists antimony orange as 'sulphide of antimony', giving antimony vermilion as another synonym. The German term for this is *Goldschwefel* (Brachert, 2001). For a fuller discussion of the issues surrounding this and closely related pigments, see the entry for the Antimony sulfides group.

Antimony group; Antimony sulfides group; *Golden sulfur of antimony*; *Golden yellow*; *Goldschwefel*
Brachert (2001) 104; Field (1835); Heaton (1928); Riffault *et al.* (1874) 392–393; Salter (1869) 256; Scott Taylor (1885) 193

ANTIMONY(III) OXIDE

White
Generic compound

Antimony trioxide (Sb_2O_6) can be formed by the direct reaction of the element with oxygen. However, in practice production methods were similar to those used for zinc oxide (*q.v.*) pigments. The usual raw material was the antimony sulfide mineral stibnite (*q.v.*), which was roasted in air to form the oxide (*Merck Index*, 1996).

Several structural modifications exist, notably the minerals valentinite and senarmontite, along with their synthetic analogues (*qq.v.*); these may therefore be found from the roasting process. However, the minerals themselves do not appear to have been used as pigments.
See: antimony oxides and hydroxides group.

Antimony oxides and hydroxides group; Senarmontite; Stibnite; Valentinite; Zinc oxide
Merck Index (1996) 739

ANTIMONY(III) OXIDE, SENARMONTITE TYPE

White
Generic compound

See: antimony oxides and hydroxides group and senarmontite.

ANTIMONY(III) OXIDE, VALENTINITE TYPE

White
Generic compound

See: antimony oxides and hydroxides group and valentinite.

ANTIMONY OXIDE SULFIDE

Red-Orange
Generic compound

Compound of possibly uncertain or variable composition associated with various orange-red pigment terms such as 'antimony red' and frequently stated to be 'antimony sulfide'. However, since antimony sulfide is commonly grey to black in colour, parallels are drawn with the black and red forms of mercury sulfide (see: mercury sulfides group). There is however no clear evidence that this red modification is an antimony sulfide, it probably being antimony oxide sulfide instead; the mineral kermesite (*q.v.*), for example, which takes on a red colour, is of this composition. In fact Heaton (1928), after repeating the comparison to vermilion, states that 'Antimony vermilion is not a pure sulphide of antimony, but always contains a certain proportion of oxide. The exact constitution is a matter of controversy, but the dark shades are considered to be an oxide sulphide of the formula $2Sb_2S_3.Sb_2O_3$, increase in the proportion of oxide resulting in a more orange tint.'

Antimony oxides and hydroxides group; Antimony sulfides group; Mercury sulfides group; Kermesite; *Antimony orange*
Heaton (1928) 127–128

ANTIMONY OXIDES AND HYDROXIDES GROUP

White
Group term

Antimony(III) oxide (Sb_2O_3), antimony(IV) oxide (Sb_2O_4) and antimony(V) oxide (Sb_2O_5) are generally given as the principal oxides. Antimony(III) oxide can be formed by the direct reaction of the element with oxygen. However, in practice production methods were similar to those used for zinc oxide (*q.v.*) pigments; in this case the usual raw material was stibnite (antimony sulfide, *q.v.*), which was roasted in air to form the oxide. Several structural modifications exist, notably the minerals valentinite and senarmontite, along with their synthetic analogues (*qq.v.*); these may be found from the roasting process. The minerals do not appear to have been used as pigments. There is also a yellow pentoxide and when either the tri- or pentoxide is heated in air at about 900°C a white insoluble powder of composition Sb_2O_4 is formed and of which there are recognised α- and β-phases (Cotton *et al.*, 1999; Rasines *et al.*, 1988).

Gloger and Hurley report that antimony(III) oxide is the principal form used for pigments; a high quality pigment would consist of 99% of this with less than 1% of the tetroxide and traces of iron, lead and arsenic oxides. Antimony(IV) oxide is also stated to have limited use as a phase in a coated silica pigment (under the trade name 'Oncor'; the pigment 'has a core (50%) of silica with a coating of 45% SbO_2 and 5% Sb_2O_6), but that antimony(V) oxide 'has no industrial importance as a pigment'. Manufacturing processes for pigments (Gloger and Hurley, 1973) include preparation from antimony sulfide ore or antimony metal, or by hydrolysis of antimony sulfate or a halide, though these latter processes appear to have been uneconomic. For the former methods, direct sublimation from ore would be used for lower grade ores (5–25% Sb) while conversion to metal took place when the sulfide or oxide ore contained 25–60% Sb. The coated pigment is produced by calcining an intimate mixture of silica and antimony(III) oxide at a temperature sufficient to cause conversion to antimony(IV) oxide.

According to Heaton (1928), antimony oxide was only used on a small scale because of its 'indifferent colour and gritty texture due to a pronounced crystalline structure' until the introduction of the product called Timonox in 1919, becoming a significant article of commerce. In the 1930s, antimony oxide went through a strong period of growth as a pigment due to its ability to control chalking when used with anatase titanium dioxide white (*q.v.*); the introduction of rutile forms of titanium dioxide white in the early 1940s, which were less prone to this, quickly reduced the importance and use of antimony oxide pigments (Gloger and Hurley, *op. cit.*). By the 1970s, use of the pigment was confined to specialist applications such as fire-retardancy.

No antimony hydroxides are currently known as pigments. There is some historical confusion over the composition of so-called 'antimony vermilion', which some sources have suggested was an antimony oxide sulfide; this compound is now thought to be an amorphous antimony sulfide. A red mineral antimony oxide sulfide, kermesite (*q.v.*), also exists, though this does not appear to have been recorded in pigment use.

Gloger and Hurley (1973) record a number of synonymous terms for antimony oxide whites, including antimony oxide, a. white, a. pigment, a. bloom, a. sesquioxide, antimonious oxide and flowers of antimony. Related trade names include *Timonox* and *Oncor*.

Antimony group; Antimony oxide sulfide; Antimony(III) oxide; Kermesite; Senarmontite; Stibnite; Valentinite; Zinc oxide; *Antimony white*; *Timonox*; *Titanium dioxide white*
Cotton *et al*. (1999) 400–401; Gloger & Hurley (1973); Heaton (1928) 99; Rasines *et al*. (1988)

ANTIMONY RED

Red-Orange-Yellow
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77061) this is 'antimony pentasulphide' – that is, the so-called antimony(V) sulfide (*q.v.*); however, it may also be antimony oxide sulfide (*q.v.*) since the former is orange-yellow, the latter red.

Salter (1869) provides the synonym *Mineral kermes* for this term, describing the colour as ranging from light orange to deep carmine.

Antimony oxide sulfide; Antimony(V) sulfide
Colour Index (1971) 77061; Salter (1869) 159

ANTIMONY(III) SULFIDE, AMORPHOUS TYPE

Red
Generic compound

See: antimony sulfides group.

ANTIMONY(III) SULFIDE, STIBNITE TYPE

Black
Generic compound

See: antimony sulfides group and stibnite.

ANTIMONY(III) SULFIDE

Variable
Generic compound

Antimony(III) sulfide (Sb_2S_3; antimony trisulfide) occurs naturally as the black mineral stibnite (which is also known as antimonite, antimony glance or grey antimony). The synthetic product is a yellow to deep crimson colour and can be prepared by heating together solutions of a soluble antimony salt and sodium thiosulfate; a yellow precipitate forms at 32°C which becomes scarlet when washed and dried; alternatively heat together solutions of calcium thiosulfate and antimony trichloride at 60–70°C; the precipitate changes hue from straw-yellow, lemon-yellow, orange-red to deep crimson. It is also obtainable from hot solutions in an anhydrous greyish-black form known as antimony black (*q.v.*; *Colour Index*, 1971). Antimony(III) sulfide has a ribbon-like polymeric structure in which each antimony atom and each sulfur atom is bound to three atoms of the opposite kind forming interlocking SbS_3 and SSb_3 pyramids (Cotton *et al*., 1999).

Colour Index designation CI 77060/Pigment red 107.
See: antimony sulfides group.

Antimony group; Antimony sulfides group; Antimony(V) sulfide; Stibnite; *Antimony black*
Colour Index (1971) 77060; Cotton *et al*. (1999) 403

ANTIMONY(V) SULFIDE

Yellow-Orange
Generic compound

So-called antimony(V) sulfide (Sb_2S_5) is not a stoichiometric substance and, according to Mössbauer spectroscopy, contains only Sb(III) (Birchall and Della Valle, 1970; Cotton *et al*., 1999). It is an orange-yellow powder. Preparation is given by Gmelin (1949).

The *Colour Index* (1971) lists this compound ('antimony pentasulphide') as CI 77061; it was also known as *golden antimony sulphide*, *antimonial saffron* and *antimony red* (*Colour Index*, 1971; *Merck Index*, 1996).
See: antimony sulfides group.

Antimony sulfides group; Antimony(III) sulfide; *Antimonial saffron*; *Antimony red*
Birchall & Della Valle (1970); *Colour Index* (1971) 77061; Cotton *et al*. (1999) 403; *Gmelin* (1949) 534–539; *Merck Index* (1996) 738

ANTIMONY SULFIDES GROUP

Variable
Group term

There appear to be three relevant antimony sulfides. First, antimony forms a black orthorhombic antimony(III) sulfide (Sb_2S_3), which can be synthesised by direct combination of the elements or by aqueous precipitation with H_2S from Sb(III) solutions. The mineral stibnite (*q.v.*) is the direct analogue. Second, an amorphous antimony(III) sulfide with a yellow-orange colour is known. A number of sources also cite an antimony pentasulfide; however, so-called antimony(V) sulfide (Sb_2S_5) is not a stoichiometric substance and, according to Mössbauer spectroscopy, it contains only Sb(III) (Cotton *et al*., 1999).

Sources such as Riffault *et al*. (1874) and Heaton (1928) also describe the composition of an antimony vermilion (presumably the same as antimony red mentioned in other sources) as a red form of antimony sulfide. This generally seems to be prepared by precipitation from the chloride – for example, Gettens and Stout (1966) state that synthesis is by precipitating antimony chloride with sodium thiosulfate or with hydrogen sulfide. It was apparently introduced as a pigment by Murdoch in 1847.

Since antimony sulfide is commonly grey to black in colour, parallels are drawn with the black and red forms of mercury sulfide (see: mercury sulfides group). However, there is no clear evidence that this red modification is an antimony sulfide, it probably being an antimony oxide sulfide (*q.v.*) instead; the mineral kermesite for example, which takes on a red colour, is of this composition. In fact Heaton, after repeating the comparison to vermilion, states that 'Antimony vermilion is not a pure sulphide of antimony, but always contains a certain proportion of oxide. The exact constitution is a matter of controversy, but the dark shades are considered to be an oxide sulphide of the formula $2Sb_2S_3.Sb_2O_3$, increase in the proportion of oxide resulting in a more orange tint' giving rise to various pigments called antimony orange, golden yellow, golden sulfur of antimony, and *Goldschwefel* (German). Examples of antimony vermilion examined by the present authors using X-ray diffraction showed them to consist of amorphous material.

Antimony group; Mercury sulfides group; Antimony oxide sulfide; Stibnite; *Antimony vermilion*
Cotton *et al.* (1999); Gettens & Stout (1966); Heaton (1928) 127–128; Riffault *et al.* (1874) 441

ANTIMONY TRIOXIDE
White
Generic compound

See: antimony(III) oxide. A fuller discussion of antimony oxides in general is given under Antimony oxides and hydroxides group.

Antimony oxides and hydroxides group; Antimony(III) oxide

ANTIMONY VERMILION
Red
Synonym, variant or common name

Sources such as Riffault *et al.* (1874) and Heaton (1928) describe the composition of an antimony vermilion as a red form of antimony sulfide. This generally seems to be prepared by precipitation from the chloride, for example, Gettens and Stout (1966) state that synthesis is by precipitating antimony chloride with sodium thiosulfate or with hydrogen sulfide. It was apparently introduced as a pigment by Murdoch in 1847. See Antimony sulfides group for a fuller discussion of the likely composition.

Antimony sulfides group; Antimony oxide sulfide; Kermesite; *Crimson antimony*
Gettens & Stout (1966); Heaton (1928) 127; Riffault *et al.* (1874) 441

ANTIMONY WHITE
White
Synonym, variant or common name

Generally a synthetically produced antimony oxide. However, so-called Antimony white is rarely used alone and according to the *Colour Index* (1971; CI 77052/CI Pigment White 11) in the UK it is generally mixed with zinc oxide or baryte (*qq.v.*).

Several nineteenth century authors refer to whites of antimony (as well as of various other elements such as zinc, bismuth, mercury or 'quicksilver' and tin in the same context, usually when discussing alternatives to lead white (*q.v.*)). For example Osborn (1845) writes that: 'From antimony and from zinc, whites have been made which have been said to possess, with sufficient body, and great beauty, assured permanence.' Heaton (1928) also lists antimony white, giving the composition as 'antimony oxide'. The British firm Cookson Lead and Antimony Co. developed and introduced an antimony oxide-based white pigment around 1920 under the trade name *Timonox*.

See: antimony oxides and hydroxides group.

Antimony oxides and hydroxides group; Baryte; Zinc oxide; *Lead white*; *Timonox*
Colour Index (1971) 77052; Heaton (1928); Osborn (1845) 8–9

ANTIMONY YELLOW
Yellow
Synonym, variant or common name

Antimony yellow, or yellow of antimony, was typically a synonym for lead antimony oxide (Lead antimonate or Naples yellow, *qq.v.*). However, various nineteenth century authors draw a distinction between these. Osborn (1845) for example, states, 'Yellow of Antimony holds the middle place between chrome yellow and Naples yellow. According to the *Manuel*, Guimet … has prepared a kind of a fine golden color, more intense than that of Naples Yellow, and that seems to be solid. The author of the *Traité Complet* considers Antimony-yellow preferable to Naples yellow, and quite as solid.' Salter (1869) likewise distinguishes antimony yellow from Naples yellow, stating that it was 'likewise a preparation of that metal, of a deeper colour than Naples yellow, but similar in its properties. It was principally used in enamel and porcelain painting, and differed greatly in tint.'

Lead antimony oxide; *Naples yellow*
Osborn (1845) 51; Salter (1869) 104–105

ANTIMONY-TIN YELLOW
Yellow
Synonym, variant or common name

Term for a lead antimony tin oxide pigment used by Santamaria *et al.* (1998).

Lead antimony tin oxide; *Naples yellow*
Santamaria *et al.* (1998)

ANTLER
Black-White
Synonym, variant or common name

There are a number of directions in the documentary sources for the production of pigments from horn, such as calcined (harts) horn, or horn black, or horns of hind, as well as stag-horn black. In the deer family the branched structures, commonly known as stag's horn or antlers, are composed entirely of bone with no actual horn or keratin substance; they are usually present only in the male and are shed annually (*Columbia Encyclopedia*, 2003). References to horn in the context of pigment preparation are therefore to antler rather than true horn, where the keratin would be unsuitable. Some terms make this clear as with hartshorn and horns of hind. These form a variety of bone black, white or ash.

For a general discussion on the bone black pigments see: carbon-based blacks group: cokes sub-group. Where the bone or antler forms a white pigment see: Bone, calcined.

Carbon-based blacks group: Cokes sub-group; Bone; Bone, calcined; *Hartshorn*
Columbia Encyclopedia (2003) 'Horn'

ANTLERITE
Green
Generic compound

Antlerite is green copper sulfate hydroxide mineral which varies in colour from light green to dark green-black. With chemical composition $Cu_3(SO_4)(OH)_4$, antlerite is found as a secondary mineral in the weathered zones of carbonate-poor copper deposits where it precipitates as acicular crystals or reniform concretions. It is named after its type locality at the Antler mine, Mojave County, Arizona.

First listed by Van'T Hul-Ehrnreich and Hallebeek (1972) as a pigment, Purinton and Newman (1985) have also identified antlerite as a form of verdigris encountered in their study of a group of Indian paintings; it may, however, be the synthetic analogue of antlerite. Antlerite has also been discussed by Scott (2002).

Copper group; Copper sulfates group
Purinton & Newman (1985); Scott (2002); Van'T Hul-Ehrnreich & Hallebeek (1972)

ANTOZONITE
Purple
Generic compound

Antozonite is a dark purple to purple-black variety of fluorite (*q.v.*), found particularly in Nabburg-Wölsendorf and Kittenrain areas of Bavaria, Germany and Quincié and Lantignié, France and Joachimsthal in the Czech Republic. Richter *et al.* (2001) have recently reported that antozonite has been identified on a small number of painted works of art from the mid-fifteenth/early sixteenth centuries in a discreet area of Europe, in particular from southern Germany, the Austrian Tyrol, Switzerland, Hungary and Silesia in Poland. Antozonite is not currently recognised as a mineral.

Fluorite
Richter *et al.* (2001)

ANTWERP BLUE
Blue
Synonym, variant or common name

In the earlier nineteenth century Antwerp blue was identified as a copper-based pigment (for example, de Massoul, 1797; Ibbetson, 1803; *Compendium*, 1808). However, Field (1835), writing not much later, described it as a lighter and brighter form of Prussian blue (*q.v.*); Salter (in his 1869 edition of Field) said the paler tint was due to a higher proportion of aluminous base while Mallet (in his 1870 edition of Field) mentions the addition of white clay or chalk (*q.v.*). Late nineteenth century authors such as Martel (1860), Seward (1889) and Church (1901) all describe Antwerp blue as modified forms of Prussian blue containing alumina or sometimes 'carbonate of magnesia and carbonate of zinc' (Martel). Mierzinski (1881) describes Antwerp blue as the mixture of two components: one is zinc oxide (*q.v.*) dissolved in iron vitriol ('*Eisenvitriol*') and the other is a solution of potassium hexacyanoferrate and water; a higher content of iron vitriol results in a darker colour. Linke and Adam (1913) record the pigment as a form of Paris blue (*q.v.*). By the earlier twentieth century (1928) Heaton states that it is rarely encountered, but that it is either 'reduced Prussian blue' (that is, Prussian blue with a white pigment added) or 'zinc ferrocyanide' made by precipitating a mixture of zinc and iron(II) sulfates with sodium ferrocyanide. This identification is reiterated by more recent sources such as the *Colour Index* (1971).

Other terms specifically associated with Antwerp blue include Haarlem (or 'Haerlem') blue, Berlin blue and mineral blue (*q.v.*) (Salter).

Copper group; Hexacyanoferrate group; Chalk; Zinc hexacyanoferrate(II); Zinc oxide; *Blue verditer*; *Haarlem blue*; *Paris blue*; *Prussian blue*
Church (1901); *Colour Index* (1971); *Compendium* (1808); Field (1835); Heaton (1928) 379; Ibbetson (1803); Linke & Adam (1913); Mallet (1870); Martel (1860) 16; Massoul (1797); Mierzinski (1881) 23; Salter (1869) 207–208; Seward (1889)

ANTWERP BROWN
Brown
Synonym, variant or common name

Synonym for an asphalt pigment (*q.v.*). Williams (1787; cf. Harley, 1982) states this is an adulterated form of asphalt. It was manufactured by heating asphalt over a fire until the volatiles are driven off and then to each half ounce of the asphalt, the same amount of sugar of lead (lead acetate) was added and the two ground together with a strong drying oil. This produced a pigment which was easier to work with and less liable to cracking than asphalt alone. Salter (1869) also defines Antwerp brown as the form of the asphalt pigment in drying oil, as opposed to turpentine.

Asphalt
Harley (1982) 151; Salter (1869) 339; Williams (1787)

ANTWERP GREEN
Green
Synonym, variant or common name

A recipe for Antwerp green is given by Fishwick, who was writing in the late eighteenth/early nineteenth centuries: 'For 1lb of blue vitriol dissolved in [?] of water, add immediately 1lb of purified alkali, & 4oz powdered white arsenic, dissolved previously in 1 gallon of boiling water: the precipitate, from the mixture of these two solutions is to be well washed, and dry'd on white paper spread on flat pieces of chalk [*q.v.*].' This appears to be for the copper arsenite compound commonly known as Scheele's green.

Chalk; *Scheele's green*
Fishwick (1795–1816) 138

ANTWERP RED
Red
Synonym, variant or common name

Antwerp red is listed in the Scott Taylor edition of *Field's Chromatography* (1885) as a variety of red ochre (*q.v.*).

Red ochre
Scott Taylor (1885) 187

APATITE GROUP
Variable
Group term

The apatite group of minerals are phosphates and fall into the hexagonal and monoclinic crystals systems with the general chemical formula $Ca_5(PO_4)_3(F,Cl,OH)$. The structure was defined and described independently by Mehmel (1930) and Naray-Szabo (1930), and the composition of apatites is readily determined by infra-red microspectroscopy (Siddall and Hurford, 1998). There is theoretically complete solid solution between the end-members. Pure fluorapatite is hexagonal; chlorapatites and hydroxylapatites belong to the monoclinic crystal system. The structures of these groups are described by Beevers and MacIntyre (1946), Mackie *et al.* (1972), LeGeros *et al.* (1960) and LeGeros (1994). Apatite will crystallise in four distinct environments:

1. As 'igneous apatite' in rocks crystallising from a siliceous or carbonatitic magma where it commonly adopts the fluorine end-member, fluorapatite, $Ca_5(PO_4)_3F$.

2. In zones of mineralisation generally associated with granites where all end-members may occur, but fluorapatite and chlorapatite are the most abundant.
3. As ‘sedimentary’ apatite in the form of (fossilised) guano and other coprolitic material and also as authigenic mammilated ‘staffelite’.
4. As biogenic apatite where it is the prime constituent of vertebrate tooth and bone, including ivory, fish teeth and pathological calcifications. In this last context, the apatite species present are fluorapatite and hydroxylapatites plus the calcium carbonate-bearing dahllite ($Ca_5[PO_4,CO_3]_3OH$).

Igneous apatite crystallises as small (c. 50 μm) grains in so-called ‘accessory amounts’, meaning it constitutes less than 5% of the rock. Therefore, though it is very common, it is far from abundant. However, being relatively inert to weathering, it is also commonly found in sandstones as a detrital mineral, again in small amounts. In zones of mineralisation, large, varicoloured crystals may occur, but the colour is lost on crushing. Phosphate and sedimentary apatite deposits are generally massive and cryptocrystalline. The structure of biogenic apatite is discussed with bone (*q.v.*) and ivory. The natural occurrence of calcium phosphate apatites has been discussed by Smith (1994).

A very large number of substitutions for calcium and the phosphate group commonly occur in apatite, strontium (strontian apatite) and magnesium being common. Igneous and mineralisation associated apatite are uranium bearing. There are major structural and chemical similarities between this mineral and the lead phosphate pyromorphite (*q.v.*), which is technically lead-bearing apatite. However, other minerals within the pyromorphite group have major substitutions for phosphate and therefore they are classed separately.

‘Apatite’ has been identified in several *gigaku* masks from Kanagawa Prefecture, Japan, by Naruse (1996), who also states that it was used as a white pigment during the Qin (Ch’in) dynasty, China. Amorphous apatite, ‘collophane’, has been identified in Hellenistic Greek art (Kakoulli, 2003). Apatite is likely to be a constituent of rock varieties including ochres and some limestones. It may occur as a trace in poorly levigated china clays (*q.v.*). Biogenic apatite in the form of bone and ivory has had widespread use of a pigment in its calcined state as bone black (*q.v.*).

The name apatite comes from the Greek *απαταω*, meaning ‘to deceive’. It was derived due to the superficial similarities between this mineral and others (particularly beryls), due to its wide range in colours and also for its common but inconspicuous presence in many rocks due to its small grain size.

Calcium group; Calcium phosphates group; Bone; Dahllite; Fluorapatite; Hydroxylapatite; Pyromorphite; *Bone black*; *Ivory black*
Beevers & McIntyre (1946); Kakoulli (2003); LeGeros (1994); LeGeros *et al.* (1960); Mackie *et al.* (1972); Mehmel (1930); Naray-Szabo (1930); Naruse (1996); Siddall & Hurford (1998); Smith (1994)

APIGENIN

Yellow
Generic compound

A flavone dyestuff, 4′,5,7-trihydroxyflavone, extracted from *Reseda luteola* L. and *Petroselenium crispum* (Miller) A.W. Hill. (Schweppe, 1992).
See: weld and parsley.

Flavonoids group
Schweppe (1992) 320, 346

APPIAN GREEN

Green
Synonym, variant or common name

The classical author Pliny (77 AD) describes a green earth (*q.v.*) from Rome which he calls *Appianum*, or Appian green, valued by him at a sesterce per pound: ‘There are also two colours of a very cheap class that have been recently discovered: one is the green called Appian [apianum], which counterfeits malachite; just as if there were too few spurious varieties of it already; it is made from a green earth and is valued at a sesterce per pound.’ Pliny adds that it was not suitable for fresco painting. Rackham (1952), however, who translated Pliny, suggested that appianum might be an emendation of *apiacum* or *apianum*, which means parsley (*q.v.*); this would appear to mean the colour of parsley rather than that the pigment was in any way produced from parsley.

Green earth; *Iris green*; *Parsley*
Pliny (1st cent AD/Rackham, 1952) XXXV.xxix

APPIANUM

Green
Synonym, variant or common name

See: Appian green.

APPLE-TREE BARK

Yellow
Synonym, variant or common name

Thompson (1935) and Oltrogge (2003) cite two fifteenth century German texts (the so-called *Trierer Malerbuch*, Clarke MS 3170 and the Baverische Staatsbibliothek, München, MS 55, Clarke MS 2200) that refer to the production of a yellow from the bark of apple trees; thus from the München MS: ‘*Nÿm past oder rynt ab den öpfelpavm vnd seudcz mit essich vnd tüe alavn darein*’ (‘Take the skin or bark of the apple tree and cook with vinegar and alum’).

Apple trees, *Malus* species (Rosaceae), are known to contain the yellow flavonoid compound quercetin (*q.v.*) in their bark, especially that covering the roots.

Flavonoids group; Quercetin
Oltrogge (2003); Thompson (1935) 415, n.1

ARAGONITE

White
Generic compound

Aragonite is one of the three natural calcium carbonate ($CaCO_3$) polymorphs, along with calcite and vaterite (*qq.v.*). It differs from the latter minerals in that the CO_3 ions occupy different positions in the crystal lattice leading to an orthorhombic structure. Aragonite is named after its type locality in Aragon, Spain and is less common than calcite. However, it does occur in a wide variety of environments as prismatic or acicular crystals, often in radiating clusters, or as massive or stalactitic varieties. Aragonite forms in evaporite deposits in association with gypsum (*q.v.*), or may precipitate as spherical granules (‘ooids’) from hot springs (for example, Lake Bogoria, Kenya). It may also precipitate in vesicles in basaltic and andesitic lavas together with zeolite minerals such as analcime and heulandite. Aragonite is also found as veins in serpentine, in blueschist metamorphic rocks produced at low temperatures and high pressures (for example, Franciscan blueschists, California), aragonite marbles (for example, western Crete, Greece) and in the oxidised zones of ore deposits in association with limonite, malachite and calcite (*qq.v.*). Importantly, as a primary biogenic precipitate, it is also the material from which the majority of shells and corals are composed. Over time, aragonite reverts to the more stable form calcite (Yoshioka *et al.*, 1986). Fossil shells are calcite. Important aragonite-based pigments are the shell whites, used in Japan since the sixteenth century (Gettens *et al.*, 1993a).

Calcium carbonates group; Calcium group; Calcite; Coral; Gypsum; Limonite; Malachite; Vaterite; *Shell white*
Gettens *et al.* (1993a); Yoshioka *et al.* (1986)

ARCHIL

Blue-Purple
Synonym, variant or common name

See: orchil.

ARGENTUM MUSICUM

Metal
Synonym, variant or common name

See: mosaic silver.

ARIABEL DARK BLUE

Blue
Synonym, variant or common name

See: Prussian blue.

ARKELITE

Variable
Generic compound

Arkelite is a naturally occurring cubic form of zirconium oxide, although it is a rare mineral. The material was first discovered by the German chemist Klaproth in 1789 from the reaction of zircon compounds with alkalis. The natural form is closely related to baddeleyite (*q.v.*) and is listed with variable oxygen contents (for example, $ZrO_{1.87}$ and $ZrO_{2.12}$). It may occur as a minor component in many different rock types.

Although arkelite is not known to have been used specifically as a pigment, zirconium oxide (*q.v.*) is listed by the *Colour Index* (1971) as CI 77990/Pigment White 12.

Zirconium group; Baddeleyite; Zirconium oxide
Colour Index (1971) 77990

ARMENIAN BOLE

Red
Synonym, variant or common name

A deep red ochre (*q.v.*) found originally in Cappadocia (Field, 1835).
See: bole

Clay minerals group; Iron oxides and hydroxides group; *Bole*; *Red ochre*
Field (1835) 95

ARMENIUM

Blue
Synonym, variant or common name

The classical author Vitruvius (first century BC) lists *Armenium* and Pliny (77 AD) lists this among his ‘florid’ colours (at a massive 300 sesterces per pound). Pliny also reports that it came from Armenia as well as from Spain. It is interpreted to be the mineral azurite (*q.v.*).

Azurite
Pliny (1st cent AD/Rackham, 1952) XXXV.xii.30; Vitruvius (1st cent BC/Grainger, 1934) VII.v.8, VII.ix.6

ARNAUDON’S CHROME GREEN

Green
Synonym, variant or common name

This pigment is mentioned by authors such as Terry (1893), Church (1901) and Coffignier (1924) and was usually a basic hydrated chromium phosphate of variable composition. The manufacturing process and possibly the specific chemical composition of these various pigments were in some cases different (Champetier *et al.*, 1956). Hurst (1913) described the precipitation of chromium phosphates from chromium chloride solutions, or in a mixture of potassium dichromate and sodium phosphate. Windholz (1983) gave the composition of this pigment as the hemiheptahydrate of $CrPO_4$. No pigments of this type appear to have been identified on paintings (Newman, 1997).

Also known as Arnaudan’s green (*Colour Index*, 1971), *Vert Arnaudon*, Mathieu-Plessy’s green or Plessy’s green and *Vert Schnitzer* (Newman, 1997); however, these colours may have had different compositions as they were produced by variations of the manufacturing process. Other related pigments include Dingler’s green, variously reported as synonymous with Arnaudon’s chrome green or said to be a mixture of chromium and calcium phosphates.

Listed by the *Colour Index* (1971) under CI 77298.

Chromium phosphates group; *Mathieu-Plessy’s green*; *Plessy’s green*; *Vert Dingler*; Vert Schnitzer
Champetier *et al.* (1956); Church (1901) 195; Coffignier (1924); Hurst (1913); Newman (1997); Terry (1893) 128; Windholz (1983)

ARRABIDA RED

Red
Synonym, variant or common name

Church (1901) lists this as a form of red ochre (*q.v.*). It presumably comes from Arrabida, near Lisbon, Portugal.

Iron oxides and hydroxides group; *Red ochre*
Church (1901)

ARSENIC GROUP

Variable
Group term

The two most familiar arsenic-based pigments are probably orpiment and realgar, and the name ‘arsenic’ is derived from the Greek *arsenikon*, referring to the mineral orpiment. However, in practice, there is a series of sulfides and oxides that can occur in association as well as synthetic analogues of minerals (Cotton *et al.*, 1999; FitzHugh, 1997). The sulfides are yellow to red in colour while the oxides are white. Arsenides and arsenates have variable colours. Associated cobalt compounds are blue or purple and form the raw materials of pigments such as smalt and cobalt violet (Corbeil *et al.*, 2002). Associated copper compounds include the pigments emerald green and Scheele’s green. Associated lead compounds produce yellow pigments. Those compounds or alteration products currently recognised as pigments are:

Oxides and hydroxides: arsenolite and its synthetic analogue (cubic As_4O_6); claudetite (monoclinic As_4O_6).

Sulfides: alacranite and its synthetic analogue (As_8S_9); dimorphite (two forms: type I, α-As_4S_3, and type II, β-As_4S_3); duranusite (As_4S); orpiment and its synthetic analogue (As_2S_3; the latter also in several manufacturing morphological variants); pararealgar (α-AsS); realgar and its synthetic analogue (β-AsS, plus several other modifications); uzonite (As_4S_5).
Arsenides: smaltite ($CoAs_2$).
Arsenates and arsenites: erythrite ($Co_3[AsO_4]_2.8H_2O$); schultenite ($PbHAsO_4$); mimetite ($Pb_5(AsO_4)_3Cl$); trippkeite ($CuAs_2O_4$); tyrolite ($Ca_2Cu_9[AsO_4]_4[OH]_{10}.10H_2O$).

Copper arsenates and arsenites form a large and varied group of pigment-related compounds; see: copper arsenite group.

In addition, various other pigments contain arsenic, but are classed here under different headings. For example, manganese red is described by Salter (1869) as a 'sulpharsenate of manganese'.

Arsenic oxides and hydroxides group; Arsenic sulfides group; Copper arsenite group; Alacranite; Arsenolite; Claudetite; Dimorphite; Duranusite; Erythrite; Lead arsenate; Lead arsenite; Mimetite; Orpiment; Pararealgar; Realgar; Smaltite; Trippkeite; Tyrolite; Uzonite; *Cobalt violet*; *Emerald green*; *Manganese red*; *Scheele's green*
Corbeil *et al.* (2002); Cotton *et al.* (1999) 386 ff.; FitzHugh (1997); Salter (1869) 168–169

ARSENIC ORANGE
Red-Orange
Synonym, variant or common name

Heaton (1928) provides this as a synonym for realgar (*q.v.*).

Arsenic group; Realgar
Heaton (1928) 379

ARSENIC OXIDE, ARSENOLITE TYPE
White
Generic compound

Arsenolite is a naturally occurring arsenic trioxide (As_2O_3) also known as white arsenic or arsenious acid. It is not common in nature but the synthetic analogue has been extensively manufactured. This compound was a starting point for the preparation of arsenic sulfide pigments and Heaton, for example, describes the preparation of arsenic yellow 'by precipitating an acid solution of arsenious oxide with sodium sulphide'.

Analysis published by FitzHugh (1997) showed that arsenolite was a major constituent of some late eighteenth/early nineteenth century manufactured arsenic sulfide pigments she studied. One, labelled 'King's Yellow', was a mixture of orpiment, realgar and arsenolite while another, labelled 'Red Orpiment', contained arsenolite and possibly some alacranite but no detectable realgar. Since arsenolite was probably the starting point, it seems unsurprising to find it in the end product.

Arsenic group; Arsenic oxides and hydroxides group; Arsenolite
FitzHugh (1997)

ARSENIC OXIDE, CLAUDETITE TYPE
White
Generic compound

See: claudetite.

ARSENIC OXIDES AND HYDROXIDES GROUP
White
Group term

The principal oxides of arsenic encountered in a pigment context are the trioxides arsenolite and claudetite (both As_4O_6 (As_2O_3), the former cubic, the latter monoclinic); these may occur as the minerals or their synthetic analogues. Chemically, a pentoxide also exists (As_4O_{10}), but this does not appear to have been identified as a pigment. Arsenic oxides are readily soluble in water. See: arsenic oxide, arsenolite type, arsenolite and claudetite.

ARSENIC SULFIDE
Red-Orange-Yellow
Generic compound

See: arsenic sulfides group.

ARSENIC SULFIDE, ALACRANITE TYPE
Red-Orange-Yellow
Generic compound

See: alacranite.

ARSENIC SULFIDE, DIMORPHITE TYPE
Yellow-Orange
Generic compound

See: dimorphite.

ARSENIC SULFIDE, ORPIMENT TYPE
Yellow
Generic compound

Synthetic analogue of the mineral orpiment with a composition As_2S_3. Literature indicates that, in a similar fashion to vermilion (*q.v.*), there were 'dry' – sublimation – and 'wet' – aqueous – routes to manufacture (analogy and terminology according to Wallert, 1984). Sources such as Cennini's *Il Libro dell'Arte* (c. 1400, Clarke MS 590), Jehan le Begue (fifteenth century, Clarke MS 2790; cf. Merrifield, 1849) and an unpublished early fifteenth century MS cited by Wallert either refer to artificial orpiment or give instructions involving heating, for example 'red sulfur and red orpiment' (le Begue). Dossie (1764) in the eighteenth century discusses the production of 'King's yellow or pure orpiment', which 'must be prepared by mixing sulfur and arsenic by sublimation'; by the nineteenth century a mixture of sulfur and arsenic(III) oxide was used. Wet-process methods have also been described, though FitzHugh (1997) doubts that the product has been used as a pigment; she describes passing hydrogen sulfide through a hydrochloric acid solution of arsenic(III) oxide to precipitate a very fine, amorphous material.

FitzHugh also tentatively suggests that the term King's yellow, historically applied to the synthetic pigment, may derive from Arabic alchemical references to orpiment and realgar as 'the two kings' (Crosland, 1962). However, while King's yellow appears in English documentary sources from the eighteenth century, synthetic orpiment was known to have been used by the Dutch in the previous century (Harley, 1982).

Arsenic group; Orpiment; *King's yellow*; *Vermilion*
Cennini (c. 1400/Thompson 1960) 29; Crosland (1962) 36; Dossie (1764) I-97; FitzHugh (1997); Harley (1982) 93–94; Merrifield (1849); Wallert (1984)

ARSENIC SULFIDE, REALGAR TYPE

Red-Orange
Generic compound

See: realgar.

ARSENIC SULFIDE, UZONITE TYPE

Red-Orange-Yellow
Generic compound

See: uzonite.

ARSENIC SULFIDES GROUP

Red-Orange-Yellow
Group term

The two most familiar arsenic sulfide pigments are orpiment and realgar. However, in practice, there is a series of sulfides which can occur in association, as well as synthetic analogues of minerals. Those currently recognised as pigments or alteration products in a pigment context are the following minerals and synthetic analogues: alacranite (As_8S_9), dimorphite (two forms: type I, α-As_4S_3, and type II, β-As_4S_3), duranusite (As_4S), orpiment (As_2S_3), pararealgar (α-AsS), realgar (β-AsS, plus several other modifications) and uzonite (As_4S_5). The sulfides are yellow to red in colour. Synthetic analogues of orpiment (Arsenic sulfide, orpiment type) have also been produced following both aqueous and non-aqueous ('dry') routes.

The arsenic sulfides have recently been reviewed by FitzHugh (1997).

Arsenic sulfides group; Alacranite; Arsenic sulfide, orpiment type; Arsenolite; Dimorphite; Duranusite; Orpiment; Pararealgar; Realgar; Uzonite
FitzHugh (1997)

ARSENIC YELLOW

Yellow
Synonym, variant or common name

A synonym for orpiment according to Terry (1893) and Weber (1923). However, Salter (1869) states that arsenic yellow 'Called also Mineral Yellow, has improperly been classed as an orpiment, from which it differs in not being a sulphide, and in containing lead. It is prepared from arsenic fluxed with litharge, and reduced to a powder.' This suggests that it was a lead arsenic oxide, perhaps analogous to lead-tin and lead-antimony oxides (FitzHugh, 1997).

Arsenic sulfides group; Orpiment; *Mineral yellow*
FitzHugh (1997); Salter (1869) 116; Terry (1893) 257; Weber (1923) 96

ARSENIKON

Yellow
Synonym, variant or common name

αρςενικόν (arsenikón) is a Greek term generally assumed to be the yellow arsenic sulfide mineral orpiment (*q.v.*). It may be found mentioned in works by authors such as Theophrastus (c. 315 BC) and later writers (see FitzHugh, 1997).

Orpiment
FitzHugh (1997); Theophrastus (c. 315 BC/Caley & Richards, 1956) 51

ARSENOLITE

White
Generic compound

Arsenolite is a white cubic arsenic oxide mineral with chemical composition, As_2O_3 (Almin and Westgren, 1942). It is not a common mineral in nature, but is found as a secondary oxidation mineral in the form of white crusts or crystals around arsenic ore bodies (such as White Caps mine, Nevada; Amargosa mine, California). Its colour may vary from white to bluish, yellow, brown or reddish due to the presence of impurities. Arsenolite is sometimes known as white arsenic, *arsenicbluthe*, arsenite or arsenomarcasite, and is the low temperature polymorph of claudetite (*q.v.*) (Dana, 1855).

Arsenolite has been identified by Duffy and Elgar (1995) in pigments from a group of late seventeenth century Tibetan *thangkas*, although they believe this to be a degradation product of the orpiment (*q.v.*) used.

The synthetic analogue, Arsenic oxide, arsenolite type (*q.v.*), has been extensively manufactured, notably as a starting point for the preparation of arsenic sulfide group (*q.v.*) pigments. For example, Heaton (1928) describes the preparation of 'arsenic yellow' by 'precipitating an acid solution of arsenious oxide with sodium sulphide'. FitzHugh (1997) has demonstrated that arsenolite was a major constituent of some late eighteenth/early nineteenth century manufactured arsenic sulfide pigments. One, labelled 'King's Yellow', was a mixture of orpiment, realgar (*q.v.*) and arsenolite, while another, labelled 'Red Orpiment', contained arsenolite and possibly some alacranite (*q.v.*) but no detectable realgar. As arsenolite is likely to have been the starting material for the preparation of these products, it is probable that unreacted initial materials remain present in the final products.

Arsenic oxides and hydroxides group; Arsenic sulfide group; Alacranite; Arsenic oxide, arsenolite type; Claudetite; Orpiment; Realgar; *King's yellow*; *White arsenic*
Almin & Westgren (1942); Dana (1855) 2, 139; Duffy & Elgar (1995); FitzHugh (1997); Heaton (1928) 142

ARSENOUS SULFIDE

Yellow
Synonym, variant or common name

See: orpiment.

ARTINITE

White
Generic compound

Artinite is a white monoclinic hydrated magnesium carbonate mineral with chemical composition $Mg_2(CO_3)(OH)_2.3H_2O$. It is physically and chemically similar to both hydromagnesite and lansfordite (*qq.v.*). Named after the Italian mineralogist E. Artini (1866–1928), artinite commonly forms as silky radiating acicular crystals in veins in hydrothermally altered ultrabasic rocks (such as Val Laterna, Lombardy, Italy and New Idria District, San Benito County, California).

Magnesium group; Hydromagnesite; Lansfordite

ARYLIDE PIGMENTS

Red-Orange-Yellow
Synonym, variant or common name

The arylides constitute a group of around 30 synthetic 'azo' pigments, primarily monoazos but not exclusively so. Initially discovered by Meister Lucius & Brüning in Germany (now Hoechst AG) in 1909 and produced commercially in 1910, these are almost exclusively yellow pigments that are relatively inexpensive, but offer only moderately good colourfastness. Orange and red monoazo compounds are also available, but are apparently not used as artists' pigments. These were (and, to some extent, still are) known as Hansa yellows, 'Hansa' being the trade name used originally by Hoechst for its range of arylide yellows.

Arylide pigments are generally monoazo pigments that are derived from aniline-based diazonium salts and acetoacetylarylide coupling components. A number of diazo (diarylide) pigments were developed somewhat later (c. 1940) and are related in terms of their chemical structures to the monoazo pigments where, typically, the molecule contains a central (perhaps dichlorinated) biphenylene unit bonded directly at either end to two arylide moities via discrete azo groups. The increased conjugation in the molecule compared with the monoazo analogues increases the intensity of hue, but reduces the lightfastness. Yellow hues include CI Pigment Yellows 3, 65, 73, 83, 74, 97 and 98; orange includes Pigment Orange 1 and 6; red is represented by Pigment Red 211 (Berrie and Lomax, 1997; Herbst and Hunger, 1997).

Other terms associated with the arylides include acetoacetarylide, acetoacetarylamide and monoarylide (Berrie and Lomax) as well as permanent yellow, yellow toner, monofast yellow and toluidine yellow (Kositzke, 1973).
See: azo pigments group: monoazo sub-group.

Azo pigments group: Monoazo sub-group
Berrie & Lomax (1997); Herbst & Hunger (1997) 214–237; Kositzke (1973)

ARZICA
Yellow
Synonym, variant or common name

This term generally refers to the lake pigment derived from weld (*q.v.*) plants; however, Merrifield (1849) explains that there were two meanings for this, one of them being a yellow earth used to make the moulds for casting brass (le Begue, 1431; Clarke MS 2790; cf. Merrifield): 'a yellow loam is still used for this purpose in the foundries at Brighton. It is bought by sea from Woolwich, and when washed and dried it yields an ochreous pigment of a pale yellow colour.'
See: yellow ochre and weld.

Merrifield (1849) cliii

ARZICON
Yellow
Synonym, variant or common name

See: orpiment.

ASBESTINE
White
Synonym, variant or common name

Heaton (1928) states that this term was applied to a number of 'mineral powders' such as (originally) finely ground and levigated asbestos or 'French chalk' (a variety of talc, *q.v.*). Toch (1916) differentiates asbestine and asbestos by stating that both are 'silicates of magnesia', but that the former has a short fibre, the latter a long fibre. Mayer (1991) is more specific, describing it as a 'species of talc … mined in northern New York and used as an inert pigment in certain mixed paints'; he also says that it is not the same as asbestos.

Mineralogically, asbestin is a synonym of agalite, which in turn is a synonym of talc (Dana, 1892; Hintze, 1893).
See: asbestos.

Magnesium silicates group; Talc; *Asbestos*; *French chalk*
Dana (1892) 678; Heaton (1928) 379; Hintze (1893) 992; Mayer (1991) 37; Toch (1916) 128–130

ASBESTOS
Variable
Synonym, variant or common name

The term asbestos covers a family of naturally occurring, flexible, fibrous mineral silicates that are divided into two subgroups, the serpentines and the amphiboles (*qq.v.*). The primary serpentine mineral is chrysotile; among the amphiboles are anthophyllite, amosite, actinolite, tremolite and crocidolite; the latter is an asbestiform variant of the mineral riebeckite (*q.v.*) and is also commonly known as 'blue asbestos' (*Merck Index*, 1996). As is well known, there are serious human toxicological issues concerning asbestos; however, there has been widespread use of the material. According to Axelson (1973) asbestos was rarely used as a true pigment since its colour is not especially suited to this application. More often, asbestos was introduced as a viscosity control agent in paints, where its fibrous nature was useful. Weatherability was also good and it apparently functioned as a 'reasonably good low-cost extender'. Other authors indicate that asbestos also found use in fire-retardant paints (for example, Toch, 1916). The possible extent of use should not be underestimated; Axelson adds that although the actual tonnage of pigmentary asbestos is not accurately known, it is estimated that in 1969 about four million pounds (approximately 1800 tonnes) was sold for this purpose, with a 3% annual growth rate. A *terminus ante* date for the employment of asbestos is difficult to give, though it is specifically (if briefly) mentioned in early twentieth century texts such as Zerr and Rübencamp (1906) and Heaton (1928). Church (1901) recommends 'a small quantity of the most silky and white asbestos, cut with scissors into short uniform lengths' as 'a desirable addition' to grounds for fresco painting.

Some confusion of asbestos with asbestine (*q.v.*) exists in the literature. According to Heaton this latter term derived from its origin as a 'fine powder obtained by grinding and air floating waste asbestos'; Toch differentiates between the two as asbestine having a short fibre and asbestos having a long fibre.

Amphibole group; Serpentine group; Actinolite; Anthophyllite; Chrysotile; Riebeckite; Tremolite; *Asbestine*
Axelson (1973); Church (1901) 21; Heaton (1928) 113; *Merck Index* (1996) 863; Toch (1916) 128–130; Zerr & Rübencamp (1906/1908) 381

ASH GREEN
Green
Synonym, variant or common name

According to Fiedler and Bayard (1997), a less common name for Scheele's green (*q.v.*).

Scheele's green
Fiedler & Bayard (1997)

ASHES BLUE
Blue
Synonym, variant or common name

See: blue ashes.

ASHES OF LEAD

Grey

Synonym, variant or common name

Apparently a mixture of lead(II) oxide and metallic lead. Tingry (1804) for example, in a discussion of the oxides of lead obtained by heating, describes how a grey coloured compound is formed before the formation of massicot, minium, and finally litharge (*qq.v.*). He calls this 'grey oxide of lead' or 'grey calx of lead'. Martin (1813), however, refers to this as 'ashes of lead'. Tingry states that grey oxide of lead was not used in painting, but only in varnishing pottery.

Lead group; Lead oxides and hydroxides group; Lead(II) oxide, litharge type; Litharge; Massicot; Minium; *Grey oxide*
Martin (1813); Tingry (1804) 343–344

ASPHALT

Black-Brown

Generic variety

The terminology concerning the use of asphalt, bitumen, pitch and tar are confused and confusing, and within the field of pigment analysis, used variously to describe the same or similar materials, essentially the naturally occurring hydrocarbon, asphalt. The descriptions given below list the terminology used by previous authors and also attempt to clarify the substances on a geological and chemical level. In this work, 'asphalt' refers to naturally occurring (that is, preindustrial revolution) materials and is classed as a variety of bitumen (*q.v.*). Bitumen is discussed under a separate entry and is fully defined there.

Asphalt occurs naturally in sedimentary rocks and can also be produced as a by-product of the petroleum and coal industries. Asphalt residue after the distillation of petroleum has only been available from 1860. Prior to this, artificial asphalt was produced as a by-product from coal gas (that is, 'coal tar') and lamp black (*q.v.*) manufacture. Nineteenth century sources distinguish 'natural' and 'artificial' forms of asphalt, the latter being coal tar derivatives. Artificial asphalt made from coal tar was considered not so good as the natural material. It was believed to be more likely to stain and bleed into other colours (Church, 1901). Child (1995) defines 'asphaltum' as a separate substance from 'asphalt' using the former term to describe the naturally occurring material and the latter to refer to the residues of destructive distillation of coal tar. It is given the *Colour Index* (1971) designation Natural Black 6. Heaton (1928) lists asphaltum as being 'natural bitumen'. Definitions of the substances involved are blurred. According to White (1986), asphalt as a term may encompass bitumens, true asphalts ($<$10% associated mineral matter) and rock asphalts ($>$10% mineral matter). Clarification of the situation is found in the terminology of the modern hydrocarbon industry. Asphalts are varieties of bitumen, long chain hydrocarbons (22–50 carbon atoms present) forming the heaviest fraction of crude oils. They are concentrated naturally in surface environments as asphaltic bitumens and kerobitumens. Asphaltic bitumens are derived from petroleum reservoirs but have been concentrated at the earth's surface by water washing and microbial action. It is these varieties that have found use as pigments, shellac and varnishes. Kerobitumens are disseminated in sedimentary rocks ('tar sands') are largely varieties of pyrobitumens, they are infusible and insoluble in organic compounds. Strictly speaking the term 'asphalt' is applied to semi-solid varieties, which will soften at temperatures exceeding 20°C. Solid, less fusible (requiring temperatures exceeding 110°C) are called asphaltites. Both varieties are soluble (or semi-soluble) in organic solvents.

Natural, mineral, rock or native asphalts and asphaltites, occurring as semi-solid materials, are emulsions of the organic group of compounds called asphaltenes (polycyclic aromatic and heterocyclic hydrocarbons with the general formula C_nH_{2n-4}) partially dissolved in a mixture of 'maltenes' (aliphatic and alicyclic hydrocarbons). Sulfur is also generally present in varying but significant amounts. They occur as 'hard, bright and lustrous' masses (Church, 1901), or as viscous semi-solids. As asphalts and asphaltites are heated the polymer chains disassociate and the maltenes begin to evaporate. This fractionation process leaves the higher evaporation temperature asphaltenes as a residue, and it is this fraction that is used as a pigment. Many historical recipes for the preparation of asphalt record that it must be heated 'until it ceases to boil' (Williams, 1787) or heated to 'no less than 250°C' (Church, 1901) to remove the maltenes. This was to improve the workability of the pigment and to reduce its propensity to crack on drying.

Naturally occurring asphalt 'seeps' are known from several localities and are now widely recognised as indicators of hydrocarbon-bearing potential of various regions including many in the Middle East and the USA. As far as historical pigments are concerned, the best asphalt was derived from the Dead Sea, known as *lacus asphaltites*. Here the asphalt floats on the surface in lumps and is easily collected from the shoreline. Another important locality is the 'Great Pitch Lake' in Trinidad. Church (1901) also cites sources in Peru, Switzerland and Albania. Mexico, Cuba and California are also well-known sources and Harrell and Lewan (2001) have documented sources available to Ancient Egypt in the Red Sea coasts. The chemical composition of sources varies widely. 'High purity' asphalt sources are considered to be the 'Egyptian' occurrences, including those in the Dead Sea, and these were most suitable as pigments.

Naturally occurring deposits of asphalt have been worked since the Palaeolithic period (c. 38 000 BC) predominantly for waterproofing. According to treatises on artist's materials it clearly attained use as a pigment in the sixteenth and seventeenth centuries. Early European references to asphalt as an artist's colour can be found in Borghini (1584, cf. Bothe, 2004), Nunes in 1615 ('*spalto*'), Palomino (1655–1726), who calls it a useless colour (cf. Veliz, 1986), and Volpato (1685, cf. Merrifield, 1849) who describes its supposed use by Titian. Dossie refers to it in 1764 and surprisingly, Hilliard (1624) notes occurrences of asphalt ('*spalte*') as a watercolour in the sixteenth century. This was a shortlived use, but ground asphalt pigments were reintroduced as watercolours in the nineteenth century (see Newman *et al.*, 1980). By the eighteenth century, the pigment was in routine use in oil painting, ground in turpentine, particularly for glazing, shading and specifically for flesh shadows (Harley, 1982). The popularity of this pigment is attested to by the large number of uses indicated from artist's daybooks. As the pigment gained in popularity it became overused; 'the poor condition of some paintings from that period may be attributed to the presence of excessive quantities of asphalt' (Harley, 1982). This, despite the warning of authors such as Weber (1923) that asphalt should not be applied thickly as 'it never dries' and will even slide off the canvas. Church (1901) remarks that the pigment was prone to decomposition when exposed to sunlight and had a tendency to bleed into other colours. The characteristic cracking displayed by asphalt blacks is called variously crocodile hide

(Rosciszewska, 1994), *craquelure anglais* (Carlyle, 2001) or 'alligatoring' (Harley, 1982).

Ancient and mediaeval use is possible but the difficulties of proper identification of this substance has probably impeded its identification on works of art until recently, as reliable analytical techniques were not available (Bothe, pers. comm., 2003). Massing (1988) and Groen (1994) have identified bituminous paint on a painting by Gentilleschi painted between 1625 and 1634 and it has been found in a paint box belonging to Winslow Homer (Newman *et al*., 1980). Languri *et al*. (2002) have identified a natural asphalt, probably derived from the Dead Sea in the stock of Michiel Hafkenscheid & Son, a supplier of pigments during the early nineteenth century. Asphalt began to go out of fashion in the late nineteenth and early twentieth centuries. Connan (1999) and Harrell and Lewan (2001) have fingerprinted archaeological asphalts and bitumens and their natural sources from the Middle East using gas chromatography, mass spectrometry and stable isotope analyses. There are a large number of further identifications of this substance on paintings; however, many of these are based on artist's documentary evidence or have been reported with insufficient analytical support to be absolutely certain of the identification (Bothe).

Gilsonite is very high purity asphaltite known for its flexibility; the asphalt grahamite is a brittle variety (Child). Many asphalts have derived names from their sources; manjak is asphaltite from Barbados (also known as glance pitch). Historical synonyms include asphaltites, asphalte, spaltam (*q.v.*) or spalte, aspalathum, asphalt brown, bitumen of Judea, Syrian asphalt, mineral pitch, Jew's pitch and liquid asphaltum (Salter, 1869; Church, 1901; Harley, 1982); Salter adds that it was common to call a solution of asphalt in turpentine asphaltum and that in drying oil bitumen or Antwerp brown (*qq.v.*). However, Antwerp brown has been recorded as being modified asphalt (Williams). German terms include *Erdpech*, *Erdhartz* (earth pitch, resin); *Bergpech*, *Berghartz*, *Bergteer* (mountain pitch, resin, tar); *Judenhartz*, *Judenleim* (Jew's pitch, glue); other terms include the Dutch *aardpek* (earth pitch) (Bothe) and the French *poix minerale* (mineral pitch) (Mérimée, 1830). Asphalts may be referred to as tars and pitches and generically as bitumens.

Carbon-based blacks group; Hydrocarbons group; Bitumen; *Antwerp Brown*; *Coal tar*; *Mummy*; *Spaltam*

Bothe (2004); Carlyle (2001) 479–482; Child (1995); Church (1901) 235; *Colour Index* (1971); Connan (1999); Dossie (1764); Groen (1994); Harley (1982) 150–152; Harrell & Lewan (2001); Heaton (1928) 379; Hilliard (1624/Thornton & Cain 1981) 94; Languri *et al*. (2002); Massing (1988); Mérimée (1830/trans. Taylor 1839) 46; Merrifield (1849) 749; Newman *et al*. (1980); Nunes (1615) 57; Rosciszewska (1994); Veliz (1986) 26, 154; Weber (1923) 20; White (1986); Williams (1787)

ASPHALTUM

Brown

Synonym, variant or common name

See: asphalt.

ASSIETTE ROUGE

Red

Synonym, variant or common name

Towne (1811; cf. Harley, 1982) mentions *assiette rouge*, which may be compared to the English term saucer colour (*q.v.*); this latter was a pigment based on safflower. The term is also found in bookbinding, where it referred to the preparation applied prior to gilding the edges of pages; for example, the *English Mechanic* for October 1869 mentions that 'Assiette … is composed of Armenian bole, 1 lb.; bloodstone, 2 oz.; and galena [*q.v.*], 2 oz.' (cf. *OED*, 2002).

Galena; Safflower; *Saucer colour*

Harley (1982) 147; *OED* (2002) 'Assiette'; Towne (1811)

ATACAMITE

Green

Generic compound

Atacamite is a green orthorhombic copper chloride hydoxide mineral with composition $Cu_2(OH)_3Cl$. It commonly occurs as euhedral or fibrous crystals (although it may be massive or granular in form) and forms in the weathering zone around copper lode deposits, particularly when the erosion occurs in a desert environment. It is named after its type locality at Atacama, Chile, in the Atacam Desert, and is also known as remolinite after Los Remolinos in South America where it occurs. Other associated historical mineral terms include halochalzit and smaragdocalcite. Atacamite is also found at Botallack mine (St Just, Cornwall, England), Linares (Spain) and Burra mine (south Australia) and is polymorphous with botallackite, paratacamite and the recently assigned clinoatacamite (*qq.v.*).

The relative rarity of the mineral has led some authors to conclude that the synthetic analogue (copper chloride hydroxide, atacamite type, *q.v.*) was used as pigment and in fact there are numerous mediaeval recipes for preparing a green copper pigment with common salt. Of these perhaps the best known is that of Theophilus for *viride salsum* (*q.v.*).

Atacamite has been identified as a major component in green pigments in Egyptian wall paintings by El Goresy *et al.* (1986), although it is possible that this is a synthetic form. Green (2001) also reports that copper chloride has been identified as a component in ancient Egyptian green pigments. Atacamite has been identified on eighth century paintings from Dunhuang by Delbourgo (1980), although the method used to identify it (X-ray fluorescence) would not be able to distinguish between the polymorphs. It was also apparently found in wall paintings of almost all dynasties at Dunhuang, and the report by Wainwright *et al.* (1993) further states that a quarry for atacamite existed at Dunhuang. Atacamite has also been identified on several eleventh to fifteenth century paintings (Van'T Hul-Ehrnreich and Hallebeek, 1972; Kerber *et al*., 1972; Banik *et al*., 1982) and in thirteenth century Romanesque frescos where it was present as an alteration product of artificial azurite (Richter, 1988). Additional identifications are given by Naumova and Pisareva (1994).

Copper group; Copper halides group; Azurite; Botallackite; Clinoatacamite; Copper chloride hydroxide, atacamite type; Paratacamite; *Viride salsum*

Banik *et al.* (1982); Delbourgo (1980); El Goresy *et al.* (1986); Green (2001); Kerber *et al.* (1972); Naumova & Pisareva (1994); Richter (1988); Van'T Hul-Ehrnreich & Hallebeek (1972); Wainwright *et al.* (1993)

ATRAMENTUM

Black

Synonym, variant or common name

Atramentum ('blacking') is a term for blacks and black inks based on carbon found in the writings of the classical author Vitruvius (first century BC). He describes it as coming from soot produced by burning resin, charcoal from brushwood and pine chips and burnt wine dregs. Supposedly the best wines produce a colour akin to indigo; this appears to be an example of a so-called 'optical' blue, where mixtures of finely divided black pigment with white appears blue to an observer. Pliny (77 AD) generally corroborates this, though adding that the legendary Greek artist Apelles invented the process of making black – *elephantinum* – from burning ivory; he further mentions an Indian black without actually knowing what it was. Heraclius (tenth–thirteenth centuries) largely repeats this information describing it as being made of ground soot, soft charcoal of wood or of peach stones or charred twigs. Summarising, Merrifield (1849) lists four contexts for use of the term: (a) artificial black pigments such as lamp and charcoal blacks made from soot; (b) writing ink; (c) soot of burnt wood, perhaps beech, mixed with salt and used as a substitute for gold; (d) a black dye for leather made by boiling oil and iron scales that was also known as *atramentum sutorium*, or 'shoemaker's black'.

A mediaeval German manuscript *de coloribus diuersi faciendis* (1460, Clarke MS 2160; cf. Oltrogge, 2003) describes a colour called *attramentum* which is made from burning old leather and '*stercore canino*' (dog turd).

Carbon-based blacks group
Heraclius/Romano (10–13th cent/1996) III, 53; Merrifield (1849) I, 248; Oltrogge (2003); Pliny (1st cent AD/Rackham, 1952) XXXV.xxv. 41,43; Vitruvius (1st cent BC/Grainger, 1934) VII.x.1

ATTAPULGITE
White
Synonym, variant or common name

A clay group mineral now known as palygorskite (*qq.v.*). Listed in older texts as the substrate for Maya blue (*q.v.*).

Clay minerals group; Maya blue; Palygorskite

ATTIC SIL
Yellow
Synonym, variant or common name

See: sil.

AUGITE
Variable
Generic compound

Augite is a calcium magnesium iron silicate mineral of composition $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$. It varies in colour between brown-green, green, light brown, dark brown and black (Rutley, 1988). Augite is a pyroxene mineral (Peacor, 1967), common worldwide and found in basic igneous and regional high-grade metamorphic rocks.

Although augite is not considered to have been used as a pigment itself, it may be a relict component in green earth (*q.v.*) pigments where these have been derived from rocks in which the mineral occurs.

Aluminium group; Calcium group; Iron group; Magnesium group; Silicates group; Titanium group
Peacor (1967); Rutley (1988) 379–380

AUREOLIN
Yellow
Synonym, variant or common name

Synonymous with cobalt yellow (potassium hexanitrocobalt(III) or the part-sodium substituted form) (Gates, 1995; Church, 1901). The name is derived from the Latin *aureus*, meaning 'golden' (Cornman, 1986).

Cobalt group; Potassium hexanitrocobalt(III); Potassium sodium hexanitrocobalt(III); *Cobalt yellow*
Church (1901); Cornman (1986); Gates (1995)

AURICHALCITE
Blue-Green
Generic compound

Aurichalcite is a copper-zinc carbonate hydroxide mineral with chemical formula $(Cu,Zn)_5(CO_3)_2(OH)_6$. It forms as a secondary mineral in the oxidising zone around copper and zinc deposits (such as Salida, Colorado; Lucin, Utah). The colour of aurichalcite varies from pale green to bright blue or green-blue and it forms as druse crystals in rock cavities, as encrustations, or as acicular crystals upon a matrix (Harding *et al*., 1994; Scott, 2002).

Aurichalcite is closely related to the other blue or green zinc-copper carbonate minerals claraite and rosasite (*qq.v.*), the latter of which has been identified as a pigment by Dunkerton and Roy (1996).

Copper carbonates group; Copper group; Zinc group; Claraite; Rosasite
Dunkerton & Roy (1996); Harding *et al*. (1994); Scott (2002)

AURIPETRUM
Yellow
Synonym, variant or common name

Merrifield (1849) notes that *Auripetrum* is a lacquer made using gall, saffron (*qq.v.*) or similar materials used over tin to make imitation gold.
See: aureola.

Saffron; *Gallstone*
Merrifield (1849) 158, 240

AURIPIGMENTUM
Yellow
Synonym, variant or common name

A Latin term synonymous with orpiment (*q.v.*). *Auripigmentum* (or *auripigmento*), which means literally 'gold paint', was used by the classical authors Vitruvius (first century BC) and Pliny (77 AD) as well as later authors such as Agricola (1556). It referred to its colour as well as the supposed gold content and is the origin of the modern term. Vitruvius mentions that it comes from Pontus which, in ancient times, was the name of the north-eastern province of Asia Minor, a long and narrow strip of land on the southern coast of the Black Sea – *Pontus Euxinus* – from which the designation was later transferred to the country.

Orpiment
Agricola (1556/trans. Hoover & Hoover, 1950) 111, 222; Pliny (1st cent AD/Rackham, 1952) XXXIII.79, XXXV.30, 49; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.5

AUROCOLINE
Yellow
Synonym, variant or common name

See: cobalt yellow.

AURORA YELLOW
Yellow
Synonym, variant or common name

Winsor & Newton describe this pigment (which they introduced) thus: 'An opaque and brilliant variety of Sulphide of

Cadmium introduced by us in 1889' (cf. Carlyle, 2001). Church (1901) describes this as 'a bright, beautiful pigment consisting essentially of cadmium sulphide, more opaque than most other varieties of cadmium'. Heaton (1928) simply lists aurora yellow as a 'variety of cadmium yellow' (*q.v.*).

Cadmium sulfides and selenides group; *Cadmium yellow*
Carlyle (2001) 524–525; Church (1901) 142; Heaton (1928) 379

AURUM MUSSIVUM
Yellow
Synonym, variant or common name

See: mosaic gold.

AUSTRALIAN CINNABAR
Red-Orange
Synonym, variant or common name

According to the review of chrome red and chrome orange pigments by Kühn and Curran (1986), this was an older term for basic lead chromate (lead chromate(VI) oxide) (*qq.v.*).

Lead chromates group; Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*
Kühn & Curran (1986)

AUSTRIAN CINNABAR
Red-Orange
Synonym, variant or common name

According to Schiek (1973), this was an older name for chrome orange (*q.v.*). Kühn and Curran (1986) and the *Merck Index* (1996) list this as a synonym for lead chromate(VI) oxide (*q.v.*).

Lead chromate(VI) oxide; *Chrome orange*
Kühn & Curran (1986); *Merck Index* (1996) 5423; Schiek (1973)

AUSTRIAN RED
Red-Orange
Synonym, variant or common name

Reported by Schiek (1973) as an older name for chrome orange, and by Kühn and Curran (1986) as an older term for chrome orange and chrome red (*qq.v.*).

Lead chromates group; *Chrome orange*; *Chrome red*
Kühn & Curran (1986); Schiek (1973)

AVIGNON BERRIES
Yellow
Synonym, variant or common name

Various species of *Rhamnus* produce a dyestuff, generally extracted from the unripe berries; these latter are known as yellow berries or buckthorn, and French berries or Avignon berries. Tingry states that 'the plant which furnishes these berries is grown in great abundance in the neighbourhood of Avignon'. We should note, however, that in France the berries of *R. alaternus* and *R. infectorius* were known as '*graine d'Avignon*', a term also used in translation as Avignon berries. This is the dye used to produce the various yellow lake pigments called 'pink' (*q.v.*).

For a fuller discussion of the plant species involved, constituent compounds, substrates and alternative terminology, see the entry for *Rhamnus*.

Flavonoids group; Rhamnus; *Buckthorn*; *French berries*; *Pink Stil de Grain*; *Yellow berries*
Tingry (1804) 364

AZO PIGMENTS GROUP
Variable
Group term

Azo dyes and pigments form a large class of synthetic compounds which are characterised by the presence of one or more azo linkage groups (–N=N–) consisting of two nitrogen atoms which are also linked to carbon atoms. In general they are structurally based on the formula Ar–N=N–R, where Ar is an aromatic or a heteroaromatic moiety (an aromatic carbocycle, an aryl moiety, usually benzene or naphthalene derivatives or a heterocycle like pyrazolone or thiazole) and R is either an aromatic unit or represents the function R^1–(C=O)–C=(C–OH)–R^2, where R^1 is an alkyl or aryl group (often $-CH_3$) and R^2 is typically –HN–Ar (Ar being an aromatic or a heteroaromatic moiety as before). The diazotisation reaction was discovered by Gries in 1858; the first azo dye, chrysodin, was synthesised by Caro and Witt in 1875.

Individual compounds are generally referred to either by the components linked to form the product or, more commonly and conveniently, by the uniquely assigned number in the *Colour Index*, a comprehensive listing of such compounds and other dyes and pigments now in its fourth edition (2002). The azo compounds are also normally sub-classed (notably in the *Colour Index*) into monoazo (one azo group; *Colour Index* numbers 11000–19999) and disazo (two azo groups; CI numbers 20000–29999); triazo and higher structures also exist. Moreover, since azo pigments are usually manufactured by coupling a given diazo component (D) with a coupling component (C), they can be categorised according to the nature of D, C and the coupling direction; monoazos are consequently represented by $D \rightarrow C$ and disazos by $C \leftarrow D \rightarrow C$ or $D \rightarrow C \leftarrow D$. Compounds with three or more azo groups are possible but have not achieved commercial importance.

It has also been found helpful to sub-group the azo pigments; monoazo pigments can for example be further sub-classed according to the coupling component (C), giving such groups as the yellow pigments from acetoacetyl compounds (CI numbers 11640–11770), red pigments from 2-naphthol (CI 12050–12211) and 3-hydroxy-2-naphthanilides (CI 12300–12505).

Reviewing azo pigments for artists' colours, Berrie and Lomax use the following categories: arylides; benzimidazolones; diarylides; naphthols; β-naphthols (including the di- and ortho-nitroanilines), para red, chlorinated para red, toluidine red, lithol reds, BON (or BONA) pigments, red lake C and clarion red; nickel-azos; pyrazolones (Berrie and Lomax, 1997). Herbst and Hunger (1997) use the groups: monoazo yellow and orange pigments; disazo pigments; β-naphthol pigments; naphthol AS pigments (naphthol reds); azo pigment lakes; benzimidazolone pigments; disazo condensation pigments; metal complex pigments; isoindolinone and isoindoline pigments.

Additionally, azo pigment lakes may be formed (also known as 'salt-type pigments' or 'toners'). These are made by precipitating a monoazo compound which contains sulpho – and/or carboxy – groups. The coupling component in the reaction may vary; for example, β-naphthol lakes are derived from 2-naphthol, BONA lakes use 2-hydroxy-3-naphthoic acid and naphthol AS lakes contain anilides of 2-hydroxy-3-naphthoic acid as coupling components. Metal complex azo pigments are prepared by chelating a dye with a metal, usually nickel, but also cobalt or iron(II). The azo group may further be replaced by the analogous –CH=N– group to form an azomethine complex pigment, in this case most commonly using copper as the chelating metal.

The earliest water-insoluble pigments to be commercialised were the red β-naphthols; para red was introduced in 1885, toluidine red in 1905 and dinitroaniline orange in 1907. Hansa yellow, the first monoazo pigment, was introduced in 1909. The earliest red naphthol AS pigments followed in 1912, while the diarylide yellows, though some were patented as early as 1911, were not commercialised until 1935. Disazo condensation pigments appear in 1954, the benzimidazolone series from 1960 and the isoindolinone pigments from 1964.

An excellent modern review of this whole class of pigments is given by Herbst and Hunger (1997).

Anthraquinones group; Indigoid group; Phthalocyanine group; Polycyclic pigments group; *Dinitroaniline orange*; *Para red*; *Toluidine red*
Berrie & Lomax (1997); *Colour Index* (1971); Herbst & Hunger (1978); Herbst & Hunger (1997)

AZO PIGMENTS GROUP: BENZIMIDAZOLONE SUB-GROUP

Red-Brown
Group term

This group of synthetic azo pigments is characterised by the presence of the benzimidazolone structure, which is introduced as part of the coupling component (for a discussion of this latter aspect, see the entry under Azo pigments group). The pigments obtained by coupling to 5-acetoacetylaminobenzimidazolone give greenish yellow to orange colours while 5-(2′-hydroxy-3′-naphthoylamino)-benzimidazolone gives medium red to carmine, maroon, bordeaux and brown shades (Herbst and Hunger, 1997).

Azo pigments group
Herbst & Hunger (1997)

AZO PIGMENTS GROUP: DISAZO CONDENSATION SUB-GROUP

Variable
Group term

These pigments result from the condensation of two carboxylic monoazo components with an aromatic diamine to form a high molecular weight compound. Typical colours achieved within this group range from greenish yellow to orange and bluish red or brown. First synthesised in the early 1950s by the Ciba company, disazo condensation compounds were a way of conferring higher solvent and migration resistance to a Naphthol AS pigment. A monoazo yellow pigment obtained from acetoacetarylide constitutes the monoazo portion in a typical yellow product while red types are derived either from a β-naphthol derivative or a BONA pigment. Typical products of commercial importance that fall within this group include Pigment Yellows 93–95 and 128, Pigment Orange 31, Pigment Reds 144, 166, 214, 220, 221, 242 and 248 and Pigment Brown 23 (Herbst and Hunger, 1997).

Azo pigments group
Herbst & Hunger (1997) 370–389

AZO PIGMENTS GROUP: DISAZO SUB-GROUP

Red-Orange-Yellow
Group term

Disazo pigments are defined as those compounds which contain two azo groups and the diaminodiphenyl skeleton. There is in fact also a dual classification system for disazo pigments based on differences in the starting materials. The primary group includes compounds whose synthesis involves the coupling of di- and tetra-substituted diaminodiphenyls as diazonium salts with acetoacetic arylides (diarylide yellows) or pyrazolones (disazo pyrazolones) as coupling components. The secondary group is the bisacetoacetic arylide pigments, obtained from diazotisation of aromatic amines followed by coupling with bisacetoacetic arylides. Achievable colours with disazo group pigments covers greenish yellow to reddish yellow, orange and red.

Diarylide yellow pigments were first patented as early as 1911 but were not utilised for some time due to the market dominance of the monoazo ('Hansa') yellows, taking about 25 years to be rediscovered. These products were first introduced into the USA, for example, in 1938 as printing inks; European use followed in the later 1940s, with a shift from monoazo to diarylide pigments in that context occurring in the early 1950s. However, no comparable transition seems to have taken place with paints and the monoazo compounds continue to dominate the market (Herbst and Hunger, 1997).

Azo pigments group
Herbst & Hunger (1997)

AZO PIGMENTS GROUP: ISOINDOLINONE/ISOINDOLINE SUB-GROUP

Red-Orange-Yellow
Group term

First described in 1946 and commercialised some 20 years later. This small group (<12) of azo pigments is more properly termed disazomethine compounds in which two isoindole groups (comprising a polychlorinated six-membered carbocyclic ring fused with a five-membered nitrogen heterocyle containing a carbonyl group) are joined via a p-diaminobenzene unit. Control of the hue may be achieved by chemical modification of the symmetrical substitution in the aromatic rings. These are apparently lightfast pigments, even in very pale shades and in thin applications. Commercially important products include CI Pigment Yellows 109, 110, 139, 173 and 185, Pigment Orange 61, 66 and 69 and Pigment Red 260 (Herbst and Hunger, 1997).

Azo pigments group
Herbst & Hunger (1997)

AZO PIGMENTS GROUP: LAKES SUB-GROUP

Variable
Group term

Herbst and Hunger (1997) define this group of pigments as 'azo colorants bearing sulfonic and/or carboxylic acid functions, which are used as pigments after being rendered insoluble by conversion into insoluble alkali earth or manganese salts'. These are generally lakes in the modern sense of metal salts rather than dyes struck onto an insoluble base such as aluminium hydroxide. The red azo pigment lakes can be further categorised according to the coupling component; four groups are industrially important – β-naphthol types, those based on 2-hydroxy-3-naphthoic acid (BONA), naphthol AS derivatives and naphthalene sulfonic acid derivatives. In contrast, the corresponding monoazo yellow pigment lakes are much less significant.

β-naphthol pigment lakes originate with the discovery of lithol red by Julius at BASF in 1899, a pigment synthesised by an indirect diazotisation process using 2-naphthylamine-1-sulfonic acid and formed as calcium or barium salts. Lithol red was one of the earliest colourants specifically developed as a pigment rather than initially as a dyestuff. It was followed by the lake red C pigments, discovered by Meister Lucius & Brüning (now Hoechst AG) in

1902. According to Herbst and Hunger, the β-naphthol pigment lakes have largely lost their commercial importance although certain types remain significant. Resinated forms are also produced, where a colophony-based rosin is incorporated during the laking process to create insoluble rosinate salts making up to 30% of the total weight. Most applications of this class appear to be as inks though CI Pigment Red 53:1 (a barium lake) is noted as being used for 'inexpensive pencils and water colours', while Pigment Red 68 (a calcium lake) finds application more generally in paints.

A group of monoazo pigment 'lakes' that derive their name from 2-hydroxy-3-naphthoic acid, which is used as a general coupling component for the entire group, this compound also being known as Beta-OxyNaphthoic Acid ('BONA'). 2-Hydroxy-3-naphthoic acid was first synthesised in 1887 by Schmitt and Burkard as a coupling component; however, it was not until 1902 that the compound was used for dye synthesis. The first pigment, CI Pigment Red 57, discovered in 1903 by Gley and Siebert of AGFA, was to develop into one of the most important organic pigments on the market. Almost all pigments within this series contain two acidic functional groups – one a sulfonic acid, the other a carboxylic acid group. Precipitation is principally accomplished with calcium or manganese; to a lesser extent barium, strontium or magnesium is used. Two groups of BONA pigments have found particular favour, the Pigment Red 57 group just mentioned and those related to Pigment Red 48. The latter comes in a number of modifications (designations 48:1 to 48:5 according to the metal salt) and is also sometimes known under its original marketing name permanent red. Other commercially significant pigments of this type listed by Herbst and Hunger include Pigment Reds 52, 58, 63, 64, 200 and Pigment Brown 5.

The naphthol AS derivatives form a small group of pigments, all of which contain one or two sulfonic acid groups; it is through these groups that the salts may be formed. There is apparently no common molecular structural feature within this group apart from the basic naphthol AS pigment skeleton. According to Herbst and Hunger, the commercially important pigments of this type appear to be primarily used in the coloration of plastics rather than paints.

Naphthalene sulfonic acid pigment lakes are monoazo pigment lakes that are obtained by using a naphthalene derivative bearing one or two sulfo groups as a coupling component. The metal cations are barium, sodium or aluminium; some grades are actually precipitated onto an aluminium hydroxide substrate. Of the forms which are used in paints, Herbst and Hunger note the chlorine-bearing barium salt CI Pigment Orange 19 and the barium salt Pigment Red 60, which was discovered as early as 1902.

Monoazo yellow pigment lakes are synthesised by introducing acidic groups into the diazo or coupling component and then precipitating the product as an insoluble salt with, typically, calcium, barium, strontium or manganese. They appear to have found little use in paint applications.

Azo pigments group; Azo pigments group: Monoazo sub-group; Azo pigments group: Naphthol AS sub-group; Azo pigments group: β-Naphthol sub-group; *Lithol red*
Herbst & Hunger (1997) 315–345

Azo pigments group: Metal complex sub-group

Yellow
Group term

There are two groups of pigment which fall under the general heading of azo metal complexes, the azo metal complexes themselves and the azomethine metal complexes. Only a few azo metal complex pigments are available; of these most are nickel complexes or, less commonly, cobalt and iron(II). Additionally, the azo group –N=N– may be replaced by the analogous –CH=N– group to form azomethine complex pigments, usually with copper as the metal. The colours found in this group typically range through greens and yellows to oranges and reds.

The earliest commercial pigment of this general class is Pigment Green B (CI 10006/Pigment Green 8), which was discovered by O. Hoffmann in 1885; it is of the azo metal type, the iron complex of 1-nitroso-2-naphthol. It was not exploited industrially until 1921 and was subsequently largely displaced by copper phthalocyanine group (*q.v.*) pigments, thereby losing most of its importance. Two other azo metal types have also been of significance. In 1946, Du Pont described a nickel/azo complex that it marketed as 'Green Gold'; it is CI 12775/Pigment Green 10. Another nickel/azo complex, CI 12764/Pigment Yellow 150, has also been of significance. Of the three, Pigment Green 8 has found particular use as an artists' pigment.

Of the azomethine complex pigments, Herbst and Hunger (1997) document a number of forms employed commercially. Among these, Pigment Yellows 129 and 153, and Pigment Orange 59, are recommended for architectural paints.

Azo pigments group; Phthalocyanine group
Herbst & Hunger (1997) 390–403

Azo pigments group: Monoazo sub-group

Yellow-Orange
Group term

Monoazo pigments are prepared by coupling a diazotised substituted aniline with a coupling component containing an active methylene moiety in a linear structure. Yellow monoazo pigments were discovered by Meister Lucius & Brüning (now Hoechst AG) in 1909, being sold commercially from 1910 under the tradename 'Hansa'. Monoazo yellow and orange pigments may be formed either as laked or non-laked types, that is, as metal salts; the metals used in these lake-type pigments is often calcium, but strontium and ammonium are also found.

The oldest monoazo yellow pigment is CI 11680/Pigment Yellow 1, a compound which continues to be in widespread commercial production. Its discovery in 1910 heralded the development of a range of related pigments of the monoazo type, though none appears to have had the same importance. The principal types of non-laked monoazos are CI Pigment Yellows 1, 2, 3, 5, 6, 49, 65, 73, 74, 75, 97, 111, 116 and 130, plus Pigment Orange 1; among the laked monoazos, CI Pigment Yellows 61, 62, 100, 133, 168, 169, 183, 190 and 191 are of significance (Herbst and Hunger, 1997).
See: arylide pigments.

Azo pigments group; *Arylide pigments*
Herbst & Hunger (1997) 214–237

Azo pigments group: Naphthol AS sub-group

Variable
Group term

Naphthol AS pigments (also known as naphthol reds) are a class of azo pigments obtained by coupling substituted aryl diazonium salts with arylides of 2-hydroxy-3-naphthoic acid (2-hydroxy-3-naphthoic acid anilide is naphthol AS). Colours range from

'yellowish and medium red to bordeaux, carmine, brown, and violet' (Herbst and Hunger, 1997).
See: azo pigments group: β-naphthol sub-group.

Azo pigments group; Azo pigments group: β-Naphthol sub-group
Herbst & Hunger (1997)

Azo pigments group: β-Naphthol sub-group

Red-Orange
Group term

The β-naphthol pigments have the same basic chemistry as the monoazo subgroup (*q.v.*) yellow pigments except that they are produced by coupling 2-hydroxynaphthalene (β-naphthol) instead of acetoacetarylides. Members of this class are among the oldest modern synthetic dyes known and, likewise, the corresponding pigments were the earliest of their kind in the pigment industry, first manufactured in 1889. Colours range from orange to medium red.

Well-known members of this group include orthonitroaniline orange (CI 12060/Pigment Orange 2; discovered in 1895 and prepared by coupling o-nitroaniline with β-naphthol), dinitroaniline orange (CI 12075/Pigment Orange 5; introduced 1907), para red (CI 12070/Pigment Red 1; discovered by Gallois and Ullrich in 1885), toluidine red (CI 12120/Pigment Red 3; launched 1905), chlorinated para red (CI 12085/Pigment Red 4; marketed from 1906) and parachlor red (CI 12090/Pigment Red 6). According to Herbst and Hunger (1997), the most important commercial products from this class still produced include Pigment Oranges 2 and 5 as well as Pigment reds 1, 3, 4 and 6; both oranges are noted to have been used for artists' colours, as are the Pigment Reds 3 and 4.
See: azo pigments group: naphthol AS sub-group and para red.

Azo pigments group; Azo pigments group: Naphthol AS sub-group; *Dinitroaniline orange*; *Lithol red*; *Para red*; *Toluidine red*
Herbst & Hunger (1997) 272–281

Azorium romanum

Blue
Synonym, variant or common name

Historical term referring to indigo (*q.v.*; Schweppe, 1997).

Indigo
Schweppe (1997)

Azul baxo

Blue
Synonym, variant or common name

According to Veliz (1986), this refers to a low grade of azurite (*q.v.*). It is mentioned in the Spanish treatise of Carducho, *Diálogos de la Pintura* of 1633.

Azurite
Carducho (1633); Veliz (1986) 197, n.6

Azûr à poudrer

Blue
Synonym, variant or common name

Historical term associated with smalt (*q.v.*). Merrifield (1849), however, states that there were two forms of pigment with this name, the first being a zaffre (*q.v.*) and the second being also called Vestorian azure described by Vitruvius (first century BC) as composed of sand, copper and potassium nitrate (presumably Egyptian blue, *q.v.*).

Smalt; *Egyptian blue*
Merrifield (1849) ccvi; Vitruvius (1st cent BC/Grainger, 1934) ii.123

Azûr d'acre

Blue
Synonym, variant or common name

Historical term associated with natural ultramarine (lazurite, *q.v.*; Plesters, 1993).

Lazurite
Plesters (1993)

Azurblau

Blue
Synonym, variant or common name

Mühlethaler and Thissen (1993) note *azurblau* as a historical term associated with smalt (*q.v.*). Rose (1916) mentions *azurblau* in a discussion of cobalt blues (*q.v.*) and smalt. Mierzinski (1881) on the other hand indicates that it could be made of one part white (zinc or lead white) and 1/140 part Berlin blue (a form of Prussian blue) or 100 parts white and 1 part indigo (further, when 1 part of white is mixed with 1/110 of indigo (*qq.v.*); Mierzinski calls it bluish white – '*Blaeuliches Weiss*'). Finally, Brachert (2001) found links between this term and smalt, ultramarine (*q.v.*) and cobalt blues.

However, for a discussion of the complexities which surround this term see: azure.

Indigo; Smalt; Ultramarine; *Azure*; *Berlin blue*; *Lead white*; *Prussian blue*; *Zinc white*
Brachert (2001) 33; Mierzinski (1881) 25; Mühlethaler & Thissen (1993); Rose (1916) 279

Azure

Blue
Synonym, variant or common name

Essentialy, azure simply means 'blue', not necessarily being tied to any particular pigment. The conventional view is that the word azure derives from Old French *azur*, *asur* (eleventh century), which is cognate with Old Spanish *azur*, Portuguese and Spanish *azul*, Italian *azzurro*, *azzuolo*, and mediaeval Latin *azura*, *azzurum*, *azolum*. These are adaptations of the Arabic *(al-)lazward* and ancient Persian *lajward*, *lazhward*, and are considered to mean *lapis lazuli* (*q.v.*) or 'blue stone'. The initial *l* is absent in the Romance languages, apparently having been dropped along with Arabic article *al-*, though it remained in mediaeval Greek (*lazonrion*) and Latin (*lazurius*, *lazur*, *lazulus*) as well as German. Alternate spellings include *azer*, *asur(e)*, *aser(e)*, *aserre*, *asour*, *aisur*, and *azur* (*OED*, 2002).

While this might seem to imply that the term was reserved for ultramarine (that is, a pigment derived from lapis lazuli), other meanings are evident from documentary sources. Merrifield (1849), for example, lists a number of different interpretations of azure according to stated locale: German, Lombardy, Spanish and Teutonic a. were azurite (*q.v.*) while Indian and Persian a. referred to natural ultramarine. Occurrences of azure are also noted by Harley (1982), who came across it in certain sixteenth century English sources in the context of natural ultramarine; however, she further mentions that various archaic recipes of the seventeenth century for synthetic copper blue pigments are also headed azure (or byce). An interesting and plausible interpretation is given by Burmester and Krekel (1998); in a study of the materials of Albrecht Dürer and fifteenth and sixteenth century German pharmacy *taxae* (statutory price lists) they argue that ultramarine – the '*ultra maryn plo*' of Boltz von Ruffach – and smalt (*q.v.*) ('*schmeltze*') were rarely used, and that as blues are not differentiated in the German literature of this period all blue pigments could be called *lazur* or, simply, *plo* ('blue'). On the other hand where it is clear that azurite is concerned, *lazur* is generally the term used and it was apparently traded throughout Germany by that name. On the other hand, for international trade where greater specificity was needed, the name would be qualified – for example, '*azur bonum de allemagna*' ('good blue from Germany'). Finally, *lazur* also meant the processed mineral, the raw material being called *lapis lazuli* (Ploss, 1955; Burmester and Krekel, 1998). Interestingly, however, by the time of the German sources of the later nineteenth century such as Gentele (1860) and Mierzinski (1881), *lazurblau* is listed as a term synonymous with ultramarine; Jännicke (1893) refers instead to *lazurstein*, which he equates directly with lapis lazuli.

Flexibility of meaning persisted well beyond this period. According to Tingry (1804), azure was a vitreous oxide of cobalt (that is, *smalt*) and also called enamel blue, saffer blue and Saxony blue, as 'it is manufactured on a large scale in Saxony, where mines of cobalt are abundant. From this circumstance only it has acquired the denomination of Saxon blue.' Ure (1875–78) on the other hand writes of 'The darkest-coloured smalts, known as King's-blue or azure.' According to Heaton (1928), *azure cobalt* was a 'pale cobalt blue'.
See: azurite.

Azurite; Lazurite; Smalt; Ultramarine; *Bice*; *Cobalt blue*; *Enamel blue*; *King's blue*; *Lapis lazuli*; *Saxon blue*
Burmester & Krekel (1998); Gentele (1860) 26–27; Harley (1982) 43; Heaton (1928) 379; Jännicke (1893) 67; Merrifield (1849) 431; Mierzinski (1881) 431; *OED* (2002) 'Azure'; Ploss (1955) 77–78; Tingry (1804) 300–301; Ure (1875–78) I, 874

AZURE COBALT

Blue
Synonym, variant or common name

According to Heaton (1928), azure cobalt was a 'pale cobalt blue' (*q.v.*).

Cobalt blue
Heaton (1928) 379

AZURE GREEN

Green
Synonym, variant or common name

According to Harley (1982), a synonym for malachite (*q.v.*).

Malachite
Harley (1982) 79

AZURITE

Blue
Generic compound

Azurite is a bright blue hydrated copper carbonate mineral of composition $Cu_3(CO_3)_2(OH)_2$. Isomorphous with the green mineral malachite (*q.v.*), the isostructural synthetic analogue, commonly called 'blue verditer' (*q.v.*), was also produced and used widely as a pigment. The mineral, however, forms as a secondary mineral in the weathered zone of copper deposits (e.g. Chessy, France; Redruth, Cornwall; Katanga, Zaire) by the interaction of carbonated solutions with the copper minerals. Its name is derived from the Persian word *lazhward* meaning blue. Important sources of azurite have been Germany, Hungary and France in Europe, and Harley (1982) points out that Central America was also an important source in the seventeenth century. Azurite is always found in association with malachite and often with other copper-rich minerals such as cuprite, tenorite, limonite and chrysocolla (*qq.v.*). It commonly forms as stubby pyramidal crystals or as a massive, earthy deposit.

Preparation of the mineral for use as a pigment typically involved crushing and washing. Sometimes it would be washed with vinegar followed by extensive rinsing in water; traditionally honey, fish glue or gum was added to the water to induce the blue pigment particles to separate from the dross (Harley, 1982). Examination of protein-washed azurite supplied by Kremer Pigmente for this book showed that the process effectively removed the naturally associated cuprite.

In classical times azurite is referred to by Theophrastus (c. 315 BC) and Pliny (77 AD) as Cyprian blue, which came from the copper mines of Cyprus, Theophrastus telling us that it is rare. Vitruvius calls azurite *Armenium* after its country of orgin and it is this variety that Pliny lists among his florid colours (at a massive 300 sesterces per pound). Pliny also says that a sandy form of azurite is to be derived from Spain, and that flooding the market with this product had caused prices to drop to only six denarii.

An important pigment until toward the end of the seventeenth century, associated historical mineral terms include blue malachite, chessylite, *kupferlasur*, *lazur* and *lazurite of von Kobell*. There are also many historical synonyms for azurite as a pigment, often reflecting the possible source or trade route of the mineral or pigment such as *azzurro della magna* (this is probably a corruption of *azzuro d'allemagna* and *azzurrum de alemannia*, azurite having been mined extensively in Germany in Goldberg (Saxony), Schwartz (Tirol) and Wallerfangen (Saarland)), *lapis Armenius* (a common seventeenth century term), *Melochites*, Spanish bise (probably in reference to South American sourced mineral traded from Santo Domingo (Veliz, 1986) through Spain; the term *blue ashes of Seville* also seems to be related to this), while Merrifield (1849) also lists German azure, Lombardy a., Spanish a., Teutonic a., Hungarian blue and Spanish b., though some of these latter terms probably additionally refer to the synthetic analogue. Other terms refer to the source as being from mountains; mountain blue, *bergblau* and *berglasur* (German), *bergblaw* (high Dutch). Finally, Bice, byse or bise, *biadetto*, *cendres bleues*, *cendrée*, *ceneri azzuri*, *cenizas de azul*, *azurium citramarinum* are also common names for this pigment.

Yü (1955) lists a number of Chinese terms associated with azurite as a pigment; these include 'Flat blue' or 'Pure blue' (which also came under the names Yunnan blue and Burmese blue according to where it was found), the highest quality, then 'Layered blue', 'Light blue' and 'Granulated blue' (also known as 'Buddha blue' and 'Hui blue').

Harley indicates that the English term 'bice' was, in the seventeenth century at least, used exclusively in connection with azurite; in later centuries, when azurite was uncommon, the term was applied to other blue pigments. The synthetic analogue (copper carbonate hydroxide, azurite type, *q.v.*) is generally called blue verditer.

Azurite as a pigment has been recently reviewed by Gettens and FitzHugh (1993a).
See: azure.

Copper carbonates group; Copper group; Chrysocolla; Copper carbonate hydroxide, azurite type; Cuprite; Limonite; Malachite; Tenorite; *Azurium citramarinum*; *Azzurro della magna*; *Bergblau*; *Berglasur*; *Bice*; *Bleu d'Allemagne*; *Bleu de montaigne*; *Blue ashes of Seville*; *Blue bice*; *Blue verditer*; *Chessylite*; *Lapis armenius*; *Mountain blue*; *Verditer*
Gettens & FitzHugh (1993a); Harley (1982) 46–49; Merrifield (1849); Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii; Theophrastus (c. 315 BC/Caley & Richards, 1956) 55; Veliz (1986) 197; Vitruvius (1st cent BC/Grainger, 1934) VII.ix.6; Yü (1955/trans. Silbergold & McNair, 1988) 7–8

AZURIUM CITRAMARINUM

Blue
Synonym, variant or common name

Historical term associated with azurite (*q.v.*; Gettens and FitzHugh, 1993a).

Azurite
Gettens & FitzHugh (1993a)

AZURO OLTRAMARINO

Blue
Synonym, variant or common name

Historical term associated with natural ultramarine (lazurite, *q.v.*; Plesters, 1993).

Lazurite; Ultramarine
Plesters (1993)

AZURUM TRANSMARINUM

Blue
Synonym, variant or common name

Historical term associated with natural ultramarine (lazurite, *q.v.*; Plesters, 1993).

Lazurite; Ultramarine
Plesters (1993)

AZURUM ULTRAMARINUM

Blue
Synonym, variant or common name

Historical term associated with natural ultramarine (lazurite, *q.v.*; Plesters, 1993).

Lazurite; Ultramarine
Plesters (1993)

AZZURRO

Blue
Synonym, variant or common name

Azzurro (azuro) is an historical term that can be associated with both natural ultramarine (lazurite, *q.v*; Plesters, 1993) and azurite (*q.v.*), additionally confused in the literature by the similarity of *azzuro* and azurite. However, relevant sources such as the notebooks of Richard Symonds (which were written in Italy during the middle of the seventeenth century) state that 'Azzure … is made of Lapis Lazzaro … Of Azzurro the deepest colour is the best … The best azzurro or Oltremarina is now sold in Rome at 21 crownes the ownce' (Beal, 1984). Other forms include *Azzuro oltremarino* (Plesters); *Azzurro della magna* was azurite.
See: azure for a more general discussion.

Azurite; Lazurite; Ultramarine
Beal (1984); Plesters (1993)

AZZURRO DELLA MAGNA

Blue
Synonym, variant or common name

Azzurro della magna is given as a term associated with azurite (*q.v.*), presumably with the same construction and use as *verdetto della magna* and malachite (*q.v.*; Gettens and FitzHugh, 1993a). *Della magna* is probably an Italian corruption of *Allemagna*, German.

Azurite; Malachite; *Verdetto della magna*
Gettens & FitzHugh (1993a)

B

Baddeleyite
Variable
Generic compound

Baddeleyite is a comparatively rare zirconium oxide mineral which varies in colour from colourless or white to green, brown or black (Naray-Szabo, 1936). It has chemical composition ZrO_2 (similar to arkelite, *q.v.*) and is found in small amounts in gemstone producing areas worldwide, in fluvial gravels and in veins associated with high temperature hydrothermal activity (such as Minas Gerais, Sao Paulo, Brazil; Perovskite Hill, Magnet Cove, Arkansas; Kollonnagam, Rakwana, Sri Lanka).

Although natural baddeleyite has not been identified as a pigment, its synthetic equivalent, zirconium oxide (*q.v.*), is listed as CI 77990/Pigment White 12.

Zirconium group; Arkelite; Zirconium oxide
Naray-Szabo (1936)

Baghdad indigo
Blue
Synonym, variant or common name

Historical term associated with indigo (*q.v.*; Schweppe, 1997; Eikema Hommes, 2002). 'Tropical' indigo (from *Indigofera* spp.) was grown and prepared in the Gujarat, north-western India and transported to Baghdad, where it was bought by European merchants. Merrifield (1849) lists *I. Bagadel*, *Bagadon* and *Baguedel* as variants.

Indigo
Eikema Hommes (2002); Merrifield (1849); Schweppe (1997)

Ball black
Black
Synonym, variant or common name

In Haydocke's edition of Lomazzo (1598) it records as carbon-based blacks 'The shels of almondes burnt, ball blacke, Lampe-blacke.' Composition unknown.

Carbon-based blacks group
Lomazzo/Haydocke (1584/1598) III.iv.99

Baltimore chrome yellow
Yellow
Synonym, variant or common name

Zerr and Rübencamp (1906) describe how Baltimore chrome yellow was a form of chrome yellow (*q.v.*) which contained white adjuncts such as baryte, china clay, diatomaceous earth and gypsum (*qq.v.*). Other related products were sold under names such as *new yellow*, *Paris yellow* and *American yellow*.

According to Kühn and Curran (1986), during the nineteenth century Baltimore chrome yellow was likely to have contained calcium sulfate and lead sulfate (*qq.v.*), or, according to Mierzinski (1881), alum (hydrous potassium aluminium sulfate, $KAl[SO_4]_2.12H_2O$). They state that the term is now applied to a pale chrome yellow precipitated on gypsum or asbestine *(q.v.)*.

Calcium sulfates group; Lead chromates group; Lead sulfates group; Baryte; Gypsum; *American chrome yellow*; *Asbestine*; *China clay*; *Chrome yellow*; *Diatomaceous earth*; *New yellow*; *Paris yellow*
Kühn & Curran (1986); Mierzinski (1881) 134; Zerr & Rübencamp (1906/1908) 149

Baratine
White
Synonym, variant or common name

Synonym for the mineral baryte (*q.v.*; Feller, 1986).

Baryte
Feller (1986)

Barberry
Yellow
Synonym, variant or common name

Alternate common name for *berberis* (plants of the Berberidaceae).
See: berberis.

Barite
White
Synonym, variant or common name

See: baryte.

Barium carbonates group
White
Group term

Barium carbonate ($BaCO_3$) occurs naturally as the mineral witherite (*q.v.*). Synthesis is by precipitation (for example, the reaction of barium sulfate and sodium carbonate or carbon dioxide); a fuller description is given in, for example, the *Colour Index* (see: CI 77099/CI Pigment white 10).

According to Heaton (1928) 'Pure barium carbonate in a physical condition comparable with that of blanc fixe is also prepared … but this is not used to any extent as a pigment.' However, he goes on to comment that the artificial product was sometimes marketed under the name of 'blanc fixe' (*q.v.*).

Witherite
Colour Index (1971) 77099; Heaton (1928) 105

Barium chromate(VI)

Yellow
Generic compound

The form of barium chromate encountered as a pigment is most likely to be barium chromate(VI), $BaCrO_4$. It is listed by the *Colour Index* (1971) as Pigment Yellow 31 (CI 77103), as a 'dull, greenish yellow' compound, synthesised by mixing solutions of potassium chromate or sodium dichromate and barium chloride. Kühn and Curran (1986), citing Meschezerski (1882), describe that neutral solutions yield a pale yellow pigment, while acid solutions will produce a bright orange variety. Vauquelin first described the preparation of barium chromate in 1809, although there is little record of its first use as a pigment, and as late as 1860 Gentele wrote 'It has not been introduced yet commercially as yellow paint and is not to be preferred to the lead chromates.' Commercial use expanded towards the end of the nineteenth century as, according to Church (1901), 'Of all the chromates which have been used in painting, barium chromate is the most stable … It is decomposed by heat at high temperatures but is little affected by light.' However, Gettens and Stout (1966) and Kühn and Curran report that barium chromate may slowly turn green when exposed to light due to the formation of chromium oxide (*q.v.*).

Barium chromate, sometimes referred to as barium chrome (for example, Heaton, 1928), was sold under many different names as a pure or mixed pigment, including barium yellow, baryta yellow, lemon yellow (*q.v.*), permanent yellow (*q.v.*), Steinbühl yellow (*q.v.*), ultramarine yellow (*q.v.*) and yellow ultramarine.

A barium potassium chromate (*q.v.*) paint with anti-corrosion properties was developed in the 1940s (Kastens and Prigotsky, 1949) and is listed by the *Colour Index* as a variant of barium chromate (CI Pigment Yellow 31:1; CI 77106).

From their examination of chromium-based yellow pigments, Burnstock *et al.* (2003) reported the possibility of barium chromate existing in solid solution with crocoite (*q.v.*) in which the barium and lead atoms may be exchanged.

Barium group; Chromates group; Lead chromates group; Barium potassium chromate; Chromium oxide; Crocoite; Strontium chromate; *Barium yellow*; *Baryta yellow*; *Lemon yellow*; *Permanent yellow*; *Steinbühl yellow*; *Ultramarine yellow*

Burnstock *et al.* (2003); Church (1901); *Colour Index* (1971); Gentele (1860); Gettens & Stout (1966); Heaton (1928) 379, 383; Kastens & Prigotsky (1949); Kühn & Curran (1986); Meschezerski (1882)

Barium copper silicate, blue type

Blue
Generic compound

Although various blue barium copper silicates are known, that identified by FitzHugh and Zycherman (1983, 1992) in octagonal sticks probably dating to the Chinese Warring States period (475–221 BC) has a formula of $BaCuSi_4O_{10}$. It is common for the purple type (*q.v.*) to occur within the same sample.

The compound is analogous to $CaCuSi_4O_{10}$, which is known as the pigment Egyptian blue (*q.v.*). Pabst (1959) has synthesised $BaCuSi_4O_{10}$ and the structurally analogous compounds $CaCuSi_4O_{10}$ and $SrCuSi_4O_{10}$. Pabst's method for producing barium copper silicate blue involved sintering pellets of barium carbonate, copper oxide and amorphous silica (glass) with a borax flux at 850°C, maintained for one day. Wiedemann *et al.* (1998) manufactured the pigment using natural copper oxide, tenorite and both naturally occurring barium carbonate and barium sulfate minerals, witherite and baryte (*qq.v.*). They used variously salt (NaCl), natron (sodium carbonate, $NaCO_3$) and lead oxide (PbO) as fluxes. The synthesis of the blue pigment was strongly favoured by using barium sulfate (*q.v.*) as the starting material, and high temperatures (1100°C) were required for the reaction to proceed. The perhaps unexpected choice of lead oxide as a flux was based on identifications of this compound in samples of the Chinese pigments, and it was proved to work very satisfactorily.

Barium carbonate in the form of the mineral witherite, plus baryte (barium sulfate), are relatively abundant minerals worldwide. The latter occurs commonly as gangue in areas of copper mineralisation. It is interesting therefore that barium copper silicate blues are unknown from manufactories of Egyptian blue, both in Egypt and later when the technology was exported to the Roman Empire. Perhaps importantly, FitzHugh and Zycherman (1983) point out that Han dynasty glass was barium rich and suggest, albeit tentatively, that the discovery of barium copper silicate blue may have been a serendipitous accident of glassmaking.

Barium copper silicate blue, in contrast to the purple forms, is a very stable pigment.

A mineral, effenbergerite (*q.v.*), exists with the formula $BaCuSi_4O_{10}$. However, it was not used as a pigment or as a raw material in the manufacturing process of barium copper silicate blues.

The term 'Chinese blue' has been used in association with this pigment (and 'Chinese purple' for the purple form). However, 'Chinese blue' has also been applied historically – by precedence – to Prussian blue (*q.v.*), with evident scope for confusion, and the practice has therefore been condemned by FitzHugh and Zycherman. The name Han blue has been adopted to describe Chinese barium copper silicate blues.

Barium copper silicates group; Barium group; Copper group; Silicates group; Barium copper silicate, purple type; Barium sulfate; Baryte; Effenbergerite; Tenorite; Witherite; *Egyptian blue*; *Han blue*; *Han purple*; *Prussian blue*

FitzHugh & Zycherman (1983); FitzHugh & Zycherman (1992); Pabst (1959); Wiedemann *et al.* (1998)

Barium copper silicate, purple type

Purple
Generic compound

Although various blue and purple barium copper silicates are known, that identified by FitzHugh and Zycherman (1983, 1992) on painted objects and in octagonal sticks probably dating to the Chinese Han dynasty (208 BC to 220 AD) has a formula of $BaCuSi_2O_6$.

FitzHugh and Zycherman (1983, 1992) have shown from their analyses of the Chinese purple pigments that frequently the blue and purple crystals occur together, but pure blue or pure purple masses were occasionally formed. It is impossible to discover whether these were intentional or accidental products. This is partially explained by the manufacturing processes, which are subtly different for the blue and purple compounds.

The purple barium copper silicate has been synthesised in several ways, as reported by FitzHugh and Zycherman (1992). A method identical to the synthesis of barium copper silicate blue (type, *q.v.*) as used by Pabst (1959) can also be used to prepare purple crystals by varying the temperature. Heating of barium carbonate, copper oxide and amorphous silica (glass) with a flux at 1080°C (rather than 850°C) produced purple rather than blue pigments. Alternatively, purple crystals could be formed via the devitrification of purple glass with the composition $BaCuSi_2O_6$.

Other methods used barium chloride, copper carbonate and silica sintered with a natron flux at 870°C and 1000°C. Wiedemann *et al.* (1998) successfully manufactured the pigment using natural copper oxide, tenorite and both naturally occurring barium carbonate and barium sulfate minerals, witherite and baryte (*qq.v.*). They used variously salt (NaCl), natron (sodium carbonate, $NaCO_3$) and lead oxide (PbO) as fluxes. They discovered, however, that though successful as a flux sodium carbonate added in quantities exceeding 5% caused a purple glass, rather than a crystalline substance to form. The presence of lead in analyses of Han purple promoted the use of PbO as a flux, which was similarly found to be effective for manufacturing both barium copper silicate blue and purple. The synthesis of the purple pigment was strongly favoured by using barium carbonate as the starting material. Using this phase, the reaction proceeds at lower temperatures than for barium sulfate (900–1100°C).

Barium copper silicate purple was found to be thermally unstable, and this phenomenon Wiedemann *et al.* (1998) have linked to the crystal structure. The colour is also known to fade dramatically when exposed to acid (Wiedemann and Bayer, 1997; FitzHugh and Zycherman, 1992).

The pigment has been named Han purple (FitzHugh and Zycherman, 1992).

$BaCuSi_2O_6$ has also been manufactured recently in the preparation of superconductors. This has renewed interest in this compound and resulted in analyses of the structure (see Finger *et al.*, 1989; Hazen *et al.*, 1988; McKeown and Bell, 1997).

It should be noted that Spurrell (1895) reported the occurrence of 'lilac' compounds in the excavations of an Egyptian blue workshop at Tell-El-Amarna, Egypt. Contemporary experiments suggested that this pigment could be manufactured by varying the temperatures of manufacture. The chemistry of the compounds is unclear. Egyptian blue (*q.v.*) is calcium copper silicate and by analogy the chemistry of the associated lilac pigment should be the same. Barium copper silicates have not been reported from Egypt despite the abundance of the naturally occurring raw materials, however, further work may be required in this area.

Barium copper silicates group; Barium group; Copper group; Silicates group; Barium copper silicate, blue type; Baryte; Tenorite; Witherite; *Egyptian blue*; *Han blue*; *Han purple*

Finger *et al.* (1989); FitzHugh & Zycherman (1983); FitzHugh & Zycherman (1992); Hazen *et al.* (1988); McKeown & Bell (1997); Pabst (1959); Spurrell (1895); Wiedemann & Bayer (1997); Wiedemann *et al.* (1998)

Barium copper silicates group

Blue-Purple

Group term

Various barium copper silicates are known ranging in colour from green through blue to purple. However, it is certain of the blue and purple forms are known to have been used historically as pigments are sometimes given the names 'Han blue' and 'Han purple' (FitzHugh and Zycherman, 1983, 1992). In fact at least four ternary barium copper silicates have been found to exist (Finger *et al.*, 1989): $BaCuSi_4O_{10}$ ('Han blue'), $BaCuSi_2O_6$ ('Han purple'), $BaCu_2Si_2O_7$ and Ba_2CuSiO_6. $BaCuSi_4O_{10}$ (structurally analogous to Egyptian blue) ($CaCuSi_4O_{10}$) and $SrCuSi_4O_{10}$. These compounds have all been synthesised by Pabst (1959). Other structural analogues occur which have been discussed by Hughes *et al.* (1997).

Synthesis of pure barium copper silicate phases is complicated by the starting materials, selection of fluxes and temperatures. Usually a mixture of compounds is initially formed, suggesting that the latter two forms may be found in artefacts in the future. Formation and stability of these compounds has been discussed by Wiedemann *et al.* (1998), Wiedemann and Bayer (1997) and Pabst (1959). Further discussion of methods and techniques are to be found under the entries for barium copper silicate purple and blue types respectively, and also under entries for Egyptian blue and calcium copper silicate, cuprorivaite type.

A natural phase, effenbergerite (*q.v.*), exists. This is isostructural with barium copper silicate blue, $BaCuSiO_{10}$.

Modern occurrences of these compounds as pigments are scarce. FitzHugh and Zycherman (1992) note that a German patent was filed by Le Chatelier in 1899 for the manufacture of 'green, blue and violet' barium copper silicate pigments. Identification of such compounds in works of art may well be forthcoming.

Barium copper silicate compounds have been 'rediscovered' relatively recently. Finger *et al.* (1989) analysed the structures of two barium copper silicate phases formed during the synthesis of superconductors by Hazen *et al.* (1988) as a reaction product between an oxide mixture and the silicate container. Two barium copper ring-silicate phases were produced; a turquoise, an orthorhombic compound with the formula $Ba_3CuCaSi_6O_{17}$, and a magenta phase analogous to Han purple, $BaCuSi_2O_6$. McKeown and Bell (1997) have revised structural and spectroscopic analyses of magenta barium copper silicate.

Barium group; Copper group; Silicates group; Calcium copper silicate, cuprorivaite type; Cuprorivaite; Effenberghite; *Egyptian blue*; *Han blue*; *Han purple*

Finger *et al.* (1989); FitzHugh & Zycherman (1983); FitzHugh & Zycherman (1992); Hazen *et al.* (1988); Hughes *et al.* (1997); McKeown & Bell (1997); Pabst (1959); Wiedemann & Bayer (1997); Wiedemann *et al.* (1998)

Barium group

Variable

Group term

The following barium compounds are known to have been used as pigments:

Carbonates: Barium carbonate ($BaCO_3$) and witherite ($BaCO_3$).
Tertiary oxides with Group 3–11 elements (Mn): Barium manganese oxide.
Sulphates: Baryte and its synthetic analogue ($BaSO_4$).

Additionally, barium occurs in a number of other pigments not classed under this heading, such as the blue and purple forms of barium copper silicate (so-called 'Han' blue and purple; copper pigments), barium chromate(VI) and barium potassium chromate (chromate pigments), barium tungstate (tungsten pigments) and barium uranate(IV) (uranium pigments).

Barium carbonates group; Barium sulfates group; Chromates group; Copper group; Tungsten group; Barium manganate(VI); Baryte; Witherite

Barium manganate(VI)

Blue-Green

Generic compound

Barium manganate(VI) (barium manganese oxide, $BaMnO_4$). The *Colour Index* (1971) states that this gives a green pigment and is obtained by heating manganese dioxide with barium carbonate or nitrate, or by precipitating potassium manganate with barium chloride. Three oxo anions, the blue $Mn^{V}O_4^{3-}$, green

$\mathrm{Mn^{VI}O_4^{2-}}$ and purple $\mathrm{Mn^{VII}O_4^{-}}$ have been known for over 150 years; they have been isolated as crystalline salts and shown to have a tetrahedral structure (Hursthouse *et al.*, 1992). Barium manganate(VI) sulfate ($x\mathrm{BaSo_4}.y\mathrm{BaMnO_4}$) is also known and has been widely used as a pigment under the term manganese blue (*Colour Index*, 1971).

In documentary sources related to pigments, we should note that while the use of barium manganate as a pigment only received a patent in 1935, as early as 1869 we find Salter listing both manganese blue and manganese green (also giving the alternate term Cassel green under the latter); both are clearly barium-manganese compounds. Terry (1893) provides quite detailed recipes for what he calls baryta green and baryta blue; these are again clearly barium manganate pigments. Bersch (1901) also lists manganese blue and manganese green as well as Rosenstiehl's green and Bottger's green, giving them as essentially synonymous.

Barium group; Manganese group; Barium manganate(VI) sulfate; *Bottger's green*; *Manganese blue*; *Manganese green*; *Rosenstiehl's green*
Bersch (1901) 270–272; *Colour Index* (1971) 77112; Hursthouse *et al.* (1992); Terry (1893) 109–112

BARIUM MANGANATE(VI) SULFATE

Blue
Generic compound

Often known under the name 'manganese blue', this is a barium manganate(VI) sulfate compound, probably of the form $x\mathrm{BaSO_4}.y\mathrm{BaMnO_4}$ with proportions 89% of the sulfate and 11% of the manganate (*Colour Index*, 1971). Although not infrequently described as barium manganate (barium manganese oxide), it differs markedly in its properties from the simple barium manganese oxides and is not (by analysis) a physical mixture of barium manganate and barium sulfate. Preparation is by calcination of a sodium sulfate, potassium permanganate and barium nitrate (or equivalents) at 750–800ºC in air (Gettens and Stout, 1966), or reaction of nitric acid, sulfuric acid and barium carbonate with potassium permanganate and hydrochloric acid, or thermal conversion of a mixture of barium sulfate, pyrolusite and barium nitrate at 680–700ºC, or thermal conversion of manganese oxide, barium nitrate, kaolin and silica at red heat (*Colour Index*). It is also interesting to note a recipe given by Salter (1869), who lists manganese blue as formed when 'An aqueous solution of permanganate of potash yields with baryta-water a violet mixture, which afterwards becomes colourless, and deposits a blue precipitate', though whether this actually formed the barium manganate sulfate is unknown.

Barium manganate sulfate was apparently patented as a pigment by IG Farbenindustrie AG in 1935. Following the dismantling of that company in the 1950s, the commercial interest was transferred; the *Colour Index* lists Farbwerke Franz Rasquin GmbH and G. Siegle & Co. GmbH as manufacturers in 1971. By the early 1990s the production had reputedly ceased because the German government required the manufacturers to reduce the toxicity of the preparation process (Gamblin, 2004). Commercial availability now appears to be very limited and it is usually substituted with phthalocyanine pigments in formulations carrying the name manganese blue ('hue').

Listed by the *Colour Index* as CI 77112/Pigment Blue 33. It was also know as cement blue because it was used for colouring that material.

Colour Index (1971) 77112; Gamblin (2004); Gettens & Stout (1966) 128; Salter (1869) 232

BARIUM OXIDES AND HYDROXIDES GROUP

Variable
Group term

No primary oxide or hydroxide of barium appears to have been used as a pigment. There are however a number of secondary compounds containing elements such as manganese, titanium etc., which form a significant group of pigments:

Barium chromate(VI), $\mathrm{BaCrO_4}$, is a yellow pigment also called barium yellow or baryta yellow.
Barium manganate(VI), $\mathrm{BaMnO_4}$, produces manganese blue/green.
Barium manganate(VI) sulfate, $x\mathrm{BaSO_4}.y\mathrm{BaMnO_4}$, is commonly called manganese blue.
Barium titanate, $\mathrm{BaTiO_3}$, has been listed as a possible form of titanium white (Laver, 1997).
Barium titanate yellow, $\mathrm{2NiO.3BaO.17TiO_2}$, is priderite yellow.
Barium tungstate, $\mathrm{BaWO_3}$, is listed by the *Colour Index* (1971) as CI 77128/Pigment White 13.
Barium uranium oxide (barium uranate), $\mathrm{BaU_7O_2}$, is uranium yellow.

Barium group; Barium chromate(VI); Barium manganate(VI); Barium manganate(VI) sulfate; Barium titanate; Barium tungstate; Barium uranium oxide; *Barium titanate yellow*; *Barium yellow*; *Baryta yellow*; *Manganese blue*; *Manganese green*; *Titanium white*; *Tungsten white*; *Uranium yellow*
Colour Index (1971) 77112, 77128; Laver (1997)

BARIUM POTASSIUM CHROMATE

Yellow
Generic compound

Developed by the National Lead Company for use as an anticorrosive pigment (Kastens and Prigotsky, 1949) and synthesised by treating barium chromate (*q.v.*) with potassium dichromate at high temperature. As noted in the review by Kühn and Curran (1986), the pigment hydrolyses slowly with an associated release of potassium chromate, leaving a residual barium chromate coating. The pigment is listed by the *Colour Index* (1971) as CI Pigment Yellow 31:1 (CI 77106), as a variant of barium chromate (Pigment Yellow 31; CI 77103).

Chromates group; Barium chromate(VI)
Colour Index (1971) 77103; 77106; Kastens & Prigotsky (1949); Kühn & Curran (1986)

BARIUM SULFATE

White
Generic compound

Synthetic barium sulfate, $\mathrm{BaSO_4}$, has been used since the earlier nineteenth century as a white pigment, particularly as an extender. The naturally occuring mineral analogue is baryte (*q.v.*). Barium sulfate also occurs as a component phase in various co-precipitated pigments, such as the compound known as lithopone (*q.v.*), a synthetic pigment produced by the reaction of barium sulfide and zinc sulfate to form an intimate mixture of zinc sulfide and barium sulfate. An equivalent, but less widely used, analogue known as cadmopone formed of cadmium sulfide and barium sulfate, is also known. Thirdly, blancophone was a co-precipitate of barium sulfate and calcium carbonate in a ratio of approximately 70:30 (Heaton, 1928).

In the preparation of synthetic barium sulfate the starting material is frequently the mineral baryte. (While this may at first sight appear unnecessary, essentially it permits the production of a high quality pigment from relatively impure ingredients.) The baryte is heated with coal, forming the sulfide and gaseous by-products (carbon monoxide and sulfur dioxide). After dissolving the resultant barium sulfide in water and filtering it, the sulfate can then be precipitated by adding sodium sulfate; it is filtered, washed and dried to complete the process. Alternatively, barium chloride may be used, reacting this with sulfuric acid in aqueous solution. Third, barium carbonate can be dissolved with hydrochloric acid, then again reacted with sulfuric acid to produce the sulfate (Moser, 1973a).

Among early production methods, Feller (1986) cites a process published by Hope in 1793 and Rees' *The Cyclopedia* of 1810–24. Burgess (1811) mentions a 'constant white' manufactured by Newman and Parkes; Parkes (1816) also states that 'many years previously' a Mr Hume had discovered a method of making a colour from the mineral which was sold under the name of 'Hume's permanent white', though no details are known.

Barium sulfate was also commonly called *blanc fixe*, though many other synonyms or manufacturing variant terms exist. The term *blanc fixe* is reputedly due to Kuhlman, who began producing the pigment around 1830 (Coffignier, 1924). Other popular early names were 'process white' and 'permanent white', though it is important to note that by the late nineteenth century 'constant' and 'permanent' whites were probably based on zinc white (Carlyle, 2001). Feller, citing Mierzinski, also states that late nineteenth century terms included 'enamel white', *schneeweiss*, *mineralweiss* and *neuweiss*. Since barium sulfate also finds application as a dye substrate in 'lake' pigment fabrication, it is not surprising that a commercial product known as 'lake base' existed, developed by Toch in the USA in 1895 (Toch, 1925). The *Colour Index* designation for synthetic barium sulfate is CI 77120/Pigment White 21.

Barium sulfate and baryte have been reviewed by Feller (1986) and Moser (1973a). For more information on the mineral, see: baryte.

Barium group; Barium sulfates group; Baryte; *Barium white*; *Blanc fixe*; *Constant white*; *Enamel white*; *Hume's permanent white*; *Lithopone*; *Mineral white*; *Neuweiss*; *Permanent white*; *Process white*; *Schneeweiss*
Burgess (1811) 42; Carlyle (2001) 516; Coffignier (1924) 27; *Colour Index* (1971) 77120; Feller (1986); Heaton (1928) 101, 192; Mierzinski (1881) 369–375; Moser (1973a); Parkes (1816) 129–131; Rees (1810–24) Vol. 4; Toch (1925) 115

BARIUM SULFATES GROUP
White
Group term

Only the mineral baryte and its synthetic analogue barium sulfate ($BaSO_4$) fall into this group. For more information, see the relevant entries.

Barium sulfate; Baryte

BARIUM SULFIDE
White
Generic compound

According to the *Colour Index* (1971, CI 77125) barium sulfide was prepared for use as a pigment by reducing barium sulfate. The resulting solution consists of 'barium hydrosulphide and hydroxide'.

Colour Index (1971) 77125

BARIUM TITANATE
White
Generic compound

Laver (1997) mentions barium titanate (titanium barium oxide, $BaTiO_3$) as a possible form of titanium white (*q.v.*).
See: barium titanate yellow.

Barium group; Titanium group; Titanium oxides and hydroxides group; *Titanium white*
Laver (1997)

BARIUM TITANATE YELLOW
Yellow
Synonym, variant or common name

A barium-titanium-nickel compound of composition $2NiO.3BaO.17TiO_2$. It is sometimes referred to as priderite yellow because it shares the same crystal structure as the mineral priderite ($(K,Ba)(Ti,Fe^{3+})_8O_{16}$). Principally used for ceramics, although it is currently available commercially as a paint pigment.
See: barium titanate.

Barium oxides and hydroxides group; Titanium oxides and hydroxides group; Barium titanate

BARIUM TUNGSTATE
White
Generic compound

The *Colour Index* (1971) lists this as CI 77128/Pigment White 13; it is prepared by precipitating sodium tungstate with barium acetate. Salter (1869) indicates that 'tungstate of baryta' was also known as tungstate white although various lead tungstate compounds may also be called tungsten white.

Barium group; Tungsten group; Lead tungstate; *Tungsten white*
Colour Index (1971) 77128; Salter (1869) 414–415

BARIUM URANATE
Yellow
Synonym, variant or common name

See: barium uranium oxide.

BARIUM URANIUM OXIDE
Yellow
Generic compound

Barium uranate(IV) or barium uranium oxide (BaU_7O_2) which is orange or yellow in colour may be related to uranium yellow and orange pigments (*qq.v.*). It is thought perhaps to have been used in the late nineteenth and/or early twentieth century. Modern synthesis is described by Allpress (1964) and Klima *et al.* (1966).

Uranium group; *Uranium orange*; *Uranium yellow*
Allpress (1964); Klima *et al.* (1966)

BARIUM WHITE
White
Synonym, variant or common name

A synonym for baryte and its synthetic analogue barium sulfate (*qq.v.*; Feller, 1986).

Barium sulfate; Baryte
Feller (1986)

BARIUM YELLOW

Yellow
Synonym, variant or common name

Common name used for barium chromate (*q.v.*).

Barium chromate(VI); *Lemon yellow*; *Ultramarine yellow*

BARYTA

White
Synonym, variant or common name

Synonym for the mineral baryte (naturally occurring barium sulfate (*qq.v.*); Feller, 1986).

Barium sulfate; Baryte
Feller (1986)

BARYTA GREEN

Green
Synonym, variant or common name

Terry (1893) states that this was 'manganate of baryta', proposing that it could replace the arsenical greens. He gives several manufacturing routes:

1. By 'igniting together the nitrate of baryta and manganese oxide or dioxide';
2. 'fusing a mixture of pyrolusite or black oxide of manganese, caustic baryta, and chlorate of potash';
3. A more complex process involving calcining sodium hydroxide, potassium chlorate and very finely powdered manganese, then adding a solution of barium nitrate to the cooled and powdered product, treating the washed precipitate with barium hydroxide and finally calcining again.

Other methods are also cited by Terry, including that used to manufacture known as Rosenstiehl's green (*q.v.*). Mayer (1991) lists baryta green as synonymous with manganese green, which in turn he associates with manganese blue (barium manganate). See: barium manganate(VI) and manganese green.

Manganese blue; *Manganese green*
Mayer (1991) 38; Terry (1893) 109–112

BARYTA RED

Red
Synonym, variant or common name

Terry (1893) provides a description of this pigment, indicating that it consisted of a 'sulpho-antimonite of barium'. He gives a recipe according to Wagner where the orange-red compound is formed by calcining baryte, 'native' antimony sulfide and powdered charcoal. The product of this is boiled with water and filtered, the filtrate being treated with dilute sufuric acid to precipitate the pigment.

Terry (1893) 109–112

BARYTA WHITE

White
Synonym, variant or common name

A synonym for synthetically produced barium sulfate (*q.v.*). Riffault *et al.* (1874) also give the term hepatite as a direct synonym for baryta white.

Barium sulfate; *Hepatite*
Riffault *et al.* (1874) 193

BARYTA YELLOW

Yellow
Synonym, variant or common name

According to Heaton (1928), a synonym for barium chromate (*q.v.*).

Barium chromate(VI)
Heaton (1928) 379

BARYTE

White
Generic compound

Baryte is the naturally occurring form of barium sulfate, $BaSO_4$. Although generally white, baryte may be tinted pale yellow, brown, green, blue or red as a result of impurities. The name baryte is derived from the Greek *baryos*, meaning 'heavy'. It commonly occurs as well-formed tabular crystals, but is also found as concretions, or fibrous or granular aggregates. Baryte occurs as a gangue mineral in metal-bearing veins associated with hydrothermal activity, often accompanied by minerals such as calcite, fluorite, galena and sphalerite (*qq.v.*). It also forms as nodules following the weathering of limestones containing baryte veins (for example, Virginia, USA; Derbyshire, England), or as a cement in some sandstones (such as Hemlock Stone, Nottingham, England, Rutley, 1998). Economically important deposits of baryte occur worldwide; Feller (1986), for example, lists Germany, Hungary, Romania, Slovakia and the Czech Republic, Austria, France and Spain as well as England, China and the USA as producers along with Ireland, Mexico, Canada and Peru (Hey, 1993).

Baryte also commonly alters to the barium carbonate, witherite (*q.v.*). Certain sources are also associated with specific contaminants, such as quartz in material from the Hartz Mountains in Germany and lime and fluoride in material from Virginia and Kentucky in the USA (Kittel, 1960; Toch, 1925); according to Bearn (1923) Spanish products were often associated with the presence of calcium carbonate or sulfate. Analyses of some 30 samples of baryte have been published by Coffignier (1924).

Preparation of commercial baryte begins with sorting of the coarse mineral according to colour. This is then crushed and wet-ground to the required fineness, followed by levigation either by water or air-jet. Traces of iron discoloration may be removed by treatment with hydrochloric or sulfuric acids, followed by washing. The product is then dried and screened into a series of size grades. Feller also notes that traces of synthetic ultramarine (*q.v.*) may be added by the manufacturer to improve whiteness.

Although there is little record in the literature of baryte being used as a pigment, its synthetic form, barium sulfate (*q.v.*) or '*blanc fixe*', has long been used as an extender. It is used extensively in the manufacture of white paint and in paper production. However, baryte was generally the starting point for the production of the synthetic analogue, baryte itself being sufficiently rare in a form pure enough for direct pigment use that the synthesis served as a means of refinement. The process would typically involve calcining the baryte with coal, forming barium sulfide, carbon monoxide and sulfur dioxide; the barium sulfide would then be dissolved in water prior to further treatment to form the sulfate.

While it is true that this mineral was known from the sixteenth century onwards, there currently seems to be no evidence that its use as a pigment was considered until the seminal experiments published in 1782 by Guyton de Morveau into substitutes for lead white. Reference to 'permanent white' is then found in the sixth edition of Bowles' *Art of Painting in Watercolour*, which appeared only a year later (cf. Harley, 1982).

Apart from the frequently used form ‘barytes’, baryte has many synonyms including baratine, barite, caulk, cawk, boulder, Bologna stone, Bolognian spar, heavy spar, *lapis bonoiensis, lapis solaris, Schwerspath, Spath pesant*, stinking stone, *Terra ponderosa vitriolata, Tiff*, Tyrol white and *wolnyn*. Many of these are local terms as used by miners for the mineral. In the sixteenth century the German author on mining subjects, Agricola, calls it *spat*. The Bolognese shoemaker Vincenzo Casciorolus (1602), who discovered phosphorescence in the mineral, applies the term *lapis solaris* (this is also the origin of the terms Bologna stone and spar), while Fortunius Licetus (1640) uses *lapis bonoiensis*. Miners in Derbyshire, England, called it cauk or cawk since at least 1668, while *tiff* seems to be a term favoured historically by French miners. Likewise, in the eighteenth century the proto-mineralogist Werner (1749–1817) and Torbern Bergman (1735–84) refer to baryta as *schwerspath* and *terra ponderosa* respectively; this latter term also found widespread use in British chemical treatises of the period.

Terminology changes after Scheele’s discovery of the element barium in 1774. Guyton de Morveau (1782) called it *barote*, from the Greek *barys* (heavy), due to the high density of some of the compounds of this element; this name was later changed by Lavoisier to that used nowadays, barite. *Baryta* appears in nineteenth century texts, though Feller points out that in the early 1800s, barytes may have referred to the oxide rather than the carbonate of barium. Feller also distinguishes between the use of ‘barite’ to refer to the mineral and ‘barytes’ for the pigment. Finally, Coffignier records the terms *baratine* and Tyrol white, while Riffault (1874) explains this term as coming from the incorrrect name given to it in Austria.

The use of baryte and its synthetic analogue barium sulfate in a painting context has been extensively reviewed by Feller. Natural occurrences should also be noted, however, such as the identified presence in coloured grounds of paintings of the seventeenth to eighteenth century French School where it is found as a natural impurity in earth pigments (Duval, 1992).

Barium group; Barium sulfate; Calcite; Fluorite; Galena; Sphalerite; Witherite; *Baratine*; *Baryta*; *Blanc fixe*; *Bolognian spar*; *Cauk*; *Ceruse de Venise*; *Heavy spar*; *Lapis bononiensis*; *Lapis solaris*; *Satin white*; *Schwerspath*; *Spath pesant*; *Tyrol white*

Agricola (1556/trans. Hoover & Hoover, 1950) 115; Bearn (1923); Bowles (1783); Coffignier (1924) 88–96; Duval (1992); Feller (1986); Guyton de Morveau (1782); Harley (1982) 175; Hey (1993); Kittel (1960); Riffault *et al.* (1874) 193; Rutley (1988) 317; Toch (1925) 115

BARYTES

White

Synonym, variant or common name

See: baryte.

BARYTIC WHITE

White

Synonym, variant or common name

See: constant white.

BASEL GREEN

Green

Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green

Fiedler & Bayard (1997)

BASIC COPPER CARBONATE

Blue-Green

Synonym, variant or common name

See: copper carbonates group.

BASIC LEAD CHROMATE

Red

Synonym, variant or common name

See: lead chromate(VI) oxide.

BASIC VERDIGRIS

Blue-Green

Synonym, variant or common name

Basic verdigris refers to compounds of copper(II) acetate with the formulae:

1. $[Cu(CH_3COO)_2]_2.Cu(OH)_2.5H_2O$
2. $Cu(CH_3COO)_2.Cu(OH)_2.5H_2O$
3. $Cu(CH_3COO)_2.[Cu(OH)_2]_2$
4. $Cu(CH_3COO)_2.[Cu(OH)_2]_3.2H_2O$
5. $Cu(CH_3COO)_2.[Cu(OH)_2]_4.3H_2O$

(Scott, 2002; Kühn, 1993a; Rahn-Koltermann *et al.*, 1991; and Gauthier, 1958). Only acetate (3) can exist alone (it is incompatible with the other compounds). According to Kühn other products are impure mixtures of (1) and (2) or (2) and (4). However, Rahn-Koltermann *et al.* (1991) could not produce compound (2) and suggested therefore that it did not exist. They did, however, produce the additional compound (5), thereby suggesting further compounds may exist with the generalised formulae $[Cu(CH_3OO)_2]_x.[Cu(OH)_2]_y.zH_2O$, where x = 1, y = 3 and z = 2. Basic verdigris produces plate-like, acicular and fibrous crystal forms, ranging in colour from blue to green (Kühn, 1993a; Scott, 2002).

Scott *et al.* (2001a) have identified basic verdigris in an egg medium on the fifteenth century manuscript *Barlaam and Josephat*.

Copper acetate group; *Neutral verdigris*; *Verdigris*

Gauthier (1958); Kühn (1993a); Rahn-Koltermann *et al.* (1991); Scott (2002) 270–294; Scott *et al.* (2001a)

BASSANITE

White

Generic compound

Bassanite is one of the three principal forms of calcium sulfate and has the chemical composition $CaSO_4.xH_2O$, where x lies between 0.8 and 0.5. It is intermediate between the fully hydrated form, gypsum and the anhydrous form, anhydrite (*qq.v.*). Bassanite may therefore be described as a subhydrate. The name hemihydrate has also been applied, but this correctly refers to substances with the formula $CaSO_4.0.5H_2O$. The mineral is named after the Italian palaeontologist F. Basani (1853–1916). Bassanite exists metastably during the slow dehydration of gypsum. It may be found naturally as dull white acicular crystals in limestones, shales and clays, in evaporite deposits from saline waters, or around volcanoes through the action of sulfur gas on calcium-bearing minerals.

Synthetic phases with the formula $CaSO_4.xH_2O$ occur in the manufacture of plaster of Paris (*q.v.*) and related materials. These are discussed in more detail under the entry calcium sulfate, bassanite type.

Capitán-Vallvey *et al.* (1994) have reported the occurrence of bassanite in mural paintings at the ‘Corral del Carbón’ in

Granada, Spain. However, it is unclear whether this mineral was intentionally used as a pigment or whether it is an alteration product from the gypsum plaster.

Calcium sulfates group; Anhydrite; Calcium sulfate, bassanite type; Gypsum; *Plaster of Paris*
Capitán-Vallvey *et al.* (1994)

BASTARD SAFFRON
Red-Orange-Yellow
Synonym, variant or common name

Term for dyes and lake pigments based on safflower (dye derived from *Carthamis tinctorius* L.) as opposed to 'true' saffron (*qq.v.*) derived from *Crocus sativus*. Sometimes also called carthame or safranum (for example, Watin, 1785).

Safflower; Saffron
Watin (1773/edition of 1785) 27

BAUXITE
Variable
Common generic composite

Bauxite is a mixture of mineral components, chiefly aluminium hydroxides, with minor amounts of iron oxides, phosphorous compounds and titanium oxide. It therefore varies in colour considerably from greyish white to yellow, reddish or brown. Bauxite forms from the weathering of aluminosilicate rocks under tropical conditions. During this decay process, clay minerals are formed initially, from which the silica is later leached away to leave an earthy or granular mass which is bauxite. The principal minerals comprising bauxite are the aluminium hydroxides gibbsite, diaspore and boehmite (*qq.v.*), with gibbsite the dominant component. Iron-bearing minerals such a goethite, lepidocrocite and hematite (*qq.v.*), and clay minerals kaolinite and halloysite (*qq.v.*), may also be present as minor components (Trolard and Tardy, 1987). Bauxite is the principal ore used to produce aluminium commercially and hence is the starting material for many synthetic aluminium-based pigments. It does not appear to have been used directly as a pigment itself.

Aluminium group; Clay minerals group; Boehmite; Diaspore; Gibbsite; Goethite; Halloysite; Hematite; Kaolinite; Lepidocrocite
Trolard & Tardy (1987)

BAVARIAN MOUNTAIN WHITE
White
Synonym, variant or common name

Synonym for dolomite (*q.v.*), $(Ca, Mg)[(CO_3)]_2$ (Brochwicz *et al.*, 1993).

Dolomite
Brochwicz *et al.* (1993)

BAYERITE
White
Generic compound

Bayerite is a rare white aluminium hydroxide mineral with composition $Al(OH)_3$, the type locality for which is Hatrurium, Israel. It is one of the series of polymorphs of the $Al(OH)_3$ system which includes gibbsite, doyleite and nordstrandite (*qq.v.*; Chao *et al.*, 1985). Bayerite is the polymorph which generally forms when $Al(OH)_3$ is precipitated in solution, such as in lake formation. Bayerite is therefore to be expected in a pigment context as a lake substrate or as a filler material. Thus it is generally encountered as a synthetic compound (see: aluminium hydroxide, bayerite type). It is named from its formation as part of the Bayer process of refining bauxite (*q.v.*).

Aluminium group; Aluminium oxides and hydroxides group; Aluminium hydroxide, bayerite type; Bauxite; Doyleite; Gibbsite; Nordstrandite
Chao *et al.* (1985)

BEAUTIFUL GREEN
Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

BEHRENDT GREEN
Green
Synonym, variant or common name

According to Kühn and Curran (1986), citing a 1910 German edition of Bouvier, Behrendt green (or Behrendt's green) refers to a pigment mixture of chromium oxide and cadmium or strontium yellow (*qq.v.*).
See: chrome green.

Chromium oxides and hydroxides group; *Cadmium yellow*; *Chrome green*; *Chromium oxide*; *Strontium yellow*
Bouvier (1910); Kühn & Curran (1986)

BEIDELLITE
White
Generic compound

Beidellite is a clay mineral and a member of the smectite subgroup of clay minerals (*q.v.*). Clay minerals form from the weathering of rocks, and beidellite forms principally from the degradation of minerals in the mica and feldspar groups (*qq.v.*). Beidellite has the general chemical formula $Al_4(Si,Al)_8O_{20}.(OH)_4.nH_2O$ and is named after its type locality of Beidell, Colorado, USA. It occurs naturally as thin white plates which may be occasionally tinted red, brown or yellow, forming a dull earthy mass. It is one of the dominant components of bentonite along with montmorillonite (*qq.v.*; Güven, 1988).

Clay minerals group; Clay minerals group: Smectite sub-group; Feldspar group; Mica group; Montmorillonite; *Bentonite*
Güven (1988)

BELGIAN EARTH
Green
Synonym, variant or common name

See: *Green earth.*

BELL BLACK
Black
Synonym, variant or common name

Merrifield (1849) records this as being mentioned by the sixteenth century Italian authors Borghini (1584) and Lomazzo (1584), as well as the later seventeenth century author Baldinucci (1681). It was apparently 'made from a certain crust which forms

on the moulds in which bells and artillary are cast'. The composition is unknown.
See: Campania earth.

Baldinucci (1681) 106; Borghini (1584/edition of 1787); Lomazzo (1584); Merrifield (1849)

Bentonite

White
Synonym, variant or common name

Bentonite is a mixture of clay minerals, principally montmorillonite and beidellite (*qq.v.*), found in thin layers in Cretaceous and Tertiary rocks in the western USA. It is named from its type locality at Fort Benton, Wyoming, USA and is thought to have been formed from the weathering of volcanic ash deposits.

Bentonite is mentioned by Heaton (1928) in his discussion of china clay (*q.v.*), apparently as an equivalent material; he also states that 'large deposits [of bentonite] have been exploited recently in Western Canada', which may indicate the sphere of usage. The colloidal behaviour was thought to be suited to preparation of lake pigments.

Clay minerals group; Silicates group; Beidellite; China clay; Montmorillonite
Heaton (1928) 112

Benzimidazolone pigments

Red-Orange-Yellow
Synonym, variant or common name

See: azo pigments group: benzimidazolone sub-group.

Benzol black

Black
Synonym, variant or common name

This term is mentioned by Mayer (1991), who simply gives it as a synonym for 'carbon black'. However, it appears to be specifically a flame carbon based on the incomplete combustion of a hydrocarbon precursor (*Colour Index*, 1971; CI 77266/Pigment Black 6/7); whether it is derived especially from benzene (for which benzol is a synonym) is less certain and it may simply be a by-product of burning coal gas.
See: carbon-based blacks group: flame carbons sub-group.

Carbon-based blacks group; Flame carbons sub-group; *Flame carbon*
Colour Index (1971) 77266; Mayer (1991) 38

Berberine

Yellow
Generic compound

Compositionally: 5,6-dihydro-9,10-dimethoxybenzo[g]-1,3-benzodioxolo[5,6-a]quinolizinium, an alkaloid which can be isolated from many plants notably various members of the Berberidaceae (for example, *Berberis vulgaris* L. and *Hydrastis canadensis* L.) and consequently a major component of dyes and lake pigments formed from these extracts (*Merck Index*, 1996). Use of dye extracts derived from the so-called 'Amur cork tree', *Phellodendron amurense* Rupr. (Rutaceae), which also contains high levels of berberine, have been noted by several authors (see: *Phellodendron*).
See: berberis and phellodendron.

Flavonoids group; Berberis; *Cork*
Merck Index (1996) 1195

Berberis

Yellow
Common generic composite

Members of the Berberidaceae are known to produce a yellow dyestuff extractable from the roots, of which the principal component is berberine (*q.v.*). Other components include oxyacanthine, magnoflorine, berberrubine, berbamine, jatrorrhizine, columbamine, palmatine and isotetrandine (Schweppe, 1992).

There is some limited mention of the use of this dyestuff as part of lake pigment recipes, such as that given by Tingry (1804) for a brownish variety of Dutch pink (*q.v.*), based on a berberis extract with 'yellow berries' (dye derived from the unripe berries of *Rhamnus* species).

Berberine; Magnoflorine; Palmatine; *Barberry*; *Dutch pink*; *Yellow berries*
Schweppe (1992); Tingry (1804) 365

Berg green

Green
Synonym, variant or common name

See: mountain green.

Bergblau

Blue
Synonym, variant or common name

See: mountain blue.

Berggrün

Green
Synonym, variant or common name

This is literally translated as mountain green (*q.v.*).

Mountain green

Berglasur

Blue
Synonym, variant or common name

See: azurite.

Berlin blue

Blue
Synonym, variant or common name

A term frequently found in the German literature on pigments, indicating a form of Prussian blue (hexacyanoferrate(II) pigments). For example, Linke and Adam (1913) describe Berlin blue as a form of Paris blue (*q.v.*) that was lighter and mixed with other substances. On the other hand Schulze describes how, by omitting alum in the production of the pigment, a darker blue is achieved which is called Paris blue (Schulze, 1826; cf. Brachert, 2001). Gentele (1860) states that for economic reasons Berlin blue was produced by mixing Paris blue with starch, baryte, calcium sulfate, burnt and ground clays or kaolins.

The terminology of Berlin, Paris and Prussian blues in German sources was clearly variable, although specific texts indicate particular relationships. Moreover, Prussian blue does not seem to be a widely used term in these sources whereas Berlin blue is. Gentele (1860), Bouvier (in a German edition of 1861) and Rose (1916), for example, all favour Berlin blue as the main term; Mierzinski (1881) mentions Berlin blue as a mixture of Paris blue and white substances, and Prussian blue as a synonym for Paris blue; Linke and Adam (1913) prefer Paris blue, but mention Berlin blue as a synonym; Jännicke (1893) simply refers to Prussian blue.

The origin of the term is reputedly from the discovery of Prussian blue by Diesbach, which occurred in Berlin.
See: Prussian blue.

Hexacyanoferrate group; *Paris blue*; *Prussian blue*
Bouvier (1861) 37–38; Brachert (2001) 39–40; Gentele (1860) 220; Jännicke (1893) 71–72; Linke & Adam (1913) 63; Mierzinski (1881) 31; Rose (1916) 226; Schulze (1826)

Berlin brown
Brown
Synonym, variant or common name

An alternate name given for Prussian brown (*q.v.*) by Zerr and Rübencamp (1906).

Prussian brown
Zerr & Rübencamp (1906/1908) 177

Berlin green
Green
Synonym, variant or common name

This manufacturing variant of 'ferric ferricyanide', Berlin green, is stated by the *Colour Index* (1971, CI 77533) to be prepared by precipitating potassium ferricyanide with ferric chloride.

Hexacyanoferrate group
Colour Index (1971) 77533

Berlin white
White
Synonym, variant or common name

See: lead white.

Berlinite
White
Generic compound

Berlinite is a naturally occurring white aluminium phosphate mineral with chemical composition $AlPO_4$. Its type locality is the Westana Mine, Kristianstad, Sweden, where it may be tinted grey or pink due to impurities. There is currently no indication that berlinite has been used in the pigment context, although Church (1901) indicates that synthetic aluminium phosphate (*q.v.*) has been used as a lake substrate. See: aluminium phosphates group for a fuller discussion of the issues.

Aluminium group; **Aluminium phosphates group**
Church (1901)

Bernalite
Green
Generic compound

Bernalite, $Fe(OH)_3.nH_2O$, until recently was known only from museum samples derived from Broken Hill, New South Wales, Australia and was discovered only in 1992 (Birch *et al.*, 1992). Schwertmann and Cornell (2000) admit that very little is yet known about this mineral. Another discovery of the mineral has been noted from the Clara mine, Black Forest, Germany (Kolitsch, 1998). It has not been identified in any pigments to date, though of course other iron oxides and hydroxides have.

Iron oxides and hydroxides group
Birch *et al.* (1992); Kolitsch (1998); Schwertmann & Cornell (2000)

Berndtite
Yellow
Generic compound

Berndtite is a tin(IV) sulfide mineral with chemical composition SnS_2. Named after the German mineralogist F. Berndt, berndtite is a yellow mineral which varies in colour from greyish yellow to brown-yellow (Oftedal, 1926; Guenter and Oswald, 1968). Although natural berndtite has not been reported to have been used as a pigment, its synthetic counterpart, known as mosaic gold (*q.v.*), has been identified on a number of paintings and manuscripts, particularly those from the fourteenth and fifteenth centuries (for example, Smith *et al.*, 1981; Speleers, 1999).

Tin group; Tin sulfides group; *Mosaic gold*
Guenter & Oswald (1968); Oftedal (1926); Smith *et al.* (1981); Speleers (1999)

Biacca
White
Synonym, variant or common name

Italian term used for lead white (*q.v.*), the term being found in numerous sources, such as the mid-seventeenth century notebooks of Richard Symonds (Beal, 1984).

Also related is the term *Biacca di Venetia*, which Harley (1982) suggests could either be (trivially) lead white from Venice, or else a mixture of lead white and baryte. This is translated in English sources of the late sixteenth and early seventeenth centuries as the 'fashionable but ambiguous' term Venice ceruse or *blanc de ceruse de Venise*.

Baryte; *Lead white*; *Venice white*
Beal (1984) 123–126; Harley (1982) 165–166

Biadetto
Blue
Synonym, variant or common name

Merrifield (1849) provides a clear summary of *biadetto*, stating that 'This term, which occurs so frequently in technical works on painting, has been applied both to the native and to the artificial pigment prepared from copper. There is no doubt that at an early period of art the natural pigment… was much used. Mr. Eastlake has discovered the true derivation of the term "biadetto" in the "Bladetus de Inde" of the Venetian MS., which is identified by De Mayerne [BL MS Sloane 2052] *with* "la cendrée," and *beis* or *bice*. "La cendrée" is described to be "made of the blue stone which comes from India, and which is found in silver mines." The "azzurro di biadetti" of Borghini and Baldinucci was the artificial pigment… The biadetto now sold in Italy is the artificial pigment which is imported from England; but I could not ascertain the commercial name. The modern biadetto is described in the "Secreti" of Fra Fortunato to be composed of verdigris, sal-ammoniac, and tartar.'

Copper carbonates group; Azurite; *Bice*
Merrifield (1849) ccii

Bianco di Sangiovanni
White
Synonym, variant or common name

Bianco di Sangiovanni (also *bianco san Giovanni*; literally, 'Saint John's white') was a form of synthetically produced calcium carbonate made from lime (*q.v.*). Instructions are given in the treatise by Cennino Cennini (c. 1400, Clarke MS 590), though other Italian authors also give preparation methods (cf. Merrifield, 1849). Essentially the lime was prepared by macerating it in water until it had lost causticity. According to Imperato (*Istoria Naturale*, Lib. Iv, Cap. 13), pulverised white marble was also added to the lime; however, this would not have the same properties. Denninger (1974) comments that the recipe by Cennini indicates the bianco di Sangiovanni did not require any binding media. This would indicate that the reaction with lime had not entirely completed, leaving a considerable proportion of calcium hydroxide. This then mixed with pigments for fresco painting and exposed to atmospheric carbon dioxide would react to completion, forming calcium carbonate, thus binding the pigments.

Lomazzo (1584) states that the pigment was known to later authors as *biancho secco*.

Calcium carbonates group; Lime; *Saint John's white*
Cennini (c. 1400/Thompson 1960) 34; Denninger (1974); Lomazzo (1584) 192, 194; Merrifield (1849) cli

Bice

Blue
Synonym, variant or common name

In the Vulgate edition of the Bible (St Jerome, 405 AD; Exodus 38:23) it states '*iuncto sibi socio Hooliab filio Achisamech de tribu Dan qui et ipse artifex lignorum egregius fuit et polymitarius atque plumarius ex hyacintho purpura vermiculo et bysso*', *bysso* meaning 'blue'. In the Wyclif translation of the Vulgate (1382), *bysso* is rendered *bijs*. Further early use of the term bice has been discussed by Thompson (1935), who has pointed out that in fourteenth century manuscripts the term tends to be used adjectivally, as in 'azure bys' or 'a. byse', whereas in the fifteenth century the use is substantive, as in 'asure and bise' or 'azour or elles bys'. Thompson considered that from the various manuscripts contexts this term primarily referred to a synthetic copper blue, but that sometimes azurite (*q.v.*) was meant. However, according to Harley (1982), in British documentary sources bice (or byce) was used specifically for azurite in the seventeenth century (although certain archaic recipes of the period for synthetic copper blues also use the term), but that later the colour term came to mean various other pigments. In the eighteenth century it simply meant a very pale blue and several references (for example, Dossie, 1764) indicate that finely ground smalt (*q.v.*) was sold under the name. Field (1835) knew that bice had been both smalt and verditer; he additionally lists the term iris blue as a synonym.

Copper carbonates group; Azurite; Smalt; *Blue verditer*; *Verditer*
Dossie (1764) I-95; Field (1835); Harley (1982) 49; Thompson (1935) 415, n.7

Bideford black

Black
Synonym, variant or common name

Bideford black was a noted black pigment until relatively recent times; the mines at Bideford essentially represent an extension of the South Wales Coal Field which reach the surface at the other side of the Bristol Channel in north Devon (England). Field (1835) mentions 'mineral black', which he states came from Bideford, and must therefore be the same pigment, though that name has been applied to a variety of inorganic black pigments.

Since the late eighteenth century Bideford has been a source of a pigment described by Remington (1946) as 'of the nature of a pasty clay, occurring in rocks of the carboniferous age, the local name being "Culm measures"'. There was a string of workings on lenticular deposits of the high-grade coal, anthracite (*q.v.*), and the associated paint pigment deposits, found in the Culm Measures between Abbotsham on the coast and Hawkridge Wood on the River Taw south-east of Tawstock. The most extensive workings are in the Bideford area, particularly the Union mine under the western part of the town, the Bideford anthracite mine and the Bideford black mine. Other workings include the Tawstock mine, at Somers Hiscott, and the Hawkridge Culm works, on the east bank of the Taw.

According to Acworth (1991) and Bristow (1996b), Bideford black was widely used for painting the hulls of ships. It was also known as 'mother-of-coal'.

Carbon-based blacks group; Anthracite; *Mineral black*
Acworth (1991); Bristow (1996b); Field (1835); Remington (1946)

Biebrich scarlet

Red
Synonym, variant or common name

Biebrich scarlet was discovered in 1878/9, a very pure red disazo dye said originally to 'rival cochineal in brightness'. It is described by Zerr and Rübencamp (1906). Synonyms include Ponceau Biebrich Scarlet, CI 26905/Acid Red 66, Croceine Scarlet and Double Scarlet BSF. Now principally used as a histological stain.

Colour Index (1971) 26905; Zerr & Rübencamp (1906/1908) 529

Bile yellow

Yellow
Synonym, variant or common name

See: gallstone.

Binder's cobalt blue

Blue
Synonym, variant or common name

Listed by Terry (1893) as an alternate method of preparing Cobalt blue (*q.v.*). Rose (1916) cites comments by C.H. Binder (1857) regarding Saxonian production methods for cobalt blue.

Cobalt blue
Rose (1916) 285; Terry (1893) 29

Bindheimite

Yellow
Generic compound

Bindheimite is a yellow lead antimony oxide mineral with a cubic structure and formula $Pb_2Sb_2O_6(O,OH)$. Named after the German chemist J.J. Bindheim (1750–1825), bindheimite occurs as cryptocrystalline crusts which have a dull earthy appearance. It forms in the weathered zones of lead and antimony deposits (for example, at Nerchinsk, Siberia) and may vary in colour from yellow to greenish yellow or brown (Dana, 1932). Bindheimite is closely related chemically to the synthetic lead antimony oxide pigment commonly known as Naples yellow (*qq.v.*; Wainwright *et al.*, 1986). However, bindheimite is not known to have been used as a pigment in its own right.

A related lead antimony oxide mineral, rosiaite (*q.v.*), is also known.
See: lead antimony oxide.

Antimony group; Lead group; Lead oxides and hydroxides group; Lead antimony oxide; Rosiaite; *Naples yellow*
Dana (1932) 737; Wainwright *et al.* (1986)

BIOTITE
Black
Generic compound

Biotite is a sheet silicate group (*q.v.*) mineral with ideal composition $K_2(Fe,Mg)_6[(Si_6Al_2)O_{20}](OH,F)_4$. It has a high iron content and is a very common member of the mica group, forming a series with phlogopite (*qq.v.*), the Mg-rich member; intermediate members with decreasing Mg contents are siderophyllite, lepidomelane, haughtonite and annite (Deer *et al.*, 1992; Rutley, 1988; Bailey, 1984; Brigatti and Davoli, 1990). Biotite is named after the French physicist J.B. Biot (1774–1862) and occurs as pseudo-hexagonal tabular crystals which cleave into thin flakes along weak planes. The flaking is caused by the layered structure of the mineral which consists of sheets of $(Si,Al)O_4$ tetrahedra weakly bonded to complete sheets of K, Fe and Mg in octahedral sites (a trioctahedral mica). Different stacking sequences of the $(Si,Al)O_4$ layers result in three polymorphs of biotite, with the most common polymorph being the one-layered monoclinic (type 1M); two-layered monoclinic (type 2M) and three-layered triclinic (type 3T) polytypes also occur. Biotite is generally black but may be dark brown, brown-green, yellow or white due to variations in the Mg:Fe ratio and impurity content (such as Na, Ca, Ba, Ti, Mn, Li and Rb), with darker varieties having higher densities and Fe contents. Biotite is a common mineral, occurring in a wider range of environments than the other micas. It forms in most intermediate or acid igneous rocks, in a wide range of metamorphic rocks, and as detrital grains in some sedimentary rocks. It may decompose to form muscovite, chlorite and clay group minerals such as kaolinite, montmorillonite or vermiculite (*qq.v.*).

Watchman *et al.* (2001) identified biotite as a component of crusts covering rock paintings at Carpenter's Gap (Southern Kimberley, Australia) along with kaolinite, albite (*q.v.*), muscovite and other minor minerals. The *Colour Index* (1971) lists naturally occurring micaceous potassium aluminium silicates as Pigment White 20/26 (CI 77019).

Aluminium group; Chlorite group; Clay minerals group; Iron group; Mica group; Sheet silicates group; Albite; Kaolinite; Montmorillonite; Muscovite; Phlogopite; Vermiculite
Bailey (1984); Brigatti & Davoli (1990); *Colour Index* (1971) 77019; Deer *et al.* (1992) 298–307; Rutley (1988) 401–402; Watchman *et al.* (2001)

BIRNESSITE
Black
Generic compound

A sodium-bearing hydrated manganese oxide of composition $Na_4Mn_{14}O_{27}.9H_2O$. A common constituent of black manganese oxide earths (wad, *q.v.*; Ford, 2001), it is closely related to the mineral todorokite (*q.v.*). Identifications of this mineral in wad-based pigments may be forthcoming.

Manganese oxides and hydroxides group; Todorokite; Wad
Ford (2001)

BISMITE
Yellow
Generic compound

Bismite is a yellow bismuth oxide mineral with formal chemical composition Bi_2O_3. However, it is commonly impure and often hydrated (such that some sources give it as an oxide hydrate, $Bi_2O_3.3H_2O$). Named after its composition, bismite occurs as a weakly coherent powdery mass with a dull earthy lustre and is often known as bismuth ochre. It occurs primarily as an oxidation product of bismuth and bismuthinite, Bi_2S_3, and is found in oxidised veins associated with copper, lead, tin and other metal ore deposits (such as in Cornwall and Cumberland, UK, Saxony in Germany, Bolivia and Nevada, USA; Rutley, 1988). None of the literature sources surveyed mention the use of bismite as a pigment, although Bristow (1996b), citing an editor of Tingry, links 'bismuth white' with bismuth oxide (*qq.v.*). The connection otherwise seems to be through the general assumption that the term 'ochre' necessarily means a pigmentary material.

Bismuth group; Bismuth oxides and hydroxides group; *Bismuth white*
Bristow (1996b); Rutley (1988) 273; Tingry (1830)

BISMOCLITE
Variable
Generic compound

Bismoclite is a mineral of variable colour, named after its chemical composition BiOCl. It varies from white to grey, yellow or brown and occurs as soft, greasy, translucent crystals. Its occurrence was first reported by Mountain in 1935 from its type locality at Jackal's Water, Namaqualand, South Africa and has since been identified from mines at Wittichen (Germany), St Hilary (Cornwall, England) and Iron Knob (South Australia). Although there are no records of natural bismoclite being used as a pigment, the synthetic analogue, bismuth chloride oxide (*q.v.*) has been used extensively and is listed in the *Colour Index* as CI 77163/Pigment White 14.

Bismuth group; Bismuth halides group; Bismuth chloride oxide
Colour Index (1971) 77163; Mountain (1935)

BISMUTH
Metal
Generic compound

Bismuth is a metallic element found in Europe and South America (for example, Erzgibirge, Saxony; Piedmont, Italy; Sierra Morena, Spain and Peru and Bolivia, among others). It has often been confused historically with antimony, to which it is closely related physically.

Bismuth is cited in Agricola (1556), and is further described as a material used to imitate silver; this use is also given in the text on illumination by Boltz von Ruffach (1549), where it is called *argentum musicum*; however, other writers use this term and the English term mosaic silver (*q.v.*) to describe amalgams of bismuth and tin.

A grey-black colour containing bismuth has been found in works of art in Italy of the fifteenth and sixteenth centuries particularly in the work of Fra Bartolomeo and Correggio (Buzzegoli *et al.*, 1996). It is found in conjunction with iron sulfides, and sometimes zinc or antimony. This has led to the hypothesis that the bismuth here is of a mineral origin, possibly pyrite (*q.v.*) available from mines in Piedmont (Traversella-Brosso and possibly nearer to Florence) where pyrite is rich in these impurities. The bismuth sulfide mineral bismuthinite (*q.v.*) has also been tentatively identified in a painting by the Master of Cappenberg (Spring, 2000). However, metallic bismuth has been used in southern Gemany, particularly Nürnberg, and Switzerland from the fourteenth to the sixteenth centuries where its use is termed *wismut-malerei*. Pure powdered bismuth was applied in a medium and then burnished with an agate to produce a false silver, or gold when glazed. Early literature as to its use in inks with gum arabic is to be found in the Library of the German National Museum from 1384. Analysis has found that some layers of paint in manuscripts are practically pure bismuth (Mayr, 1984).

Bismuth has also been referred to as *marchesita* or marcasite (*q.v.*); however, there was considerable confusion and this term is therefore imprecise in early literature.

A marginal note in the so-called de Mayerne MS (British Library MS Sloane 2052, 92r) also mentions a 'Noir grisâtre, Antimoine Wismut'.

Bismuth group; Metal pigments; Bismuthinite; Marcasite; Pyrite *Mosaic silver*

Agricola (1556/trans. Hoover & Hoover, 1950) 116–117; Boltz von Ruffach (1549/Benziger, 1913) 57; Buzzegoli *et al.* (1998); Gold (1994) 166–178; Mayr (1984); MS Sloane 2052 (nd) 92r

BISMUTH CHLORIDE OXIDE

White
Generic compound

Bismuth chloride oxide (BiClO; basic bismuth chloride or bismuth oxychloride) is a tetragonal compound consisting of alternating sheets of O and Cl atoms with Bi atoms in between. It is generally synthesised from a basic bismuth nitrate solution and sodium chloride or by dilution of a concentrated aqueous bismuth chloride solution (MacIntyre, 1992).

The chloride was also sold as *blanc de Perle* or pearl white when it was prepared by precipitation of aqueous bismuth nitrate with hydrochloric acid and *blanc d'Espagne*, where aqueous bismuth nitrate was mixed with brine (*Colour Index*, 1971). Other terms apparently associated with this compound are flake white and bismuth white (*qq.v.*). The *Colour Index* identifies two white bismuth compounds used as pigments: CI 77163/Pigment White 14, which is listed as bismuth chloride oxide (BiClO), and CI 77169/Pigment White 17, which is described as 'basic bismuth nitrate'.
See: bismuth nitrates group.

Bismuth group; Bismuth halides group; Bismuth nitrates group; Bismoclite; *Bismuth white*; *Blanc d'Espagne*; *Flake white*; *Spanish white*

Colour Index (1971) 77163, 77169; MacIntyre (1992)

BISMUTH CHROMATE(VI)

Red-Orange-Yellow
Generic compound

See: bismuth chromates group.

BISMUTH CHROMATE(VI) OXIDE

Red-Orange
Generic compound

See: bismuth chromates group.

BISMUTH CHROMATES GROUP

Red-Orange-Yellow
Group term

Bismuth chromate, formed from combining chromic acid with bismuth metal, was mentioned as a possible pigment in the early nineteenth century by Godon (Berthollet and Vauquelin, 1804). It was later described by Gentele (1860) as an expensive lemon yellow pigment, with no advantage over chrome yellow (*q.v.*), used mainly as an additive to yellow mineral pigments. Salter (writing in 1869) states that in Brunswick green, Prussian blue would be destroyed by lead chromate (*qq.v.*) and was 'better compounded with barium or bismuth chromate'.

Bismuth chromates of varying stoichiometries can be synthesised. The *Colour Index* (1971) lists a 'basic bismuth dichromate' with composition $Bi_2O_3.2CrO_3$, prepared by precipitating bismuth nitrate with potassium dichromate and used as an orange-red pigment (CI 77166). It is presumably more accurately described as bismuth chromate(VI) oxide, which is one of the formulations of bismuth yellow (*qq.v.*; Kühn and Curran, 1986).

Bismuth group; Chromates group; Barium Chromate(VI); Lead chromate(VI); *Bismuth yellow*; *Brunswick green*; *Chrome yellow*; *Prussian blue*

Berthollet & Vauquelin (1804); *Colour Index* (1971) 77166; Gentele (1860); Kühn & Curran (1986); Salter (1869)

BISMUTH DICHROMATE

Red-Orange
Synonym, variant or common name

See: bismuth chromates group.

BISMUTH GROUP

Variable
Group term

The following bismuth compounds are known as or have become associated with pigment use historically:

Elemental bismuth (Bi).
Sulfides: Bismuthinite (Bi_2S_3).
Oxides and hydroxides: Bismite ('bismuth ochre'; Bi_2O_3); Bismuth hydroxide (Bi[OH]$_3$); Bismuth hydroxide (BiO[OH]).
Halides: Bismuth chloride oxide (BiClO).
Nitrates: Bismuth nitrate oxide (BiO[NO$_3$]); Bismuth hydroxide nitrate oxide (Bi_2O_2[OH][NO$_3$]).

Bismuth vanadate, $BiVO_4$, has been used as a pigment since the 1970s, although it also occurs naturally as the minerals pucherite (brown, orthorhombic), clinobisvanite (monoclinic) and deyerite (tetragonal) and was reportedly first synthesised in 1924 for pharmaceutical purposes. In 1976 Du Pont described the preparation and properties of a 'brilliant primrose yellow', which was the monoclinic bismuth vanadate, while pigments containing other phases such as Bi_2XO_6 (where X is molybdenum or tungsten) were subsequently developed (for example, bismuth vanadate molybdate, $4BiVO_4.3Bi_2MoO_6$). Trade names for these include Sicopal; CI Pigment Yellow 184 is bismuth vanadate (Buxbaum, 1998). Additionally, bismuth chromate(VI) oxide is known as a pigment (see: chromate pigments). There is also an obscure lead antimony bismuth zinc oxide, the precise composition of which is unclear.

The occurrence of bismuth in dark grey-brown areas of paintings by Fra Bartolomeo has been noted by Buzzegoli *et al.* (1996, 1998); the presence of antimony as well as bismuth (both associated with iron and the latter sometimes with zinc) led them to hypothesise the use of an iron mineral such as pyrite (*q.v.*) – apparently that from the Brosso-Traversella mine in Piemonte would have a comparable profile. A marginal note in the so-called de Mayerne MS (British Library MS Sloane 2052, 92r) also mentions a 'Noir grisâtre, Antimoine Wismut'.

A specific technique, known as *Wistmutmalerei* – 'bismuth painting' – used elemental bismuth.
See: bismuth.

Bismuth halides group; Bismuth nitrates group; Bismuth oxides and hydroxides group; Chromates group; Metal pigments; Vanadium group; Bismuth chloride oxide; Bismuth chromate(VI) oxide; Bismuth vanadate; Clinobisvanite; Deyerite; Pucherite; Pyrite; *Bismuth ochre*; *Bismuth purple*; *Bismuth white*; *Bismuth yellow*

Buxbaum (1998); Buzzegoli *et al.* (1996); Buzzegoli *et al.* (1998); MS Sloane 2052 (nd) 92r

BISMUTH HALIDES GROUP

Variable
Group term

Only one halide – the white bismuth chloride oxide (*q.v.*) – appears to have been used significantly as a pigment. However, Salter (1869) describes a purple compound (bismuth purple) prepared by passing chlorine through a bismuth oxide hydrate suspension in aqueous potash; the precise composition is unknown.

Bismuth group; Bismuth chloride oxide; *Bismuth purple*
Salter (1869) 304

BISMUTH HYDROXIDE NITRATE OXIDE

White
Generic compound

See: bismuth nitrates group.

BISMUTH NITRATE

White
Generic compound

See: bismuth nitrates group.

BISMUTH NITRATE OXIDE

White
Generic compound

See: bismuth nitrates group.

BISMUTH NITRATES GROUP

Variable
Group term

Bismuth nitrate is identified in several sources as a form of bismuth white (*q.v.*) (Harley, 1982; *Colour Index*, 1971). However, the aqueous chemistry of bismuth (Bi^{3+}) in the presence of the nitrate ion gives rise to a range of compounds; from acid solutions, for example, it is possible to form $Bi(NO_3)_3.5H_2O$, while treatment of Bi_2O_3 with HNO_3 gives basic salts such as $BiO(NO_3)$ and $Bi_2O_2(OH)(NO_3)$ (Cotton *et al*., 1999).

The *Colour Index* (1971; CI 77169/CI Pigment White 17) is specific in identifying 'basic bismuth nitrate' as a white pigment; the stated preparation is by dissolving bismuth in fuming nitric acid and then pouring the solution into a large volume of water so that a white precipitate is formed. According to the *Merck Index* (1996), 'bismuth subnitrate' (defined there as the bismuth hydroxide nitrate oxide) is also known as bismuth white, magistery of bismuth, novismuth, paint white and Spanish white; the *Merck Index* also states that bismuth nitrate (given there as $Bi(NO_3)_3$) finds application in luminous paints. Note that bismuth chloride oxide could also be called bismuth white.

Bismuth group; Bismuth chloride oxide; *Bismuth white*; *Magistery of bismuth*; *Novismuth*; *Paint white*; *Spanish white*
Colour Index (1971) 77169; Cotton *et al*. (1999); Harley (1982) 173; *Merck Index* (1996) 1311; 1326

BISMUTH OCHRE

Yellow
Synonym, variant or common name

Bismuth ochre is synonymous with bismite (*q.v.*), a yellow bismuth oxide mineral found as an alteration product of bismuth-containing minerals. No evidence for pigmentary use is currently known.

Bismuth group; Bismuth oxides and hydroxides group; Bismite

BISMUTH OXIDE

Yellow
Generic compound

See: bismuth oxides and hydroxides group.

BISMUTH OXIDES AND HYDROXIDES GROUP

Variable
Group term

The only well-established oxide of bismuth is Bi_2O_3, which occurs in nature as the mineral bismite. Bismuth(III) oxide exists as a yellow powder. A bismuth(V) oxide is known, but it is extremely unstable. A hydroxide – $Bi(OH)_3$ – can also be precipitated from solutions of bismuth salts; it is a white to yellowish white amorphous powder which readily loses one molecule of water to form the yellow BiO(OH) (Cotton *et al*., 1999; *Merck Index*, 1996; *Gmelin*, 1932).

Bristow (1996b), citing an editor of Tingry (1830), links bismuth oxide to bismuth white. It seems highly unlikely that any of the above compounds were actually used or known as this, however.

Bismuth chromate is described by Salter (1869) under bismuth yellow. Bismuth vanadate, in combination with bismuth-molybdenum-tungsten oxides, are known as yellow pigments of modern introduction (Buxbaum, 1998; see: bismuth vanadate).

Bismuth group; Bismuth vanadate; *Bismuth white*; *Bismuth yellow*
Bristow (1996b); Buxbaum (1998) 113; Cotton *et al*. (1999) 401; *Gmelin* (1932); *Merck Index* (1996) 1314; Salter (1869) 116; Tingry (1830)

BISMUTH PURPLE

Purple
Synonym, variant or common name

Salter (1869) describes the preparation of what he calls bismuth purple by 'passing chlorine gas through the hydrated oxide [of bismuth] suspended in a saturated solution of potash. As soon as the oxide becomes brown-red, the mixture is boiled and the liquid decanted off at once, the residue being immediately washed first with alcohol and then with water.' Salter clearly felt the effort was not worthwhile.

Bismuth group; Bismuth halides group
Salter (1869) 304

BISMUTH VANADATE

Yellow
Generic compound

According to Buxbaum (1998), greenish yellow pigments based on bismuth orthovanadate ($BiVO_4$) have found increasing popularity, substituting for comparable shades of lead chromate and cadmium sulfide pigments. Bismuth vanadate occurs naturally as the brown minerals pucherite, clinobisvanite and deyerite. Although the synthesis of the compound was reported as early as 1924, the development of pigments with this composition did not begin until the mid-1970s when, in 1976, Du Pont described a 'brilliant primrose yellow'. Subsequently a range of related pigments with additional phases of the form Bi_2XO_6 (where X is molybdenum or tungsten) have been reported and supplied commercially.

Listed by the *Colour Index* as CI Pigment Yellow 184.

Bismuth yellow
Buxbaum (1998) 113; *Colour Index* (1971)

BISMUTH WHITE

White
Synonym, variant or common name

The *Colour Index* (1971) identifies two white bismuth compounds used as pigments: CI 77163/Pigment White 14, which is listed as bismuth chloride oxide (*q.v.*; BiClO), and CI 77169/ Pigment White 17, which is described as 'basic bismuth nitrate' (see entry for bismuth nitrate for possible compounds). A further possibility from literature sources (see below) is an oxide; this may probably be discounted, however (see: Bismuth oxides and hydroxides group).

References in the historical literature to bismuth white were found by Harley (1982), Bristow (1996b) and Carlyle (2001). According to Harley, bismuth white was the 'nitrate' (not differentiating the form); Bristow, citing an editor of Tingry, considers it to be an oxide. Harley, Bristow and Carlyle also all essentially concluded that while reference to 'Bismuth white' occurs in the literature, it was rarely or unlikely to have been prepared commercially for artistic purposes and appears to have been used mainly as a cosmetic. Heaton (1928) lists bismuth white as a pigment that is obsolete or of little importance; it was, according to him, bismuth oxychloride.

Tingry (1804) found that some of the pigments called Cremnitz white were magistery of bismuth (*qq.v.*), although the third edition of Tingry (1830) describes bismuth white, or magistery of bismuth from Cornwall, as pearl white. Both Field (1835) and his later editor Salter (1869) discuss bismuth nitrate under pearl white. The *Merck Index* (1996) lists magistery of bismuth as a synonym for a basic bismuth nitrate. Interestingly, a 'magistery' is a historical term for a residue prepared by precipitation from an acid solution and among the materials used for this were true pearls; it may be surmised that the two became conflated at some time prior to the nineteenth century, leading to the association of bismuth white and pearl white. However, bismuth chloride was also sold as *blanc de Perle* (when prepared by precipitation of aqueous bismuth nitrate with hydrochloric acid) and as *blanc d'Éspagne* (where aqueous bismuth nitrate was mixed with brine) (*Colour Index*). Another synonym was apparently *bougival white*, although this term clearly had multiple historical meanings.

Bismuth group; Bismuth nitrates group; Bismuth oxides and hydroxides group; Bismuth chloride oxide; *Blanc d'Éspagne*; *Bougival white*; *Cremnitz white*; *Magistery of bismuth*; *Novismuth*; *Pearl white*; *Spanish white*

Bristow (1996b); Carlyle (2001) 518; *Colour Index* (1971); Field (1835) 70; Harley (1982) 173; Heaton (1928) 379; *Merck Index* (1996) 1326; Salter (1869) 78–79; Tingry (1804) 283; Tingry (1830) 61

BISMUTH YELLOW

Yellow-Orange
Synonym, variant or common name

Synonym for a bismuth chromate(IV) oxide pigment (*q.v.*); Salter (1869) states that it was available as a lemon or an orange-yellow colour.

Bismuth vanadate (*q.v.*) and vanadate molybdate-type pigments are also yellow in colour; modern paints labelled bismuth yellow will be of this type. This is listed by the *Colour Index* (1971) as CI Pigment Yellow 184.

Bismuth group; Bismuth chromate(VI) oxide; Bismuth vanadate

Colour Index (1971); Salter (1869) 116

BISMUTHINITE

Grey
Generic variety

Bismuthinite, traditionally known as bismuth glance, is bismuth sulfide Bi_2S_3, it forms a solid solution series with antimony sulfide, stibnite (Sb_2S_3) and may therefore contain varying amounts of antimony. All minerals in the series belong to the orthorhombic crystal system, forming lead grey, needle-like crystals or more commonly occurring in massive forms. Bismuthinite and stibnite both form in veins in association with lead and tin mineralisation. Deposits occur worldwide, including Cornwall (England) and Saxony (Germany) and numerous deposits in the New World (Lueth *et al.*, 1990).

Bismuthinite has been identified on several paintings by Correggio (Seccaroni, 1999a,b) while a further tentative identification has been made on a work by the Master of Cappenberg, where the pigment occurs with a red earth (Spring, 2000).

Bismuth group; Stibnite

Lueth *et al.* (1990); Seccaroni (1999a); Seccaroni (1999b); Spring (2000)

BISTRE

Brown
Common generic composite

Bistre (also bister) was prepared from wood soot, preferably beechwood (*Fagus* species). After the soot was collected close to the flames, it was treated with hot or boiling water; when the particles had settled out, the supernatant liquors were decanted and the sediment taken to dryness. It is a mixture of flame carbon, char and possibly some coke along with uncarbonised tarry material, though this may not be a sufficiently diagnostic composition since a similar profile may occur with, say, wood soots from domestic chimneys (see: carbon-based blacks group). It is also the latter, tarry, component which gives rise to the brown shade of the pigment, as well as its poorer lightfastness compared to other carbon-based blacks (Harley, 1982; Winter, 1983; White, 1986).

Harley, in surveying British documentary sources, found little mention of the term bistre before the seventeenth century, and then only in works where there was a strong French connection (notably the two manuscripts by de Mayerne (MS Sloane 2052) and Boutet); wholly English sources generally refer to soot, soot of wood or similar. Harley adds that the pigment was used primarily in watercolour, since asphalt supplied the needs for oil painting, further noting that Spanish liquorice (for which, see: spanish brown) was often incorporated to help with the working properties. It appears to have been primarily used for a short period in the eighteenth century.

Heaton (1928) simply calls bistre 'bituminous charcoal'. Other historical terms include *caligo*, *fuligino* and *fuligo* (for example, Merrifield (1849), who also lists one of the meanings of *atramentum* as being related).

Carbon-based blacks group; Carbon-based blacks group: Flame carbons sub-group; *Spanish brown*

Boutet (1674); Harley (1982) 154; Heaton (1928) 379; Merrifield (1849) 27; MS Sloane 2052 (nd); White (1986); Winter (1983)

BITUMEN

Brown
Common generic composite

Here, bitumen is defined as a group term for long chain hydrocarbons which includes the naturally occurring materials known as asphalts (*q.v.*). The terms bitumen and asphalt (plus pitch and tar) are often used in the historical literature indescriminately. The definitions given below attempt to provide a simplified classification based on chemistry and geological occurrence. 'Bitumens', generically, were manufactured from the beginning of the industrial revolution as a by-product of the coal industry, and in the twentieth century as the residual hydrocarbons remaining after fractional distillation of fuel oils. For reference to artist's pigments, the reader is also directed to the entry for asphalt.

Bitumens are complex mixtures and emulsions of hydrocarbons and volatile components. It is best used as a general term to describe a range of naturally occurring or synthetically produced, high viscosity or solid materials, including asphalts (*q.v.*) with which the term has been used indescriminately. Harrell and Lewan (2001) use the term bitumen to apply to all *naturally* occurring heavy oils and asphalts.

Naturally occurring bitumens are classified into three types based on their origin (North, 1985). Kerobitumens (or native bitumens) form directly from organic matter in sediments; graphitic bitumens form *in situ* in petroleum reservoirs through thermal processes or reactions with natural gases. They are characteristically rich in aromatic compounds and have negligible sulfur, oxygen and nitrogen. They are insoluble in organic solvents and are unlikely to occur on the earth's surface. Insoluble *and* infusible graphitic bitumens (and the majority of the kerobitumens) are called pyrobitumens. Finally, asphaltic bitumens form at or near the earth's surface at low temperatures. They may also be derived from petroleum reservoirs but have been concentrated by water washing and microbial action. They contain a range of impurities and are soluble in organic solvents (North, 1985).

It is these soluble, fusible asphaltic bitumens and kerobitumens, readily accessible in surface deposits, that have found use as waterproofing agents and pigments. Among the kerobitumens, ozocerite is the most commonly occurring, forming a brown-yellow, sulfur-free mineral wax with deposits in the Carpathians and the eastern shore of the Dead Sea. The black or dark brown asphalts and asphaltites are known from both kerobitumen and asphaltic (reservoir) bitumen sources. Asphalts soften at temperatures of c. 20°C whereas the more solid asphaltites are only fusible at temperatures above 110°C. Naturally occurring deposits of asphalts are well known from the Caribbean pitch lakes of Trinidad and Venezuela. Asphaltites including the varieties manjak, glance pitch and gilsonite are known from the Dead Sea, USA and Barbados. Bitumen deposits are generally associated with oil and gas fields. Middle eastern sources of bitumen have been analysed by Connan (1999) and Harrell and Lewan (2001).

The main uses of bitumen were as a waterproofing material and an adhesive in antiquity. The pigment mummy (*q.v.*) may well have been adulterated with bitumen (Woodcock, 1996) as the use of this material was minor in Ancient Egyptian mummification processes. Its uses as a pigment (as separate from 'asphalt') are less well attested, in that it was not of the accepted hard and pure quality of the Dead Sea asphaltites.

Rivington (1901) lists 'Indestructible Paint' which he says is available in three colours (bronze-green, chocolate and black) as enamel paints, made from zinc oxides or lead oxides ground with oil and petroleum spirit, with bitumen added. These paints were useful for painting industrial surfaces subject to the attack of 'steams, acids and alkalis or to the fumes of gas' and produced a hard, washable surface. Rivington goes on to discuss bituminous paints in some detail. They are made from 'vegetable bitumen, asphalte and mineral pitches dissolved in paraffin, petroleum or naphtha, various oils and other substances … they are also … made from the products of coals and other mineral oils'. They are recommended as industrial paints particularly for 'iron work fixed under water'. Rivington names an available brand of bitumen paints as 'Crease's Anticorrosion'.

'Bitumen' or 'bituminous' has been applied to a variety of materials including lignites or humic earths (*q.v.*); however, the term has more recently been redefined to apply to hydrocarbon compounds subjected to greater degrees of temperature, such as the bituminous coals. In an art context the word bituminus has been erroneously applied to describe the behaviour of various paints which may or may not actually contain bitumen (Bothe, 2004).

Carbon-based blacks group; Hydrocarbons group; Asphalt; Coal; Humic earth; *Mummy*

Bothe (2004); Connan (1999); Harrell & Lewan (2001); North (1985); Rivington (1901) 424, 426; Woodcock (1996)

BIXA

Red-Orange-Yellow
Common generic composite

A red, light red, or yellow dye can be made from the seeds of *Bixa orellana* L. (Bixaceae), an evergreen shrub that grows in Mexico and Central and South America. Commonly known as *Annatto*, the dyestuff contains bixin and crocetin, as well as several other yellow to orange-red compounds which behave like carotene (Diemair *et al*., 1933; Schweppe, 1992).

The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *achiotl*, while the Spanish referred to it as *achiote* (Emmart, 1940/1961; Wallert, 1995c). Annatto was used as a dye for fabrics, cosmetics, and food as well as for a painting medium. Donkin (1974, 1977) indicates that along with cochineal, annatto was a reddish brown colourant commonly used for Mexican manuscript painting in the sixteenth century and before.

Dossie (1764) recommends the use of annatto to produce a lake pigment, claiming that he invented it. Several early to mid-nineteenth century English sources also note the use of bixa-derived pigments – Field (1835) records its use to form lake pigments, as does Salter in his 1869 edition of Field's *Chromatography*.

According to the *Oxford English Dictionary* (2002), the correct orthographic form of annatto is actually anatta or anatto, the earliest usage of the term being in the late seventeenth century; alternate spellings include annotto, anotta, arnotta and otta. Other related terms include *Caruera*, *Roucou* and *Terra oleana*.

Bixin

Diemair *et al*. (1933); Donkin (1974); Donkin (1977); Dossie (1764) 119–120; Emmart (1940); Emmart (1961); Field (1835) 120; Harley (1982) 118; *OED* (2002) 'Anatta'; Salter (1869) 256; Schweppe (1992); Wallert (1995c)

BIXBYITE

Black
Generic compound

Bixbyite is a black cubic manganese oxide mineral of composition Mn_2O_3, which often contains appreciable iron. Discovered by Penfield and Foote (1897) and named after the American mineralogist M. Bixby, bixbyite forms as opaque cubic crystals with metallic lustre or as granular masses. It is a relatively rare mineral and occurs in the oxidised portions of manganese deposits or as a primary mineral in metamorphic rocks. It has been identified at locations such as Simpson (Thomas Range, Utah, USA), Lapis Lazuli mine (Badakshan, Afghanistan), San Lusi Potosi (Mexico), Lleyn Peninsula (Gwyned, Wales), Siapa (India) and N'Chwaning mine (Kalahari, South Africa). It is polymorphous with braunite (*q.v.*), the orthorhombic form which often contains appreciable silica.

Bixbyite, along with hematite and the synthetic form of jacobsite (*qq.v.*), has been identified as an Etruscan pigment by Schweizer and Rinuy (1982).

Manganese group; Braunite; Hematite; Jacobsite
Penfield & Foote (1897); Schweizer & Rinuy (1982)

BIXIN

Red
Generic compound

Bixin, 6′-methyl hydrogen 9′-cis-6,6′-diapocarotene-6,6′-dioate (IUPAC, 1974; also: 6,6′-diapo-ψ,ψ-carotenedioitic acid monomethyl ester and carotenoid-carboxylic acid), is isolated from seeds of *Bixa orellana* L. (*Merck Index*, 1996; Schweppe, 1992). Classed here as a carotenoid compound, it also has the *Colour Index* designation CI 75120.
See: bixa.

Carotenoid group; Bixa
Colour Index (1971) 75120; IUPAC (1974); *Merck Index* (1996) 1347; Schweppe (1992) 171, 176

BLACK CHALK

Black
Synonym, variant or common name

Also called black earth, according to Winter (1983) the composition of black chalk is quite variable, generally consisting of graphite or a defective graphite in association with quartz (*qq.v.*) and other minerals, though the composition is not clear in all cases. Iron oxides may also be present and contribute to the colour. Harley (1982) found only a couple of specific mentions of black chalk, commenting that it 'was probably even less used than graphite'. It is listed in the late sixteenth or early seventeenth century MS by Simon Forman (Ashmole 1494) as well as being discussed by de Mayerne (MS Sloane 2052); the latter author remarks that it 'dries well, is easily extended and is a more valuable pigment in oil than common coal'. Use of black chalk as an underdrawing medium has been noted in fifteenth and sixteenth century European paintings, although its identification can be difficult (Bomford *et al.*, 2002); a specific example is from Joachim Beuckelaer's cycle *The Four Elements* (1569–70; National Gallery, London).

Iron oxides and hydroxides group; Chalk; Graphite; Quartz; *Black ochre*
Bomford *et al.* (2002) 26–37; Harley (1982) 157; MS Ashmole 1494 (nd) 636; MS Sloane 2052 (nd) f. 4; Winter (1983)

BLACK CHROMATE OF COPPER

Black
Synonym, variant or common name

See: copper chromate, calcined.

BLACK EARTH

Black
Synonym, variant or common name

See: black chalk.

BLACK LEAD

Black
Synonym, variant or common name

A term typically referring to graphite (*q.v.*; Harley, 1992), though Field (1835) called it 'a native carburet of iron or oxide of carbon'.

Carbon-based blacks group; Graphite
Field (1835); Harley (1982) 156–157

BLACK OCHRE

Black
Synonym, variant or common name

Seemingly synonymous with various terms such as mineral black and native black, this was probably a naturally occurring pigment formed of, as the *Colour Index* (1971; CI 77268) puts it, 'impure carbon of organic and mineral origin'. Salter (1869) says it was also called earth black or Prussian black (*q.v.*), describing it as 'a native earth, combined with iron and alluvial clay' and that 'Sea-coal, and other black mineral substances, have been and may be used as substitutes for the more perfect blacks'; Salter may be in error here though, confusing 'Russian' with 'Prussian' black, the latter a quite distinct product of calcined Prussian blue. However, the issue is more complex still; Osborn (1845) describes Russian black as 'A natural earth, extremely intense of tone', linking it also to Borghini, from whom he translates a passage: 'The first [black] is called earth-black, a coarse and natural color, that may be used in fresco, distemper, or oil painting' ['Il primo si chiama nero di terra, color grosso e naturale, che a fresco, a tempera, ed a olio può servire']. This suggests that there may have been a number of compounds traded under these terms, including (but not exclusively) coal (*q.v.*). Various other black substances would in fact also fit these descriptions, including such materials as jacobsite, which is an iron manganese oxide, and shungite, a carbon-bearing rock (*qq.v.*). Alternatively, manganese-rich 'earths' such as wad (*q.v.*) could also be called 'black ochre'.

Pliny (77 AD) describes a black earth which he calls 'Ampelitis' or 'vine earth'. This, he says, is very like bitumen and used as an eyelash beautifier.

Coal; Jacobsite; Shungite; Wad; *Earth black*; *Mineral black*; *Native black*; *Prussian black*
Borghini (1584/edition of 1787) ii; *Colour Index* (1971) 77268; Osborn (1845) 39; Pliny (1st cent AD/Rackham, 1952) XXXV.lvi; Salter (1869) 404–405

BLACK OXIDE OF COBALT

Black
Synonym, variant or common name

See: cobalt black.

BLACK OXIDE OF IRON

Black
Synonym, variant or common name

See: iron oxide black.

BLACK OXIDE OF MANGANESE

Black
Synonym, variant or common name

Mayer (1991) distinguishes between 'black oxide of manganese' as being derived from the natural mineral and 'manganese black' (*q.v.*) as being the synthetic form.

Manganese group; Manganese oxides and hydroxides group; *Manganese black*
Mayer (1991) 39

BLACK TONER

Black
Synonym, variant or common name

Black toner is described by Toch (1916) in the following terms: 'For making a very intense and good quality black … carefully selected bones or burnt ivory chips are taken, and digested in hydrochloric acid, which removes all the lime salts and leaves the carbon as a flocculent residue. This carbon is probably the highest priced and most intense black used by paint makers, and is frequently sold under the name of black toner, because it sometimes is used for giving an intense tone to an otherwise pure black.'
See: bone black.

Carbon-based blacks group; bone black
Toch (1916) 97–98

BLADDER GREEN

Green
Synonym, variant or common name

See: sap green.

BLANC D'ARGENT

White
Synonym, variant or common name

Field (1835) considers this to be a high quality lead white (in this context, a form of lead carbonate), the name synonymous with French white and Silver white (*qq.v.*). Church, writing in 1901, states that 'The blanc d'argent of the French is supposed to be lead carbonate free from any hydrate, but the great majority are nothing but flake-white of good quality.' However, 'silver white' could have alternate meanings, so some care should be taken in interpretation. Salter, in his 1869 revision of Field's text associates the term blanc d'argent directly to the translation *silver*, elaborates that 'It is brought from Paris in the form of drops, it is exquisitely white, but of less body than flake white.' He further remarks that *Roman white* is very similar to blanc d'argent.

Lead carbonates group; Lead group; *Flake white*; *French white*; *Lead white*; *Roman white*; *Silver white*
Church (1901) 134; Field (1835) 69; Salter (1869) 71, 74

BLANC DE BOUGIVAL

White
Synonym, variant or common name

See: Bougival white.

BLANC DE CRAIE

White
Synonym, variant or common name

Watin (1785) discusses *blanc de craie* ('chalk white'), describing it as 'a calcareous, friable farinaceous earth found in Champagne, Bourgogne, and Meudon near Paris'. He compares it to Bougival white, but says it is harder.

Bougival white
Watin (1773/edition of 1785) 21

BLANC D'ÉSPAGNE

White
Synonym, variant or common name

Blanc d'Éspagne, literally Spanish white in English, appears to be a synonym for, or manufacting variant of, bismuth white (*q.v.*), a pigment produced by mixing aqueous bismuth nitrate with brine (*Colour Index*, 1971). However, it is not clear whether this term additionally includes all possible meanings for the term Spanish white. Given by Watin (1785) as synonymous with *blanc de Bougival* ('Bougival white'), a 'white earth or marne'.
See: Spanish white.

Bismuth white; *Bougival white*; *Marne*; *Spanish white*
Colour Index (1971); Watin (1773/edition of 1785) 20

BLANC DE NEIGE

White
Synonym, variant or common name

See: snow white.

BLANC DE PERLE

White
Synonym, variant or common name

See: pearl white.

BLANC DE TREMIE

White
Synonym, variant or common name

Term associated with zinc white (Kühn, 1986).

Zinc group; Zinc oxide; *Zinc white*
Kühn (1986)

BLANC FIXE

White
Synonym, variant or common name

Generally this was a synthetically produced barium sulfate, the analogue of the mineral baryte; however, barium carbonate was also occasionally sold as 'blanc fixe' (Feller, 1986).
See: barium carbonate and barium sulfate.

Barium carbonate; Barium sulfate; Baryte
Feller (1986)

BLANC LÉGER

White
Synonym, variant or common name

According to Harley (1982) *blanc léger* was probably equivalent to the English term light white, a silver compound prepared from the dissolution of metallic silver in aqua fortis (nitric acid of variable purity). This term has also been listed as a synonym for zinc white (Kühn, 1963), but Harley further argues that this is inaccurate and that the confusion stems from the use of the term 'silver white' which may be applied to both zinc and lead whites.

Lead white; *Light white*; *Silver white*; *Zinc white*
Harley (1982) 174; Kühn (1963)

BLANCHARDITE

Green
Synonym, variant or common name

See: brochantite.

BLANCOPONE

White
Synonym, variant or common name

Blancopone is a co-precipitate, consisting of approximately 70% barium sulfate and 30% calcium carbonate. It is listed in the *Colour Index* (1971) as CI 77122/Pigment White 23.

Calcium carbonates group; Barium sulfate
Colour Index (1971) 77122

BLEIGLATTE
Yellow
Synonym, variant or common name

See: massicot.

BLENDE
Variable
Synonym, variant or common name

According to Riffault *et al.* (1874) blende is a native zinc sulfide mineral used in the production of zinc white (*qq.v.*). It is also used as a substitute for zinc and lead whites. The colour varies from white and 'honey yellow' to 'brown or reddish'. The term 'zinc blende' is synonymous with the zinc iron sulfide mineral sphalerite (*q.v.*).

Sphalerite; Zinc sulfide
Riffault *et al.* (1874) 177–178, 191–192

BLEU AZURAL
Blue
Synonym, variant or common name

See: manganese blue.

BLEU CELESTE
Blue
Synonym, variant or common name

See: cerulean blue and cobalt tin oxide.

BLEU D'ALLEMAGNE
Blue
Synonym, variant or common name

See: azurite.

BLEU D'ÉMAIL
Blue
Synonym, variant or common name

See: enamel blue.

BLEU DE GARANCE
Blue
Synonym, variant or common name

Montagna (1993) lists *bleu de garance* as a term associated with natural ultramarine (see: *Lazurite*). The origin of this term could not be confirmed, however, particularly in the context of *garance* or *garancia*, which refers to madder (*q.v.*).

Lazurite; Madder; *Garancia*
Montagna (1993) 19

BLEU DE MONTAIGNE
Blue
Synonym, variant or common name

See: azurite.

BLEU LUMIÈRE
Blue
Synonym, variant or common name

Church (1901) lists this as a new addition. It was said to be an artificial copper hydrate, though the precise composition is unknown.

Copper group
Church (1901) 225

BLIXITE
Yellow
Generic compound

Blixite is an orthorhombic lead chloride hydroxide mineral with the general chemical formula $Pb_2Cl(O,OH)_2$. Discovered by Gabrielson *et al.* (1958) and named after the Swedish chemist R. Blix, blixite was first identified at the Långban mine in Varmland, Sweden and has since been found in the Mendip Hills, Somerset, England. It is a rare mineral which occurs as thin yellow or yellow-green deposits in fractures in hausmannite and braunite (*qq.v.*) ores. Minerals which are chemically similar, but which form under different conditions are laurionite and fiedlerite (*qq.v.*).

As such a rare mineral, blixite is unlikely to have been used as a pigment. However, synthetic forms of lead chloride hydroxide (*q.v.*), have been identified as a pigment in a number of contexts and in particular Winter (1981) has shown that 'lead white' in Japanese painting is frequently composed of both the blixite and laurionite forms of lead chloride hydroxide.

For a fuller discussion of the lead chloride hydroxides see the entry under lead halides group and lead chloride hydroxide.

Lead group; Lead halides group; Braunite; Fiedlerite; Hausmannite; Laurionite; Lead chloride hydroxide
Gabrielson *et al.* (1958); Winter (1981)

BLOOD
Red
Common generic composite

Blood plasma consists of a suspension of various cell types, such as erythrocytes (red blood cells) and leucocytes (white blood cells) as well as many other organic compounds and salts. The erythrocytes contain hemoglobin (*q.v.*), the principal oxygen carrier and colouring compound present.

There is good evidence for the use of blood-derived material in a number of painting contexts, particularly as a binding medium, though clearly the material is also likely to impart some colouration. Pliny (first century AD), for example, says that *minium* may be adulterated with goat's blood. Loudon suggested the use of bullock's blood as a binder for exterior painting, though Jourdain's description of blood being used to tint interior paint is dismissed by Bristow (Loudon, 1833; Jourdain, 1914; cf. Bristow, 1996b). Additionally, blood (specifically, the 'dried blood' cited by Loudon) was the starting point for the production of early forms of Prussian blue.

Hemoglobin; Minium; *Prussian blue*
Bristow (1996b) 232, n. 13; Jourdain (1914) 32; Loudon (1833) 262; Pliny (1st cent AD/Rackham, 1952) XXXIII.xxxiv

BLOODSTONE
Red
Synonym, variant or common name

Field (1835) gives this as a term then in current use for red ochre which at the time was found in New Jersey.

Red ochre
Field (1835)

BLUE ASHES
Blue
Synonym, variant or common name

This term (in its French form, *cendres bleues*) appears to be confused in that it has been variously applied to natural and synthetic copper blues (azurite and blue verditer). According to Watin (1785), in a discussion of *cendre bleue* (‘ash blue’), ‘[t]his name is given to a friable granular blue stone, practically reduced into powder, found in copper mines in Poland and in a particular terrain in the Auvergne. It is of a great beauty in distemper but of no value in oil.’ Watin also states that this can be manufactured as well, by mixing three parts of good white crystalline sand, well dried, two parts of nitre, one part of filings of copper, one part of common salt and an eighth of salts of ammonia. The mixture is melted in a crucible, then poured into cold water, washed and filtered. The resultant blue powder is then dried and ground.

Blue ash(es) could, according to Carlyle (2001), imply a number of distinct pigments, falling into her category of synonymous terms (as opposed to substitutes). Hence she points out that while Mérimée (1830) and Osborn (1845) identify this as a ‘copper based blue’, other authors such as Standage (1887) describe it as the last grinding of the lapis lazuli, thus equating it with so-called ultramarine ash. Mayer (1991) on the other hand, though never a wholly reliable source, specifically links this term with Bremen blue, which is otherwise considered to be an artificial copper carbonate.

We should also note that, according to Harley (1982), Sanders blue was an eighteenth century English affectation from the French *cendre(s) bleues*.

Copper carbonates group; Azurite; Blue verditer; Copper carbonate hydroxide, azurite type; Lazurite; Ultramarine ash; *Ashes blue*; *Bremen blue*; *Lapis lazuli*; *Sanders blue*
Carlyle (2001) 157–158, 475; Harley (1982) 46–50; Mayer (1991) 39; Mérimée (1830/trans. Taylor, 1839) 158; Osborn (1845) 50; Standage (1887) 32; Watin (1773/edition of 1785) 30–31

Blue ashes of Seville

Blue
Synonym, variant or common name

In discussing a reference to this in the treatise by Carducho (1633), Veliz (1986) suggests that although an origin in Seville might be implied, it is also possible that the source was in the ‘Spanish Indies’, since the majority of raw material entered Europe by this route. Indeed, Harley (1982) has pointed out that Central America – New Mexico – was a significant source of azurite in the seventeenth century.

Azurite
Carducho (1633); Harley (1982) 46–49; Veliz (1986) 197, n.5

Blue basic lead sulfate

Grey
Synonym, variant or common name

See: blue lead.

Blue bice

Blue
Synonym, variant or common name

See: bice.

Blue black

Black
Synonym, variant or common name

More than just a qualified colour descriptor, blue black seems to have been charcoal, acquiring this name by virtue of the blue cast that it has. Harley (1982) states that it was generally accepted and used as a term during and after the second half of the seventeenth century in England, citing also a recipe from BL MS Harley 6376, by the painter Gyles: ‘To make a faire blewe black. Take cuttings of a vine, and burn them in a Crusiple as you doe Ivory blacke and it will be a fine blew blacke for a face blew then small cole blacke’ (N.B. *smallcoal* was another term for a form of charcoal).

In the later nineteenth century ‘blue black’ could be ivory black with a small addition of blue pigment (Carlyle, 2001) while the *Colour Index* (CI 77268/Pigment Black 8) states that it was obtained from vine twigs or cocoa nut shell and that ‘a common black shaded with a blue is often sold under this name’. Heaton (1928) merely lists it as ‘carbon black’.

Carbon-based blacks group
Charcoal; *Ivory black*; *Smallcoal*
Carlyle (2001) 160, 177, 465–467; *Colour Index* (1971) 77268; Harley (1982) 158; Heaton (1928) 379; MS Harley 6376 (nd) 108

Blue carmine

Blue
Synonym, variant or common name

Field (1835) says of blue carmine ‘little is known [of it] as a substance or as a pigment. It is said to be of a beautiful blue colour.’ Salter’s 1869 edition of *Chromatography* indicates that the initial positive estimates were well founded; he gives a recipe for it, stating that ‘It is formed when a solution of bichloride of molybdenum is poured into a saturated, or nearly saturated, solution of molybdate of ammonia. A blue precipitate falls, which is a molybdate of molybdic oxide, hydrated, and abundantly soluble in water. When dried, it furnishes a dark blue powder, resembling powdered indigo.’ Additionally, Salter also says that: ‘A more eligible preparation is the molybdate of baryta, produced by mixing solutions of molybdate of potash and acetate of baryta. A white, flocculent precipitate results, which rapidly condenses to a crystalline powder, and turns blue on ignition.’

This has also been listed as a molybdenum oxide (Harley, 1982) compound and as tungsten oxide (Rose, 1916).
See: indigo carmine.

Molybdenum group; Ilsemannite; Indigo; *Indigo carmine*; *Molybdenum blue*
Field (1835); Harley (1982) 59; Rose (1916) 378; Salter (1869) 225–226

Blue coffee

Blue
Synonym, variant or common name

Listed by Rose (1916) as a blue pigment made with yellow Java coffee and iron filings in rotating drums.

Rose (1916) 245

Blue frit

Blue
Synonym, variant or common name

Term used to refer to Egyptian blue (*q.v.*; Riederer, 1997).

Egyptian blue
Riederer (1997)

Blue green oxide

Blue-Green
Synonym, variant or common name

See: blue oxide.

BLUE IN LIQUOR

Blue
Synonym, variant or common name

See: indigo carmine.

BLUE IRON EARTH

Blue
Synonym, variant or common name

Rose (1916) states that *Eisenblau* ('iron blue') and *Blaueisenerde* ('blue iron earth') were terms for the iron phosphate mineral, vivianite (*q.v.*).

Vivianite
Rose (1916) 223

BLUE JOHN

Blue
Synonym, variant or common name

See: fluorite.

BLUE LAKE

Blue
Synonym, variant or common name

Harley (1982) found this in two seventeenth century English sources – a translation of Goeree's *Verligterie-Kunde* and the manuscript thought to be by Gyles (MS Harley 6376) – though she also links it to a pigment called *gummi lacrae* by Scheffer (1669). The German translation of Goeree (1756) described it as '*nicht viel von dem Indisch-Blau unterschieden*' (little different from indigo), though there is no other particular reason to think that blue lake was actually a form of that pigment. Moreover, Scheffer describes the pigment as 'a gum lake which exudes from trees in the Indies'; Harley links this to 'lacree', a substance used in dyeing and pharmacy. There may also be a connection to *sap blue*, a sample of which is to be found in Field's *Practical Journal 1809* (f. 318). Finally, Bersch (1901) states that 'When alum is added to a solution of indigo sulphonic acid, and then soda solution, a blue precipitate is formed, which, when dry, resembles Chinese blue in appearance. It is used in painting … It is rather dear, and is mixed with starch, so that it may be sold at low prices; the mixture is formed into slabs and sold as "new blue," "indigo extract," etc.'

Indigo; *Sap blue*
Bersch (1901) 397; Field (1809) f. 318; Goeree (1756) 275; Harley (1982) 65; MS Harley 6376 (nd); Scheffer (1669)

BLUE LEAD

Grey
Synonym, variant or common name

Blue lead is a term associated with galena (*q.v.*), a metallic grey lead ore mineral used in the manufacture of lead-based pigments. However, Toch (1931) describes blue lead as 'not strictly speaking blue, but bluish gray and is a condensed sulphate of lead, which is tinted with carbon smoke during the process of its condensation'. The same author also records in an earlier discussion (1916) that blue lead was actually produced by sublimation of galena, providing an analysis of the pigment showing it to contain lead sulfate (~50%), lead oxide (~40%), lead sulfide (~4.5–5%), lead sulfite (~0.4–1.4%), carbon (~2%) and zinc oxide (~1–2.5%). Other authors such as Dunn (1973a) consider it to be an older variant of white basic lead sulfate. The pigment has been reviewed by Rose (1942). Dunn (1973a) calls it blue basic lead sulfate.

Lead sulfates group; Galena
Dunn (1973a) 74; Rose (1942); Toch (1916) 61; Toch (1931) 90

BLUE MALACHITE

Blue
Synonym, variant or common name

Synonym for azurite (*q.v.*; Mayer, 1991).

Azurite
Mayer (1991) 39

BLUE MANGANATE OF LIME

Blue
Synonym, variant or common name

Riffault *et al.* (1874) relate the following story regarding a 'Blue manganate of lime': during experiments, Kuhlmann calcined in large furnaces a mixture of chalk and residues from the manufacture of chlorine: manganese chloride and iron chloride. Repairs to a furnace after six months revealed black crystals covered in a bright blue compound. The black crystals were said to be 'pseudomorphic Hausmannite (*q.v.*) or acerdase', but attempts to duplicate the manufacture of the blue pigment by others failed.

Calcium group; Manganese group; Hausmannite
Riffault *et al.* (1874)

BLUE OCHRE

Blue
Synonym, variant or common name

Term used to (probably) denote the mineral vivianite (*q.v.*), being described as 'a native hydrated phosphate of iron of rare occurrence, found with iron pyrites in Cornwall, and also in North America' (Salter, 1869). Another associated term is *native Prussian blue*, though Salter says the term is 'improperly used'; this pigment thus seems to have no connection with Prussian blue itself. The German author Jännicke (1893) also describes this pigment, stating that 'Blue Ochre (iron phosphate) shows a beautiful transparent colour, which tends to change quickly into green.' Harley (1982) states that this colour is mentioned in late eighteenth and early nineteenth century English sources.

Vivianite; *Blue iron earth*; *Native Prussian blue*
Harley (1982) 59; Jännicke (1893) 71; Salter (1869) 226–227

BLUE OF COSTRAS

Blue
Synonym, variant or common name

Mentioned in the *Diálogos* of the Spanish author Carducho (1633), according to Veliz (1986) it was probably a synthetic copper blue whose formation includes the formation of a 'crust' (*costra*). Many copper pigments might potentially fit this description, however.

Copper group
Carducho (1633); Veliz (1986) 197, n.7

BLUE OF ENGLAND

Blue
Synonym, variant or common name

Riffault *et al.* (1874) describe this pigment thus: 'There is also a color, called blue of England, blue of Holland, and platt of indigo, which is fine enough, but wanting durability. It is a mixture, in undetermined proportions, of Prussian blue, indigo, smalt, chalk, and starch (*qq.v.*), which is thickened and rendered homogeneous with a mucilage of rice flour, and dried in the shape of lumps or troches.'

Hexacyanoferrate group; Indigoid group; Chalk; Indigo; Smalt; Starch; *Prussian blue*
Riffault *et al.* (1874) 268–269

BLUE OF HOLLAND

Blue
Synonym, variant or common name

See: blue of England.

BLUE OXIDE

Blue-Green
Synonym, variant or common name

The German author Jännicke (1893) discusses blue oxide and green blue oxide ('*Blauoxyd*' and '*Grünblauoxyd*'). Blue oxide is described as a cobalt chromate; green blue oxide is seemingly a mixture of cobalt and chromium oxides.

Jännicke (1893) 70

BLUE SAND

Blue
Synonym, variant or common name

See: smalt.

BLUE VERDITER

Blue
Synonym, variant or common name

According to the seventeenth century writer de Mayerne (MS Sloane 2052), verditer (a copper carbonate hydroxide) was an accidental discovery when a copper nitrate solution – a by-product of the separation of silver from copper – was added to chalk or ceruse, which had at once turned green. The blue pigment, which was produced unreliably, came later (this requires lower temperatures to be made effectively), becoming considered as an English speciality. Production was not well understood in France until the late eighteenth century, when Pelletier analysed the pigment; according to Chaptal (1807), an industrial chemist, Pelletier's method consisted of mixing copper nitrate and lime, washing the green precipitate and mixing it, while wet, with quicklime so that the resulting pigment was blue. Chaptal put forward various improvements such as the use of limewater or baryta water instead of ground lime, as well as pointing out that the triple salt formed when ammonium chloride was dissolved in baryta water gave a fine blue. The pigment has been reviewed by Gettens and FitzHugh (1993a) and its preparation discussed by Scott (2002). The technology of synthesising copper carbonate compounds dates back to the mediaeval period (for example, Jehan Le Begue, 1431; Clarke MS 2790; cf. Merrifield, 1849). Standard procedures for manufacture involved adding lime and potassium carbonate to copper sulfate and then adding ammonium chloride ('sal ammoniac') to the precipitate (Scott, 2002). It is curious that many mediaeval recipes give silver as the starting point for the manufacture of artificial 'azure'. Merrifield suggests that silver coins were impure and contained copper. Several authors have replicated recipes for the manufacture of blue (and green) verditer; see Scott (2002) and Mactaggart and Mactaggart (1980). Synthetic copper carbonate hydroxide blues develop a spherulitic habit that is distinctly different from the crushed crystal shards associated with azurite when viewed microscopically.

The term verditer appears to have only come into use in the late seventeenth century, whereas before that time there were other cuprammonium blues found in recipes but only intended for small scale or individual production. The term verditer came about when large scale production as an industrial by-product of silver refining occurred. Recipes from before 1600 differ from verditer in chemical composition and manufacture (Harley, 1982).

The pigment was paler than natural azurite, but otherwise its stability and other properties are identical. At the end of the nineteenth century, Terry (1893) writes of blue verditer being 'sky blue and not very durable … used in water colour painting, closely resembles Bremen Blue in composition and manufacture. … prepared from copper chloride or nitrate though almost any salt of copper may be used.' Impurities including copper sulfate and calcium sulfate are likely to be present (Scott), and the pigment may have been adulterated with other synthetic blues, primarily smalt (Gettens and FitzHugh, 1993a). The pigment is suitable in all media; however, it may react with fats and oils in binding media to produce organo-copper compounds (Gunn *et al.*, 1999).

Identifications of the pigment are not abundant, but this is most likely due to the chemical equivalence to azurite. However, notable occurrences in art have been listed by Gettens and FitzHugh (1993a). Blue verditer has been reputedly identified on van Eyck's *Mystic Lamb* altarpiece (Coremans, 1953) and in the seventeenth century *Coram Rege Rolls* (Laurie, 1914). In other contexts it has been found on Japanese wall paintings and sculpture (Yamasaki, 1953 and Yamasaki and Nishikawa, 1970), South American pre-Colombian and seventeenth century art (Smith and Ewing, 1952, Gettens and FitzHugh, 1993a) and in a number of paintings in the National Gallery, London (see Gettens and FitzHugh, 1993a).

Blue verditer has been routinely recognised as a house-painter's colour (usually under the name of refiner's verditer) during the seventeenth and eighteenth centuries (Bristow, 1996a). Gettens and FitzHugh (1993a) review notable occurrences of the pigment in domestic and architectural settings. Verweij (2000) has identified blue verditer in the decorative schemes of an eighteenth century house in Haarlem.

Blue verditer has also been known as blue bice. However, many of the terms applied to azurite (that is, Mountain blue and linguistic variants) may also be used to describe blue verditer (and vice versa). Other terms used historically include ashes blue or *Cendres blue/bleu, Cendres bleu d'angleterre* (and the English corruption sanders blue) and Bremen blue, although the latter is more generally applied to a copper hydroxide (*q.v.*; see Harley, 1982; Gettens and FitzHugh, 1993a). Weber (1923) also gives alternate names as air blue, lime blue and neuwied blue, though these terms have complex etymologies of their own. Field (1835) also describes the pigment as 'copper oxide'. Blue verditer was still listed in the twentieth century, though Heaton (1928) lists it as a pigment that is obsolete or of little importance.

Copper carbonates group; Copper group; Azurite; Copper carbonate hydroxide, azurite type; Copper hydroxide; Smalt; *Ashes blue*; *Bice*; *Blue bice*; *Bremen blue*; *Cendres bleues*; *Lime blue*; *Refiner's verditer*; *Verditer*
Bristow (1996a); Chaptal (1807) iii, 415–419; Coremans (1953); Field 1835; Gettens & FitzHugh (1993a); Gunn *et al.* (1999); Harley (1982) 49–53; Heaton (1928) 379; Laurie (1914); Mactaggart & Mactaggart (1980); Merrifield (1849) ccix; MS Sloane 2052 (nd); Scott (2002) 114–116; Smith & Ewing (1952); Terry (1893) 41; Verweij (2000); Weber (1923); Yamasaki (1953); Yamasaki & Nishikawa (1970)

Body white

White

Synonym, variant or common name

According to Field (1835), this was a levigated form of flake white (*q.v.*).

Flake white; *Lead white*

Field (1835) 69

Boehmite

White

Generic compound

Boehmite is an aluminium oxide hydroxide mineral with composition γ-AlO(OH). It is dimorphous with diaspore (*q.v.*), α-AlO(OH), and occurs as microscopic crystals, aggregates or spherules which are white when pure (Rutley, 1988) but may be yellow, green or red when impurities such as Fe, Mn or Cr are present (Reichertz & Yost, 1946; Tettenhorst & Hofmann, 1980). Boehmite was first described by Lapparent in 1928 from Les Baux (France) and is named after the German geologist J. Böhm (1857–1938). It forms as a weathering product of aluminosilicate minerals and aluminium oxides under tropical conditions. Boehmite is a principal component of bauxite (*q.v.*; Deer *et al.*, 1992; Meyer *et al.*, 2002; Rutley, 1988; Trolard & Tardy, 1987) and is often found in association with diaspore and gibbsite, lepidocrocite, hematite, goethite, kaolinite and halloysite (*qq.v.*). It is known from areas such as Laurion (Greece), Les Baux (France), Vogelsberg (Germany), Los Pijiguaos (Venezuela) and Lages (Brazil).

Aluminium oxides and hydroxides group; Bauxite; Diaspore; Gibbsite; Goethite; Halloysite; Hematite; Kaolinite; Lepidocrocite

Deer *et al.* (1992) 576–577; Lapparent (1928); Meyer *et al.* (2002); Reichertz & Yost (1946); Rutley (1988) 278; Tettenhorst & Hofmann (1980); Trolard & Tardy (1987)

Bohemian earth

Green

Synonym, variant or common name

Mayer (1991) lists Bohemian earth as a synonym for green earth (*q.v.*); it may be a source variant.

Green earth

Mayer (1991) 39

Bole

Red

Synonym, variant or common name

Bole is either a naturally occurring or iron-rich material (such as red ochre; *q.v.*) particularly suited to applications such as substrates for gilding where a high surface polish is required. Documentary sources mention various colours such as white and red boles. Harley (1982) found among seventeenth century British documentary sources that the term bole appeared occasionally as a synonym for red ochre, but that it was more typically associated with Armenian bole – '*bole Armoniack*' – and, according to de Mayerne (BL MS Sloane 2052), in canvas priming. Merrifield (1849) lists *bularminium* as synonymous.

A fuller discussion may be found under *Red ochre*.

Clay minerals group; Iron oxides and hydroxides group; *Almagra*; *Armenian bole*; *Brunus*; *Red bole*; *Red ochre*

Harley (1982) 119; Merrifield (1849) 20; MS Sloane 2052 (nd)

Bologna stone

White

Synonym, variant or common name

A variety of baryte (*q.v.*) used as a source of material for pigment production. Terry (1893), in a discussion of Baryta white, for example, says 'at Bologna, a nodular variety is found, called Bologna stone, which is notable for its phosphorescent powers when heated'. The Bolognese shoemaker Vincenzo Casciorolus (1602), who discovered phosphorescence in the mineral baryte, is undoubtedly the cause of this phrase being used although he himself applied the term *lapis solaris*.

Related to the term Bolognian spar.

Baryte

Terry (1893) 170

Bolognian spar

White

Synonym, variant or common name

Synonym for baryte (*q.v.*) common in the mineralogical literature. Undoubtedly also related to the term Bologna stone.

Baryte

BONA pigments

Red

Synonym, variant or common name

See: azo pigments group: lakes sub-group.

Bonattite

Blue

Generic compound

Bonattite is a hydrated copper sulfate mineral, with composition $CuSO_4.3H_2O$. Pale blue in colour and soluble in water, the occurrence of bonattite was first reported by Garavelli at Elba, in Tuscany, Italy. Although it has not been reported thus far in a pigment context, bonattite is known as a corrosion product (Zachmann, 1985). More common hydrous copper sulfate minerals are antlerite, brochantite and posnjakite (*qq.v.*) and these, with their synthetic analogues, are more likely to be encountered as artists' materials.

Copper group; Copper sulfates group; Antlerite; Brochantite; Posnjakite

Garavelli (1957); Zachmann (1985)

Bone

Black-White

Common generic composite

Bone is a composite material made up of intimately mixed inorganic and organic components. The relative proportions of the inorganic and organic components reported in the literature vary considerably, with the wide range of values probably arising from the different extraction techniques used. Reiche *et al.* (2002) report an average component subdivision of 20–30 wt.% organic material and 60–70 wt.% inorganic material, with approximately 10 wt% water also present.

The organic component of bone is dominated by collagen, a protein composed of around 17 amino acids (predominantly glycine, proline and hydroxyproline) from whose composition a molecular weight of 100,000 can be estimated. Literature sources frequently cite higher weights of 300,000 which usually result from the fact that the basic collagen unit is comprised of three amino acid chains twisted together in a triple helix (collectively known as a collagen fibril). These basic units naturally aggregate together to form microfibrils, which in turn combine into larger collagen fibres and fibre bundles to give a strong rope-like structure. Osteocalcin (also known as bone Gla protein) may also be present in bone, making up 1–2% of the total mass (Price, 1983; Collins *et al*., 2002). Further proteins such as hemoglobin, albumin and alkaline phosphatase have been detected in archaeological bone samples that are associated with the fluids and cellular matter of bone tissue (for example, Ascenzi *et al*., 1985; Cattaneo *et al*., 1992; Collins *et al*., 2002; Weser *et al*., 1996).

The gaps between the collagen fibre bundles are called 'hole zones' which act as nucleation sites for the deposition of the inorganic bone component. The exact composition of the inorganic material has been the subject of some debate. Most sources agree that it is a biogenic calcium phosphate mineral belonging to the apatite group (*q.v.*), as reported by De Jong. Mehmel (1930) suggested that the composition was closer to fluorapatite ($Ca_5(PO_4)_3F$), although more recent studies have shown that significant carbonate is usually present, with the correct composition therefore termed carbonate hydroxylapatite, $Ca_5(PO_4)_{3-x}(CO_3)_xOH_{x+1}$ (such as Reiche *et al*., 2002); this is also sometimes referred to as *dahllite*. The mineralization increases the stability of the organic components, which show different behaviour when isolated in physiological solution (Collins *et al*., 2002). The morphology of the apatite crystals present in bone has been examined using transmission electron microscopy (TEM). This technique shows that the apatite commonly occurs as irregular nanometer-sized plate-like crystals. A wide range of crystal sizes has been reported. For example, Lowenstam and Weiner (1989) give dimensions of 30–150 nm by 5–80 nm (and around 2 nm thicknesses), while smaller dimensions of 4–10 nm in length and 2–4 nm in thickness have been reported by Weiner and Traub (1992), Camacho *et al*. (1999), Reiche *et al*. (2002) and Wess *et al*. (2001). The term *collophane* is sometimes also used in the context of bone (for example, Kakoulli, 2003); collophane (or *collaphanite*) is a term usually applied to cryptocrystalline or amorphous apatite found in fossil bone or sedimentary phosphatic deposits when the type of apatite present cannot be definitely identified. Therefore the term should generally be avoided (Deer *et al*., 1992; Rutley, 1998).

When bone is burnt, the collagen component is eliminated first, resulting in the formation of a chemically homogeneous nanocrystalline apatite fraction at temperatures of the order of 500–600°C; further heating promotes the growth of the apatite crystals through the aggregation of several smaller crystals and rearrangement of the apatite lattice to form larger polygonal crystals (Person *et al*., 1996; Reiche *et al*., 2002).
See: bone, calcined and carbon-based blacks group: cokes sub-group.

Apatite group; Calcium phosphates group; Carbon-based blacks group: Cokes sub-group; Bone, calcined; Carbonate-hydroxylapatite
Ascenzi *et al*. (1985); Camacho *et al*. (1999); Cattaneo *et al*. (1992); Collins *et al*. (2002); Deer *et al*. (1992) 669; Kakoulli (2003); Lowenstam & Weiner (1989); Mehmel (1930); Person *et al*. (1996); Price (1983); Reiche *et al*. (2002); Rutley (1988) 338; Weiner & Traub (1992); Weser *et al*. (1996); Wess *et al*. (2001)

BONE ASH
White
Synonym, variant or common name

See: bone, calcined.

BONE BLACK
Black
Synonym, variant or common name

See: carbon-based blacks group: cokes sub-group and bone.

BONE BROWN
Black-Brown
Synonym, variant or common name

Derived from partially charred bones. Listed as a pigment that is obsolete or of little importance by Heaton (1928).

Bone black
Heaton (1928) 379

BONE, CALCINED
Black-White
Common generic composite

Since bone (*q.v.*) consists of inorganic and organic phases, depending on the particular conditions calcination of bone can lead to formation of brown to black pigments where the organic phase (collagen) is converted to a coke on the inorganic hydroxylapatite substrate, or a white pigment where one is primarily left with the hydroxylapatite alone (Winter, 1983). The white form will be discussed here and for the black form see: carbon-based black group: cokes sub-group.

The fifteenth century *Strasburg MS* (Clarke MS 2000) describes preparing oil for colours where white calcined bone dust and an equal amount of pumice (*q.v.*) powder ('*und leg dar in alt gebrent wis bein und ouch als vil bimses*') are added to the oil, which is then boiled. Other terms associated with this pigment indicate the source for the bone to be antlers (a form of bone, see: *antler*). This gives rise to terms such as *Hartshorn and horns of hind* (*qq.v.*).

Bone ash has been found used as a white pigment on the Armenian *Glajor Gospel book* (Orna and Mathews, 1981).

See: bone; hartshorn; carbon-based black group: cokes sub-group.

Carbon-based blacks group; Bone; Pumice; *Bone ash*; *Bone white*; *Hartshorn*; *Horns of hind*
Orna & Mathews (1981); *Strasburg MS* (15th cent/tr. Borradaile, 1966) 54; Winter (1983)

BONE WHITE
White
Synonym, variant or common name

See: bone, calcined.

BONG'S BLUE
Red-Blue
Synonym, variant or common name

Terry (1893) describes a series of blue pigments attributed to Bong. Three of these ('Bong's manganese blue') are various manganates prepared by calcining calcium carbonate or barium nitrate with manganese oxide and silica or kaolin. However, under the term 'Bong's blue', Terry also describes a highly complex series of operations to give what appears to be a series of hexacyanoferrate compounds with colours in the range of blue to purple to red. Although copper is the main additional element mentioned, seemingly variants based on zinc, mercury and silver could also be formed.

Hexacyanoferrate group; *Manganese blue*
Terry (1893) 49, 62–64

BOTALLACKITE

Green
Generic compound

Botallackite is a copper chloride hydroxide mineral with composition $Cu_2Cl(OH)_3$. Green or blue-green in colour, botallackite is named after its type locality at Botallack mine, St Just, Cornwall, England, where it was first identified by Church. It has since been identified at many mines in Cornwall and also in the Tyrol (Austria), Harz (Germany), Laurion (Attica, Greece) and Conchise County (Arizona, USA). It is commonly associated with the oxidation of copper lode deposits and related polymorphic minerals include atacamite, paratacamite and the recently assigned clinoatacamite (*qq.v.*). Of these forms, botallackite is the most rare as it is comparatively unstable.

Frondel (1950) and Gettens (1951) have both reported the presence of botallackite on bronze objects as a degradation product. In a pigment context, Wainwright *et al.* (1993) identified botallackite in eighth century Buddhist wall paintings at Dunhuang where Delbourgo (1980) reported the presence of atacamite and paratacamite. However, it is unclear whether these are the original pigments or if they are degradation products of malachite (*q.v.*). The synthetic analogue of botallackite, copper chloride hydroxide, botallackite type (*q.v.*), is also recognised in a pigment context: FitzHugh (1988) identified botallackite on a fifteenth century Persian manuscript, but the spherical, zoned form of the crystals suggests that this may be the synthetic analogue.

Copper group; Copper halides group; Atacamite; Azurite; Clinoatacamite; Copper chloride hydroxide, botallackite type; Malachite; Paratacamite
Church (1865); Delbourgo (1980); FitzHugh (1988); Frondel (1950); Gettens (1951); Wainwright *et al.* (1993)

BOTTGER'S GREEN

Green
Synonym, variant or common name

Listed by the *Colour Index* (1971; CI 77110) as a form of barium manganate (*q.v.*). Preparation is described by Bersch (1901).

Barium manganate(VI)
Bersch (1901) 271; *Colour Index* (1971) 77110

BOUGIVAL WHITE

White
Synonym, variant or common name

Bougival white, or *blanc de Bougival*, appears to be a calcareous clay. According to Tingry (1804) it was a very white marl (a clay rich in calcium carbonate), remarking that it is 'of a whiteness which assigns it a conspicuous place in the order of colouring bodies'. He also comments that it was obtained from Normandy, the Auvergne and other districts in France and that, according to his experiments, it contained nearly a third of 'carbonate of lime' which made it less useful for oil painting than Spanish and Moudon whites (*qq.v.*). Watin (1785), however, contradicts this, saying that it is a softer material than chalk, and also called *blanc d'Éspagne* (Spanish white). Finally, Bristow (1996b) suggests that it in fact came from Bougival near Paris and that it is therefore a synonym for Paris white (*q.v.*).

Calcite; Chalk; *Blanc d'Éspagne*; *Moudon white*; *Paris white*; *Spanish white*
Bristow (1996b) 6–7; Tingry (1804) 280–281; Watin (1773/edition of 1785) 20

BOYLE'S BLUE

Blue
Synonym, variant or common name

See: cornflower blue.

BRACONNOT'S GREEN

Green
Synonym, variant or common name

Terry (1893) describes a method of manufacturing emerald green (*q.v.*) according to Braconnot, calling it Braconnot's green. The process involved dissolving copper sulfate in a little hot water, then mixing with a second solution prepared from potassium carbonate and arsenious acid. An abundant precipitate of a 'dirty yellowish-green colour' was produced which, on adding acetic acid, formed a 'fine crystalline green'.

Professor Henri Braconnot (1780–1855) was a French chemist more famous for the extraction of glucose from cellulose and the discovery of a precursor form of plastic than for pigment research. However, he received a sample of pigment for analysis from a Mr Noel, the owner of a wallpaper factory in Nancy and published a paper on the preparation of copper acetate arsenite green in 1822, shortly after the German chemist Liebig (1822, 1823). For more historical information see: emerald green.

Copper acetate arsenite; *Emerald green*
Braconnot (1822); Liebig (1822); Liebig (1823); Terry (1893) 123

BRAUNITE

Black-Brown
Generic compound

Braunite is a brown-black manganese oxide mineral with formal chemical composition Mn_2O_3. Natural samples commonly contain approximately 10% silica and hence the composition may be written as Mn_7SiO_{12}. Named after K. Braun (1790–1872) from Gotha, Germany, braunite was first found at Oehrenstock, Ilmenau, Germany. It commonly occurs as submetallic octahedral crystals or as large masses of indistinguishable crystals. Braunite is usually a secondary mineral, occurring in the oxidation zones of manganese ore deposits (such as the Kalahari, South Africa; Ir-Nimi, Taikan Ridge, Russia), but may crystallise as a primary mineral in hydrothermal veins (for example, Butte, Montana, USA) or in high temperature metasomatised deposits where it is often associated with rhodochrosite. It is polymorphous with bixbyite (*q.v.*) which is the cubic form (braunite being tetragonal) and usually contains appreciable iron (Deer *et al.*, 1992; Rutley, 1988).

Little evidence exists for its use specifically as a pigment although it is related to other manganese oxides which are mentioned by the *Colour Index* (1971; CI 77727/Pigment Brown 7 and 8, and CI Natural Brown 8) as a natural and impure source of manganese dioxide.

Manganese oxides and hydroxides group; Bixbyite
Colour Index (1971) 77727; Deer *et al.* (1992) 637; Rutley (1988) 266

BRAUNSCHWEIG GREEN

Green
Synonym, variant or common name

See: brunswick green.

BRAZILEIN

Red
Generic compound

Brazilein, a neoflavanoid, is the principal colouring matter in the red dye derived from *Caesalpinia* species (*C. echinata* Lam., ‘*Brazilwood*’, and *C. sappan* L., ‘*sappan-wood*’). It develops in the rasped wood by autoxidation of a precursor, brazilin (*q.v.*; Schweppe, 1992). It is listed in the *Colour Index* as CI 75280/Natural Red 24.
See: brazilwood.

Flavonoids group; Brazilin; Brazilwood
Colour Index (1971) 75280; Schweppe (1992) 413

BRAZILIN

Red-Orange
Generic compound

Brazilin, 3,4′,5′,7-tetrahydroxy-2′,3-methelen-neoflavan, is a dye precursor found in various *Caesalpinia* species (for example, *C. echinata* Lam., ‘Brazilwood’, and *C. sappan* L., ‘*sappan-wood*’) which, through autoxidation, develops into the red dye brazilein (*q.v.*; Schweppe, 1992).

Flavonoids group; Brazilein; Brazilwood
Schweppe (1992) 412

BRAZILWOOD

Red
Generic compound

Term which encompasses a number of closely related species of hard, brown-red wood of the genus *Caesalpinia* (Leguminosae) and *Haematoxylum* from which red dyestuffs have been derived, also used widely in pigment production. The principal colouring matter in all these dye-bearing species is brazilin, which develops into the dye brazilein (*qq.v.*) through autoxidation.

Species and taxonomy cited in the literature is somewhat confused, often applied erroneously. This is not surprising given the long and widespread use of these plants as dye sources, however the currently accepted terminology appears to be, according to Nowik (2001), as follows:

Caesalpinia echinata Lam.
Caesalpinia japonica Sieb. & Zucc.
Caesalpinia sappan L.
Caesalpinia violacea (Miller) Standley
Caesalpinia brasiliensis L. (This was once considered synonymous with the above but according to Nowik is distinguishable.)
Haematoxylum brasiletto Karsten

In addition, other species are sometimes mentioned: *Caesalpinia bonduc* (L.) Roxb. which has only traces of the dyestuff and *Caesalpinia crista* L. which does not produce any. Furthermore *Peltophorum linnacei* Griseb.; *Caesalpinia coriaria* (Jacq.) Willd. also appears in the literature, though it is unclear what relationship this bears to the above; finally, Notwik notes that *C. decapelata* and *Saraca indica* are known to be sources of brazilin or haematoxylin, but are of indeterminate relevance to dye/pigment use.

Nowik has also pointed out that there are six distinct common name groups derived from their geographical sources applied to these plants: the ‘Brazilwood’ group, covering *C. violacea, C. echinata* and *C. sappan* (as well as *Haematoxylum brasiletto* Karsten, for which see: logwood); the ‘Brazil’ group, covering *C. sappan, C. violacea* and *C. japonica*; the ‘Brasiletto’ group, including *C. violacea, C. echinata* (as well as *H. brasiletto* and *Peltophorum linnacei*). Additionally, there are other related terms for dye woods, such as sappanwood (*C. sappan*) and limawood (*C. sappan* and *H. brasiletto*); campeachywood may be identified with the term logwood (*q.v.*) and the two *Haemetoxylon* species which are meant by it. It seems highly unlikely that there was much differentiation between species historically.

The early seventeenth century writer gives a typical recipe for the preparation of brazil. “Take a piece of brazil being sweet to the tongue and cleave it in to small splinters. Add enough water so that it is covered to three finger’s depth. Soak like this for one day and one night, and then boil until almost half the liquid has been spent. After cooling, throw the wood aside, keeping the liquid, into which you throw a little [measure of] gum arabic and a little *agua ardiente* [sugar cane spirit]. Let it stand thus until the gum melts, stirring it two or three times every day. When it has melted, place it on a slow fire again. When it begins to boil, add well-crushed alum a little at a time until it makes the water very vermilion. When it has turned quite crimson (testing it with the fingernail), add a little crushed pepper. When it has boiled, take it from the fire and strain it; keep it in a glass and use it’ (Nunes, 1615; Harley, 1982, gives a similar recipe from de Mayerne (BL MS Sloane 2052; Clarke MS 2790), though vinegar is included in the original boiling).

Much of the history of brazilwood must be inferred from documentary and textile sources. Suleiman mentions what may be identified as brazilwood in 851 AD as coming from Sumatra, though without giving a term for it, while Masudis refers to *bokkam* some 100 years later (cf. Ploss, 1962). It has also been suggested (on the basis of textile analysis) that supply problems occurred in the second half of the fifteenth century, when supplies from *C. sappan* may have become disrupted, but before the discoveries of alternative source species in South America (Hofenk-de Graaff and Roeloffs, 1972).

Pigment-related data shows that early forms of the term include *brexillium* (on a substrate of gypsum) and *brixillium* mentioned by Alcherius (1398–1411, Clarke MS 2790), while Merrifield (1849) also lists *brasileum* and *brasilium*, *lignum braxillii*, *verxillium* and *verzino* (these latter generally applying to *C. sappan*). In the German literature, *presilg* is used by Boltz (1549) while Ploss also lists *prisilje*, *presilje* and *persilje* as forms. Heraclius (tenth–thirteenth century AD) also mentions Brazilwood in the context of a pigment. The *Traité de mignature* (thought to be by Claude Boutet, 1674) uses the term *lacque colombine* for a brazil lake; importantly, this was translated as rose pink in the English edition in 1729, the first apparent use of the term. Dossie (1764) then describes brazil lake as ‘rose lake commonly called rose pink’. Wallert (1995c) lists the *Caesalpinia* species *C. coriaria* (Jacq.) Willd. and *C. echinata* Lam. as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) names, as derived from the sixteenth-century ‘Florentine Codex’ (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, are given as *nacazcolotl* and *vitzquavitl* respectively. Various sources also mention yellow brazilwood (for example, Mierzinski, 1881; Zerr and Rübencamp, 1906). Mierzinski describes *gelbes brasilienholz*, calling it also *gelbes fernambukholz* (‘yellow pernambuco wood’); however, it is clear that the source is in fact ‘old fustic’, *Maclura tinctoria* L. (see: fustic).

Relatively few identifications of brazilwood-based pigments have been made. It has been identified in the early fifteenth century French manuscript *Boucicaut Hours* and related MSS (Turner, 1998; Guineau *et al.*, 1998). Kirby and White (1996) note only two examples in their extensive review on red lake pigments, suggesting that the reason is the evident lack of permanence. Brazilwood lakes have also been identified among pigments used by Turner (Townsend, 1993) while the nineteenth century Dutch Hafkenscheid Collection contains a series of lakes based on brazilwood under names such as '*Florentijnsche lak*' ('Florentine lake'), *Weener of Carmosijnlak*, *Venetiaansche Kogellak* and so forth (Pey, 1989).

Brazilein; Brazilin; Logwood; *Fustic*
Boltz von Ruffach (1549/Benziger, 1913) 62–64; Boutet (1674); Cardon (2003) 218; Dossie (1764) I-68; Guineau *et al.* (1998); Harley (1982) 145; Heraclius/Romano (10–13th cent./1996) III,35; Hofenk-de Graaff & Roeloffs (1972); Kirby & White (1996); Merrifield (1849) 154; Mierzinski (1881) 174; Nowik (2001); Nunes (1615) 64ff; Pey (1989); Ploss (1962) 55; Townsend (1993); Turner (1998); Wallert (1995c); Zerr & Rübencamp (1906/1908) 445–447

BREMEN BLUE

Blue
Synonym, variant or common name

Generally considered in the historical literature to be a copper hydroxide-based pigment; Heaton (1928), for example, describes it as 'a pigment of pale greenish-blue tint, consisting chiefly of hydroxide of copper, $Cu(OH)_2$, with small quantities of carbonate of copper. It is prepared by corroding copper with a mixture of common salt and copper sulfate, to form a basic chloride of copper, which is then treated with sodium carbonate.' While authoritative sources such as the *Colour Index* (1971) have concurred with this (citing in that instance Bersch, 1901) some more recent authors (such as Scott, 2002) have, however, simply stated that Bremen blue was equivalent to blue verditer, a copper carbonate hydroxide taking the crystal structure of azurite (*qq.v.*). Without synthesis from an original recipe the point is probably difficult to resolve.

Zerr and Rübencamp (1906), however, give detailed descriptions of the manufacture of Bremen blue (while noting its decline in use over the decade preceding publication of their book, due mainly to the introduction of synthetic ultramarines). The manufacturing processes are all based on the precipitation of copper sulfate with caustic alkali to produce a copper hydroxide $Cu(OH)_2$. They note that the pigment was adulterated with gypsum, ground pumice, diatomaceous earth and other materials.

Copper group; Copper oxides and hydroxides group; Azurite; *Blue ashes*; *Blue verditer*; *Copper blue*; *Italian blue*; *Lime blue*
Bersch (1901) 226; *Colour Index* (1971); Heaton (1928) 164; Scott (2002); Zerr & Rübencamp (1906/1908) 156–162

BREMEN GREEN

Green
Synonym, variant or common name

Less frequently mentioned than Bremen blue (*q.v.*), Bremen green appears to be a greener variant of that pigment; Bersch (1901), for example, makes no direct distinction in the preparation, listing it as a copper hydroxide. Again, as with the blue, some authors, such as Terry (1893), also make a direct association with (green) verditer, a copper carbonate hydroxide. However, there is apparently a secondary association of the name with malachite (Gettens and FitzHugh, 1993b) and Bremen green has also been used to refer to forms of Scheele's and/or emerald greens (*qq.v.*), supposedly because of the place of origin (Fiedler and Bayard, 1997). Mayer (1991) associates the term (Horace) Vernet green with Bremen green.

Copper carbonate hydroxide, malachite type; Malachite; *Emerald green*; *Green verditer*; *Scheele's green*
Bersch (1901) 226; Fiedler & Bayard (1997); Gettens & FitzHugh (1993b); Mayer (1991) 46, 61; Terry (1893) 112

BRIGHTON GREEN

Green
Synonym, variant or common name

Terry (1893) provides a recipe for Brighton green: 'Dissolve separately 7 lb. sulphate of copper and 3 lb. sugar of lead, each in 5 pints of water; mix the solutions, stir in 24 lb. of whiting, and when the mass is dry grind to powder.' The precise composition of the resulting pigment is unknown.

Terry (1893) 112–113

BRILLIANT SCARLET

Red
Synonym, variant or common name

Heaton (1928) lists this as a term for iodine scarlet (mercury iodide; *q.v.*), indicating that it was either obsolete or of little importance as a pigment at that time.

Mercury iodide
Heaton (1928) 380

BRILLIANT ULTRAMARINE

Blue
Synonym, variant or common name

According to Salter (1869), brilliant ultramarine was a variety of synthetic ultramarine (*q.v.*) prepared by Guimet's process, and was superior to the ordinary French ultramarine. He also noted that brilliant ultramarine was 'lately called factitious ultramarine'.

Ultramarine; *French ultramarine*
Salter (1869) 215

BRILLIANT YELLOW

Yellow
Synonym, variant or common name

See: jaune brilliant.

BRISTOL RED

Red-Brown
Synonym, variant or common name

Bristow (1996b) lists a 'common brown oker', synonymous with 'Bristol oker' made in the early nineteenth century. Fishwick (1795–1816) gives a recipe for 'Common red paint' that uses Bristol red: '4 stone Bristol red, 2 stone best venetian red, 2 Do. French white, 4 galls. Foots fine oil, sift the colours fine and mix 7 levigate.'

Ochre
Bristow (1996b); Fishwick (1795–1816) 13

BRIXEN GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

BROCHANTITE

Green
Generic compound

Brochantite is a green copper sulfate hydroxide mineral, with chemical formula $Cu_4SO_4(OH)_6$. It is a secondary mineral found in the rapid weathering zones of copper lode deposits, particularly in arid climates. Brochantite was described by Levy from Mines Bank, Ural Mountains, Russia and is named after the French geologist A.J.M. Brochant de Villiers (1772–1840). It commonly occurs as tiny vitreous, acicular green crystals or as fibrous masses which vary in shade from emerald green to greenish black. Brochantite is a relatively common mineral found at copper deposits worldwide such as in Cornwall and Derbyshire (England), Touissit (Morocco), Tsumeb (Namibia), Broken Hill (New South Wales, Australia) and Chuquicamata (Chile). It is often found in association with atacamite, antlerite and malachite, as well as chalcanthite, posnjakite and langite (*qq.v.*) to which it is closely related chemically. It was also known as blanchardite.

Brochantite has been identified in green pigments from a set of late seventeenth century Tibetan *thangkas* by Duffy and Elgar (1995); they state that it was probably associated with the malachite that was the primary pigment and was likely to have come from mines at Snye-mo-thang in Gtsang, Tibet. Richter (1988) reports an occurrence in a Norwegian church dated to 1300. It is also listed by Price *et al.* (1998) as occurring on paintings by Vincenzo Foppa (1427/30–1515/16). Synthetic brochantite has been discussed by Martin and Eveno (1992) in the context of pre-eighteenth century western easel painting and analysis of a collection of nineteenth century German pigments revealed a sample which was considered to be the synthetic form (Richter and Härlin, 1974a). Scott (2002) remarks that a recipe for making Peligot blue (*q.v.*) may well produce (synthetic) brochantite.

Copper sulfates group; Antlerite; Atacamite; Chalcanthite; Langite; Malachite; Peligot blue; Posnjakite
Duffy & Elgar (1995); Martin & Eveno (1992); Martin *et al.* (1995); Price *et al.* (1998); Richter (1988); Richter & Härlin (1974a); Scott (2002) 166

BROMOINDIGO

Purple
Generic compound

See: indigoid group and tyrian purple.

BRONZE BLUE

Blue
Synonym, variant or common name

According to Mierzinski (1881), C. Conradty discovered bronze blue by mixing white bronze (made with pure English tin) with aniline blue (*Bayerishces Industrie- und Gewerbeblatt* 1870, 367). Furthermore he describes how to make a sky blue bronze from 50 g tin, 1.5 g antimony and 0.1 g copper; grind it and leave it in hydrogen sulfide for 10 to 12 hours, remove the hydrogen sulfide, leave it to dry and then heat in double boiler until the blue colour appears. Rose (1916) describes two forms of bronze blue. The first is a mixture of 100 parts tin, 3 parts antimony and 1/6 part copper, which he states was invented in 1861 by Beckmann in Nuremberg; the second is compound for which Rose gives the formula $Na_2W_5O_{15}$. Zerr and Rübencamp (1906) associate bronze blue with Prussian blue (*q.v.*), suggesting that it be applied to those products exhibiting a metallic sheen, 'steel blue' to those which do not. Prussian blue is noted for the effect known as 'bronzing', a metallic cast which appears on the surface of particularly pure and densely applied samples of the pigment.

Hexacyanoferrate group; *Prussian blue*
Mierzinski (1881) 112–113; Rose (1916) 352, 378; Zerr & Rübencamp (1906/1908) 173

BRONZE COLOURS

Variable
Synonym, variant or common name

So-called 'bronze' colours, produced by tarnishing metal powders, have an interesting but little-known history. Starting out in southern Germany this technique reached France and England in the middle of the nineteenth century. The development of these pigments is attributed to Martin Holzinger at the beginning of the eighteenth century (Rose, 1916). However, the use of bronze colours increased widely only when almost the full range of colours had been achieved. According to Mierzinski (1881) the production of bronze colours was a special trade in Bavaria (Nuremberg, Münich and Fürth). There since 1750, waste metal (or alloy) from beaten metal production had been ground and sold as metal powder; this material was also used for the production of bronze colours. The production of bronze colours extended to Westphalia and France as well as England; Rose (1916), for example, states that in 1843 bronze colour factories were opened in London and Paris by German workers from Fürth. Due to the increased demand, not only was metal waste used but the necessary metal flakes were also produced specially. (We should also note that the 'bronze' used for this process was in fact a brass, composed of copper and zinc.)

Rose further describes how the pigments were produced at that time. The metal waste or leaves were forced through iron wire sieves. The bigger pieces were sold as brocade in different grades. For the grinding process, hot grease or oil was added; coarse bronze powders needed to be ground for 1½ hours, while the finest needed more than 4 hours. Finally the grease was removed with petrol on filter paper. The colouring of the powder was achieved by creating a tarnish through heating. Slightly above 100°C, the golden colour would change to lemon yellow, orange, then to brownish yellow, to a flesh colour, to purple, to carmine violet, bluish green, greyish violet and steel grey; the colour blue could not be achieved though, because the blue tarnish changed to green too fast and the tarnishing process could not be stopped quickly enough. In order to achieve an even temperature 0.5% paraffin in wax was added and the whole mixture was stirred constantly during the heating process. In Rose's time the grease-free bronze powder was coloured in shallow plates with boiling saline solutions or oils, or on metal plates that were heated from below. Rapid cooling was then used to halt the tarnishing process. A solution of glue or gum, dammar or copal lacquer, linseed oil or egg white would be used as binding medium. Bronze colours were especially used for wall paintings, shield painting, wallpaper painting and the printing of books. However, bronze colours were not very durable.

The literature also shows that bronze pigments should not be confused with pigments used to produce a bronze colour. Beside the pigments made of 'bronze', there are other pigments that carry the word 'bronze' in their name but are produced in other ways, such as bronze blue (*q.v.*). Mierzinski (1881), for example, describes preparing a bronze-coloured pigment by mixing '100 parts of zinc vitriol with 3 parts of nitric nickel oxide nitric cobalt oxide and 1–1½ parts of nitric copper oxide'.

Duncan *et al*. (1990) have noted the use of brass powders as metallic pigments on Japanese artefacts. Metallic bronze of a grey colour has recently been found on three paintings of Perugino, one from the National Gallery, London and two in Florence; elemental analysis showed this alloy to contain a ratio of tin to copper of 1:2 which in dry ground powder form appears grey.

Metal pigments group; *Bronze blue*
Duncan *et al*. (1990); Mierzinski (1881) 113; Rose (1916) 124–126

BRONZE GREEN

Green
Synonym, variant or common name

Salter (1869) provides an early reference to bronze (green), stating that 'Bronze is a species of Prussian green, of a dull blue-black hue. In its deep washes it appears a greenish-black with a coppery cast.' According to Mierzinski (1881), bronze green can be achieved by mixing 100 parts of chrome yellow, 100 parts of zinc white, 6 parts of Berlin blue and 6 parts of black. Linke and Adam (1913) list the name bronze green as a trade name for cinnabar green or chrome green. Rose (1916) uses the name bronze green for various cheaply made greens mixed with ochre, coal, Berlin blue or ultramarine as well as for a mixture of chrome yellow, Paris blue and coal black (*qq.v.*). According to Heaton (1928) this was at that time a current synonym for a 'variety of Brunswick green' (*q.v.*). Bronze green also occurs as a watercolour name employed by the English colourmen Winsor & Newton in 1938, where it was apparently a 'mixed chrome green'. See: chrome green.

Coal; Ochre; Ultramarine; *Berlin blue*; *Brunswick green*; *Chrome green*; *Chrome yellow*; *Green cinnabar*; *Prussian blue*
Heaton (1928) 380; Linke & Adam (1913) 70; Mierzinski (1881) 120; Rose (1916) 220, 349; Salter (1869) 79

BROOKITE

Brown
Generic compound

Brookite is a brown or reddish black titanium(IV) oxide mineral with composition TiO_2. It is the orthorhombic polymorph of anatase and rutile (*qq.v.*), to which it may invert. Named after the English mineralogist H.J. Brook (1771–1857), brookite occurs as thin bladed or platy crystals, usually as the alteration product of other Ti-bearing minerals (such as at Prentag, Gwynned, Wales). It may also occur as an accessory mineral in rocks altered by metamorphism (for example, at Magnet Cove, Arkansas, USA). It is a relatively common mineral found at locations worldwide, for example, at Salzburg (Austria), Quebec (Canada), Saxony (Germany), Attice (Greece), Tuscany (Italy), Oppland (Norway) and Siberia (Russia).

Occurrence in a pigment context is currently unknown although the synthetic analogue may be produced during synthesis and treatment of the more common titanium(IV) oxides used as pigments. Its commonality may also mean that it is found as an associated mineral.

Titanium group; Titanium oxides and hydroxides group; Anatase; Rutile
Deer *et al*. (1992) 554–555; Rutley (1988) 272

BROWN HEMATITE

Yellow-Brown
Synonym, variant or common name

See: limonite.

BROWN LAMPBLACK

Brown
Synonym, variant or common name

Synonym for bistre (Mayer, 1991).

Bistre
Mayer (1991) 40

BROWN MADDER

Brown
Synonym, variant or common name

According to Field (1835), this is a gently calcined madder lake (*q.v.*). Heaton (1928) also lists the term a century later as a current synonym for a brown lake prepared from madder root.

Madder; *Intense brown*
Field (1835); Heaton (1928) 380

BROWN OCHRE

Brown
Synonym, variant or common name

Salter (1869) states that brown ochre was 'known as Spruce Ochre and *Ocre de Rue*, or, more correctly *Ru*'.

Earth pigments group; Ochre; *Ocre de rue*
Salter (1869) 108

BROWN PINK

Yellow-Brown
Synonym, variant or common name

Salter (1869) describes this as follows: 'brown pink, brown *Stil de Grain*, citrine lake, or quercitron lake is usually prepared from the berries of Avignon (ramnus infectorius), better known as French, Persian, or Turkey berries; but a more durable and quicker drying species is obtained from the quercitron bark … In either case it is a lake, precipitated from the alkaline decoction by means of alum, in such proportions that the alkali shall not be more than half saturated. The excess of soda or potash employed imparts a brown hue.' Tingry (1804) describes a brown Dutch pink (*q.v.*) which has intense colour due to the use of pure clay as substrate. Heaton (1928) also lists brown pink, although as a pigment that is obsolete or of little importance at that time.

Quercitron; Rhamnus; *Brown Stil de Grain*; *Citrine Lake*; *Pink*
Heaton (1928) 380; Salter (1869) 312–313; Tingry (1804) 365

BROWN RED

Red
Synonym, variant or common name

Harley (1982) mentions brown red and English red as terms associated with the term light red (*q.v.*), although the exact composition is uncertain.

Light red
Harley (1982) 120

BROWN STIL DE GRAIN

Yellow-Brown
Synonym, variant or common name

Osborn (1845) states that 'Brown (or English) Stil de grain is prepared with a calcareous or marly earth, alum, and a decoction of Avignon berries.'
See: stil de Grain and brown pink.

Rhamnus; *Brown pink*; *Stil de Grain*
Osborn (1845)

BRUCITE

White
Generic compound

Brucite is a white magnesium hydroxide mineral of composition $Mg(OH)_2$. Although brucite crystallises as broad, tabular crystals, it is most commonly found as masses of silky elastic fibres (known as nemalite) or foliaceous laminae. Named after the American mineralogist A. Bruce (1777–1818), it may vary in colour to pale green, brown, blue or grey due to the presence of impurities, and readily alters to hydromagnesite (*q.v.*). Brucite is common worldwide and occurs in certain metamorphosed impure limestones and dolomites (such as at Crestmore, California; Tyrol, Austria; Skye and Assynt, Scotland) usually as an alteration product of periclase (*q.v.*). It is also found in low temperature hydrothermal veins (for example, Unst, Shetland, Scotland) associated with serpentine or chlorite- (*qq.v.*) bearing metamorphic rocks (Rutley, 1988).

Brucite has been identified by Newton and Sharp (1987) in certain plasters, introduced with the dolomite (*q.v.*) used.

Chlorite group; Magnesium group; Magnesium oxides and hydroxides group; Serpentine group; Dolomite; Hydromagnesite; Periclase
Newton & Sharp (1987); Rutley (1988) 274–275

BRUNSWICK BLUE

Blue
Synonym, variant or common name

The term is generally used to refer to Prussian blue precipitated onto a barium sulfate, baryte (*qq.v.*) or similar base. Davidson (1880) says of Brunswick, Celestial and damp blues: 'Brunswick or Celestial Blue is made by precipitating the alumine from a solution of alum by carbonate of soda, washing the precipitate, and adding sulphate of baryta, sulphate of iron, yellow prussiate of potash, and some bichromate of potash. When dried, this mixture is known as Brunswick or celestial blue; but when the sulphate of baryta is left out, and the material is not dried, it is called damp blue.' Heaton (1928) lists Brunswick blue as a current synonym, a 'reduced Prussian blue'. Mayer (1991) also indicates that it may contain some ultramarine blue (*q.v.*).

Hexacyanoferrate group; Barium sulfate; Baryte; Ultramarine; *Prussian blue*
Davidson (1880) 83; Heaton (1928) 380; Mayer (1991) 40

BRUNSWICK GREEN

Green
Synonym, variant or common name

Brunswick green is named after the town of Braunschweig ('Brunswick') where it was first prepared by the Gravenhorst brothers, Johann Heinrich (1719–81) and Christoph Julius (1731–84). Both men were born and died in Braunschweig and Johann Heinrich apparently tried several vocations before settling, in 1759, on founding a chemical factory in that city. They were the first to make sal ammoniac (ammonium chloride) and Glauber salts in Germany and, according to Krünitz' *Oekonomisch-Technologische Encyklopädie* (1789), the Gravenhorsts discovered this pigment in 1764, publishing information about it in 1767 after production had commenced at their factory. It was originally made by covering copper filings with a solution of sal ammoniac and leaving the mixture in a closed container; the solid was then washed and dried. This original recipe has been reconstructed by Scott (2002), who found that it produced the copper chloride hydroxide atacamite (*q.v.*; $Cu_2(OH)_3Cl$), though Scott also speculates that it might produce an ammonium copper chloride. However, Krünitz also states that there were two sorts of Brunswick green, the 'ordinary' type and a purified variety; the purified form is said to be similar to so-called distilled verdigris (*q.v.*), being also produced and sold as a dry or liquid substance by the Gravenhorst factory.

While consistently described as a copper-based pigment in the earlier history of the use of the term, Brunswick green appears to have had numerous formulations within that. Apart from the copper/ammonium chloride recipe given above, it is also described in late eighteenth century sources as a combination of copper and tartar ('cuprous tartar' is mentioned in the *Practical Treatise* of 1795, as well as de Massoul (1797); this presumably forms a copper tartrate); it was then described as a copper and arsenic based pigment (Mérimée, 1830), and a mixture of lead, barium or bismuth chromates and Prussian blue (*q.v.*; Salter, 1869). Mierzinski (1881) describes Braunschweig green – with neuwied, Kaiser, Berg, copper and mountain greens – as a copper acetate arsenite (that is, emerald green (*q.v.*)) lime green that contains calcium or barium sulfate. Terry (1893) says that it was 'essentially consisting of a basic chloride or oxychloride of copper', providing some seven distinct recipes to produce this; he then proceeds to describe 'modern' Brunswick greens 'which are made in a variety of shades, and sometimes known as chrome greens, Prussian greens, Victoria greens, and by other fancy names, really consist of a white pigment as a basis – usually sulphate of baryta (barytes), but occassionally also sulphate of lime (gypsum) and sulphate of lead – coloured green of varying intensity and depth by addition of a blue pigment in the shape of Prussian blue, and a yellow in the guise of chrome-yellow'. In 1906 Zerr and Rübencamp state that the term Brunswick green 'is at present applied to … Bremen blue' (*q.v.*), further noting that it was also 'wrongly applied' to emerald green; they then proceed to give a recipe using copper sulfate, tartaric acid and arsenic. These authors also state that a mixture of copper arsenite, copper hydroxide and calcium sulfate was called by this name. Heaton (1928) describes it as a 'reduced chrome green made with chrome yellow and Prussian blue, struck on a large proportion of barytes'; he further uses the plural ('Brunswick greens'), implying that various grades existed.

The plethora of meanings for Brunswick green suggests that it became, rather than a specific pigment, a colour term. Comparable shades produced using different formulations would then be marketed under the same title. Other terms include *Braunschweiger* (or *Braunschweigisches*) *grün*.

Chromates group; Copper arsenite group; Atacamite; Barium chromate(VI); Baryte; Bismuth chromate; Copper tartrate; Lead chromate; *Acetate green*; *Bremen blue*; *Chrome yellow*; *Green cinnabar*; *Green verditer*; *Prussian blue*
Heaton (1928) 380; Krünitz (1789) v. 20, 201; Massoul (1797); Mérimée (1830/trans. Taylor, 1839) 179; Mierzinski (1881); *Practical Treatise* (1795); Salter (1869) 271, 279; Scott (2002) 306; Terry (1893) 113–118; Zerr & Rübencamp (1906/1908) 219

BRUNUS

Red-Brown
Synonym, variant or common name

The *Tabula de vocabulis sinonimis* of Le Begue (1431; Clarke MS 2790; cf. Merrifield, 1849) states that '*Brunus est color quem puto esse bularminium alibi ponitur pro sanguine drachonis qui quasi coloris bularminici est*' ('Brunus is the colour which I think is bulmarinum, elsewhere taken for the blood of a dragon which is like the bulmarinum in colour'); Merrifield (1849) considered that this was 'Probably *Bruno di Spagna*, which Haydocke … identifies with Majolica, and which there is no reason to doubt is the soft red haematite, called also *Bruno d'Inhilterra*'. Thompson (1935) suggests that *brunum* was possibly bole (*q.v.*) used as a pigment, noting that he found the term in a fourteenth century MS. related to the so-called *De coloribus et mixtionibus.* Brunello (1973), discussing brunus, says that the mediaeval texts normally imply it was a variety of brown ochre rich in iron oxides and manganese, corresponding to the types currently called umber and sienna; he adds that it could have been synonymous with bole and might also have resembled *sinopis*.

Also related to the terms *cicerculum* and *lapsis fissus.*

Sienna; Umber; *Bole*; *Cicerculum*; *Lapis fissus*; *Sinopis*
Brunello (1973) 209; Clarke (2001) 2790; Merrifield (1849) 20 + n.3; Thompson (1935) 418, n.4

BUCKTHORN
Yellow
Synonym, variant or common name

Common English name for several species of *Rhamnus* and *Frangula* the berries of which produce both a yellow and a green flavonoid dyestuff. *R catharticus* L., found in southern Europe, North Africa and Asia; *R. alaternus* L., in southern Europe; and additionally *Frangula alnus* Miller (formerly *Rhamnus frangula* L.), in North Africa, North-west Asia and all of Europe except the Mediterranean. The latter is commonly known as Alder buckthorn. Other dye producing *Rhamnus* species are found in other parts of Europe.

The popularity of this lake pigment and its wide geographical production has meant that the pigment has been referred to by numerous terms, many of which relate to the place of origin. Buckthorn, being the English term, could also therefore be related to English berries and yellow berries. It is noteworthy, however, that the berries were more commonly called French, Avignon, or Persian berries in English, for example, Dossie describes pinks made with French berries.

For a fuller discussion of the plant species involved, constituent compounds, substrates and alternative terminology see the entry for *Rhamnus*.

Flavonoids group; Rhamnus; *Yellow berries, English pink, English berries*
Cardon (2003) 88–91; Dossie (1674) 100–102

BURGUNDY VIOLET
Purple
Synonym, variant or common name

Mayer (1991) gives this as a synonym for manganese violet (*q.v.*), a term itself somewhat confused in meaning.

Manganese violet
Mayer (1991) 40

BURNT CARMINE
Purple
Synonym, variant or common name

As a gently roasted form of carmine lake (*q.v.*), this could therefore be a modified version of various lakes such as those based on cochineal, kermes or madder as well as the synthetic alizarin. Salter (1869) is more specific though, reporting it to be 'the carmine of cochineal partially charred till it resembles in colour the purple of gold… It is a magnificent reddish purple of extreme richness and depth'. Osborn (1845) describes the colour as purple-violet. Listed as late as Heaton (1928), though as a pigment that is obsolete or of little importance.

Alizarin; Cochineal; Kermes; Madder; *Carmine lake*
Heaton (1928) 380; Osborn (1845) 21; Salter (1869) 298

BURNT GREEN EARTH
Brown
Synonym, variant or common name

See: green earth, burnt.

BURNT LAKE
Brown
Synonym, variant or common name

Calcined lake pigment. Salter (1869), for example, specifies crimson lake as the starting point.

Salter (1869) 298

BURNT MADDER
Purple
Synonym, variant or common name

Listed by Salter (1869) it is, unsurprisingly, 'obtained by carefully charring madder carmine until it becomes of the hue required'. Salter also considered it expensive and therefore commercially unknown. Field (1835) mentions madder brown, synonymous with Field's russet which may have been a gently calcined madder lake (*qq.v.*).

Madder; *Field's russet*; *Madder carmine*
Field (1835) 146; Salter (1869) 305

BURNT OCHRE
Red-Brown
Synonym, variant or common name

The phenomena that yellow ochre when heated converts to red ochre has been known since the Palaeolithic (see Pomiès *et al.*, 1999) which not only makes it the first synthetic pigment but also the earliest form of pyrotechnology, using fire to alter the chemistry of a naturally occurring material. The processes of producing burnt ochres were described in detail by the fourth century BC philosopher Theophrastus. Vitruvius (first century BC) later wrote that yellow ochre was burnt (*usta*) to produce a purple colour. Various degrees of heat will produce a series of shades from brown through red and violet. The process in action is the thermal transformation of goethite (*q.v.*; α-FeOOH) to iron(III) oxide (α-Fe_2O_3), whereby the goethite begins to dehydrate at temperatures of 230–280°C, maintained for 1 hour in air. Temperatures of c. 300°C should ideally be attained to dehydrate all particles thoroughly. The resulting product is iron(III) oxide but with a disordered crystal structure which makes it crystallographically distinct from naturally occurring α-Fe_2O_3, hematite (*q.v.*). Heating to temperatures exceeding 900°C results in an ordered hematite structure. It is unlikely that temperatures of 800–900°C were attained in pre-industrial ochre burning. Consequently it can be said that the disordered hematite structure is characteristic of burnt yellow ochres and distinct from hematite in natural red ochres (see Brindley and Brown, 1980; Helwig, 1997). It should be noted here that lepidocrocite (*q.v.*; γ-FeOOH), another component of some natural yellow ochres, will undergo transformation at similar temperatures to produce γ-Fe_2O_3 which transforms to ordered hematite at much lower temperatures, 400–500°C

(Brindley and Brown, 1980). However, lepidocrocite is a minor constituent of yellow ochres, when it occurs at all.

Helwig (1997) has reviewed sixteenth to eighteenth century references to burning ochre in various treatises and artist's handbooks and the technique continues in pigment preparation to this day. She performed experiments characterising the thermal transformation undergone by goethite during heating.

Béarat and Pradell (1997) have detected red ochre pigments with disordered hematite in Roman wall paintings. Burnt ochres have not been easily detected due to their similarity to red ochres. It is hoped, following Helwig's work, that more identifications will be forthcoming.

A wide variety of terms have been applied to burnt ochres, many of which were applied to red ochres before their sources were exhausted or became unavailable. Terms applied to the manufacture of iron oxide reds via the copperas (*q.v.*) process are also indiscriminately used, however, the most commonly used name is simply light red, which appeared in the eighteenth century. Harley (1982) suggests that many artists manufactured their own burnt ochre, which probably accounts for the paucity of manufacturer's names. Field (1835) and Heaton (1928) say light red is 'an ochre of orange russet hue', made by calcining Oxford ochre (*q.v.*). Weber (1923) also gives the pigment the name light red, but also lists synonyms *brun rouge*, *bruno rosso*, burnt ochre and burnt Roman ochre.

The technology and methods are identical to those used in the production of burnt siennas and burnt umbers (*qq.v.*), the iron oxide hydroxide to iron(III) oxide thermal transformation is the dominant colour-changing reaction.

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type; Lepidocrocite; Ochre; Oxford ochre; Sienna; *Burnt sienna*; *Light red*; *Red ochre*; *Yellow ochre*

Béarat & Pradell (1997); Brindley & Brown (1980); Field (1835) 110; Harley (1982) 120; Heaton (1928) 116; Helwig (1997); Pomiès *et al.* (1999); Theophrastus (c. 315 BC/Caley & Richards, 1956) 50–60; Vitruvius (1st cent BC/Grainger, 1934) VII.xi.2; Weber (1923) 92–95.

BURNT ORPIMENT

Red-Orange

Synonym, variant or common name

General term applied to synthetic realgar produced from heating orpiment (FitzHugh, 1997).

Orpiment; Realgar

FitzHugh (1997)

BURNT ROMAN VITRIOL

Red

Synonym, variant or common name

See: pabonazo.

BURNT SIENNA

Brown

Synonym, variant or common name

Burnt sienna is the calcined, oxidised equivalent of the naturally occurring earth pigment (raw) sienna (*q.v.*). The pigment, as Church (1901) writes, 'has a beautiful, warm reddish hue'. Heaton (1928) adds that it is a 'very transparent pigment with excellent colour'.

Burnt sienna has been identified by Bikiaris *et al.* (1999) on Greek Byzantine wall paintings and by Townsend (1996) on drawings by Turner.

Harley (1982) writes that the pigment was called *Terra di Siena* whether burnt or unburnt until the nineteenth century when the anglicised versions appeared and raw sienna and burnt sienna came into routine use. Church also lists various literal translations of the term sienna earth: *Terre de Sienne*, *Sienaerde*, *Terra di Siena*. Toch (1916) records a variety he calls 'American' burnt sienna as well as 'Italian'; while both are calcined raw siennas sourced from the respective countries, the principal difference appeared to manifest itself in a subtle variation of the colour; when reduced with white, the Italian gave a bluish shade, whilst the American had a brownish or yellowish tint.

Earth pigments group; Iron oxides and hydroxides group; Manganese oxides and hydroxides group; Ochre; Sienna; Umber; Wad; *Yellow ochre*

Bikiaris *et al.* (1999); Church (1901) 231; Harley (1982) 90; Heaton (1928) 118; Toch (1916) 71–72; Townsend (1996)

BURNT UMBER

Brown

Synonym, variant or common name

Roasting raw umber (*q.v.*) in an oxidising environment causes dehydration of the iron hydroxides, converting them into iron oxides and yields a pigment with a 'warm reddish brown hue' (Weber, 1923) while retaining raw umber's abilities as a drier.

Harley (1982) found that distinctions between raw and burnt umber were largely ignored in sixteenth and seventeenth century English documentary sources, suggesting that burnt umber was often meant where 'umber' was listed unqualified (arguing that it was the more widely used form). Norgate in his *More Compendious Discourse* (1648–50) describes umber as 'being A fowle and gressie Coullerr, iff when you haue bought itt you burne itt in A Crusible or Goldsmiths pott, itt is Clensed'.

According to Rivington's *Notes on Building Construction* (1901), it is perfect when mixed with white lead for making a 'stone' colour.

See: umber.

Umber; *Mineral brown*

Harley (1982) 90; Norgate/Thornton & Cain (early 17th C./1981); Rivington (1901); Weber (1923)

BURNT VERDIGRIS

Green

Synonym, variant or common name

Calcined verdigris (*q.v.*). Salter (1869) calls it 'an olive-coloured oxide of copper deprived of acid'. Tingry (1804) comments, however, that he is 'confounded by the term calcined' or burnt, as 'calcination would revive the copper'.

Verdigris

Salter (1869) 331; Tingry (1804) 374

BURNT VITRIOL

Red-Purple

Synonym, variant or common name

Essentially a synthetic reddish purple or violet pigment derived calcined iron sulfate. For a fuller discussion see: *Caput mortuum*.

This term has been found in use by the end of the sixteenth century, such as in the translation of Lomazzo by Haydocke (cf. Bristow, 1996b) and in Borghini (cf. Merrifield, 1849). Pozzo (1642–1709, cf. Merrifield, 1846) referred to this pigment as burnt Roman vitriol (*q.v.*).

Iron oxides and hydroxides group; *Burnt Roman vitriol*; *Caput mortuum*

Bristow (1996b) 46; Merrifield (1846) 58; Merrifield (1849) ccxxxviii

BURTON'S COBALT

Black
Synonym, variant or common name

See: cobalt black.

BUTTER OF ANTIMONY

White
Synonym, variant or common name

Historical synonym for antimony(III) chloride (*q.v.*; *Merck Index*, 1996).

Antimony group; Antimony(III) chloride
Merck Index (1996) 748

BUTTERCUP YELLOW

Yellow
Synonym, variant or common name

Listed by Riffault *et al.* (1874) as a synonym for zinc yellow (*q.v.*) and still commonly listed as such.

Zinc chromates group
Riffault *et al.* (1874) 387

BYTOWNITE

White
Generic compound

Bytownite is a member of the feldspar group (*q.v.*) of minerals with a composition between that of albite and anorthite (*qq.v.*). It is thus a calcium sodium alumino-silicate mineral, with composition $(Ca_{0.7-0.9}Na_{0.3-0.1})(Al,Si)_4O_8$. It is therefore comprised of 70–90% anorthite and 10–30% albite (Fleet *et al.*, 1966). Its colour is usually white, grey or colourless but can be pale shades of other colours due to the presence of impurities. There are notable occurrences of bytownite in Ottawa (formerly Bytown, after which the mineral is named), Canada, Isle of Skye, Scotland and the Limpopo Belt, South Africa.

Bytownite is a member of the plagioclase feldspar series. These minerals readily degrade to clay group minerals (*q.v.*) and zeolites in the presence of water and may occur as relict minerals in artists' materials.

Clay minerals group; Feldspar group; Silicates group; Albite; Anorthite
Fleet *et al.* (1966)

BYZANTIUM PURPLE

Purple
Synonym, variant or common name

Mayer (1991) lists this as a synonym for Tyrian purple (*q.v.*).

Tyrian purple
Mayer (1991) 40

C

CADIE GUM

Yellow
Synonym, variant or common name

Synonym for gamboge (*q.v.*; Winter, 1997).

Gamboge
Winter (1997)

CADMIA

Yellow
Synonym, variant or common name

According to Fiedler and Bayard (1986), cadmia was a term used for cadmium yellow (*q.v.*). However, cadmia (as *cadmia fornacea* or *c. fornacum*) was actually an older name for the common zinc ore calamine, though it was also applied to a sublimed zinc oxide and to a cobalt ore. The element now called cadmium is often found associated with zinc (Agricola, 1556).

Cadmium group; Cadmium sulphides and selenides group; *Cadmium yellow*
Agricola (1556/trans. Hoover & Hoover, 1950); Fiedler & Bayard (1986)

CADMIUM BROWN

Brown
Synonym, variant or common name

Salter (1869) details cadmium brown which was apparently prepared 'By igniting the white carbonate of cadmium'; this gave 'a cinnamon-brown oxide … of a very clear and beautiful colour'. It was quite unstable, rapidly reverting to white cadmium oxide.

Cadmium oxides and hydroxides group
Salter (1869) 353–354

CADMIUM CARBONATE

White
Generic compound

As noted by Fiedler and Bayard (1986), cadmium carbonate is used as a starting material in the manufacture of cadmium sulfide pigments using the 'dry process' in which it is heated with sulfur in the absence of air at 300–600°C. Early pigments which contained excess cadmium carbonate were reported to fade on exposure to light and air. The compound was also added as an adulterant to cadmium sulfide pigments, and as a lightening agent, although this again affected the stability of the pigment.

The extremely rare mineral otavite is cadmium carbonate, coming from the famous mines of Tsumeb, Otavi (hence the name), Namibia. It is one of only a few cadmium minerals as cadmium is usually a trace element in other minerals.

Salter (1869) details cadmium brown which was apparently prepared 'By igniting the white carbonate of cadmium'; this gave 'a cinnamon-brown oxide … of a very clear and beautiful colour'. It was apparently quite unstable, said to rapidly revert to white cadmium oxide.

Cadmium group; *Cadmium white*
Fiedler & Bayard (1986); Salter (1869) 353–354

CADMIUM CHROMATE

Yellow
Generic compound

Two forms of cadmium chromate are described in the literature. The first, $CdCrO_4$, is thought to be that enthusiastically described by Salter as Thwaites yellow (*q.v.*) in his 1869 edition of Field's *Chromatography* (though Carlyle, in her survey of English nineteenth century documentary sources found little other mention of it). It is mentioned in later sources such as Eibner (1909) and Bersch (1901), the latter describing its production by the precipitation of a cadmium salt with potassium chromate.

The second form of cadmium chromate is basic cadmium chromate, $Cd(OH)_2CrO_4$, described by Kühn and Curran (1986) as a rare and expensive yellow pigment, synthesised by the same route as given by Bersch. Basic cadmium chromate is listed by the *Colour Index* (1971) as Pigment Yellow 44 and Thwaites yellow (CI 77188). However, it would appear that no scientific analysis currently exists to show whether or not the historical material was in fact of this latter type.

Cadmium group; Chromates group; *Thwaites yellow*
Bersch (1901); Carlyle (2001) 260, 525; *Colour Index* (1971) 77188; Eibner (1909) 165; Kühn & Curran (1986); Salter (1869) 122

CADMIUM CINNABAR

Red
Synonym, variant or common name

Common name for cadmium mercury sulfide (*q.v.*).

Cadmium mercury sulfide

CADMIUM GREEN

Green
Synonym, variant or common name

According to Heaton (1928) this was a then current term for a composite pigment based on a cadmium yellow with viridian (*qq.v.*). Several subsequent authors such as Kittel (1953) repeat this.

Cadmium group; Chromium group; Cadmium sulfide; Chromium oxide hydrate; *Cadmium yellow*; *Viridian*
Heaton (1928) 380; Kittel (1953)

CADMIUM GROUP

Variable
Group term

The following cadmium-based compounds are known as pigments (or are closely associated with forms used as pigments):

Carbonates: cadmium carbonate.
Sulfides and Selenides: cadmium sulfide, amorphous type; cadmium sulfide, greenockite type and greenockite; cadmium sulfide, hawleyite type and hawleyite; cadmium selenide; the tertiary sulfides cadmium mercury sulfide, cadmium selenium sulfide and cadmium zinc sulfide.

Additionally, two cadmium chromates are known (classed with chromate pigments) along with a cadmium tungstate (classed with tungsten pigments). 'Lithopone' forms – that is, pigments co-precipitated with barium sulfate (*q.v.*) – of the cadmium sulfides are also extant. The composition of 'cadmium white' mentioned in later nineteenth century literature is not well known; Salter (1869) describes it as a hydrated oxide or carbonate of cadmium.

Cadmium sulfides and selenides group; Chromates group; Tungsten group; Barium sulfate; Cadmium mercury sulfide; Cadmium selenide; Cadmium sulfide, amorphous type; Cadmium sulfide, greenockite type; Cadmium sulfide, hawleyite type; Cadmium zinc sulfide; Greenockite; Hawleyite; *Cadmium white*
Salter (1869) 78

CADMIUM LITHOPONE

Yellow-Orange
Synonym, variant or common name

See: cadmium sulfide lithopone.

CADMIUM MERCURY SULFIDE

Red-Orange
Generic compound

Solid solutions can be produced to form a cadmium-mercury sulfide series (Cd,Hg)S. According to Fiedler and Bayard (1986, citing Huckle *et al.*, 1966, and Moore, 1973), they are produced by initially co-precipitating cadmium and mercury sulfides in solution. The precipitate is then calcined in an inert atmosphere, a process that converts the cubic crystal structure to a hexagonal one. A composition range of 11–26% HgS in the solid solution gives rise to colours running from orange through to maroon.

The cadmium mercury sulfide pigments were developed in specific response to adverse economic conditions in the supply of selenium in the later 1940s, this type being patented in the US in 1948 (USP 2,878,134). According to Moore, the cadmium mercury sulfides are virtually identical in behaviour and appearance to the cadmium selenide sulfides, but of lower cost.

Also known as cadmium cinnabar and mercadmium.
See: cadmium sulfides and selenides group.

Cadmium sulfides and selenides group; Mercury group; *Cadmium cinnabar*; *Cadmium orange*; *Cadmium red*
Fiedler & Bayard (1986); Huckle *et al.* (1966); Moore (1973)

CADMIUM ORANGE

Orange
Synonym, variant or common name

Salter (1869) writes that 'cadmium orange' was first introduced to the art world at the International Exhibition, London, in 1862, but adds very little regarding composition.

The *Colour Index* (1971) lists cadmium orange under three constitution numbers: 77196 (cadmium selenide), 77199 (cadmium sulfide) and 77201 (cadmium mercury sulfide); the first two of these are also given as CI Pigment Orange 20, the latter as CI Pigment Orange 23. Of these types it adds that some commercial varieties of cadmium orange are an impure form of cadmium selenide, and that the hue of cadmium sulfide varies from lemon yellow to orange red depending on secondary factors related to the structure of the colloidal aggregates and the coagulating anion in precipitation reactions.

For more information, see: cadmium sulfides and selenides group.

Cadmium mercury sulfide; Cadmium selenium sulfide; *Cadmium lithopone*; *Cadmium sulfide lithopone*; *Cadmolith*; *Cadmopone*
Colour Index (1971) 77196, 77199, 77201; Salter (1869) 36, 42, 244

CADMIUM OXALATE

White
Generic compound

Fiedler and Bayard (1986) report that cadmium oxalate, $Cd(C_2O_4)$, was used in the manufacture of early light cadmium sulfide group (*q.v.*) pigments, comprising up to 30% of the pigment in some cases. However, cadmium sulfides containing cadmium oxalate were reported to be unstable, fading during exposure to air and light. The compound was also added as an adulterant to cadmium sulfide pigments which affected the stability of the pigment.

Cadmium group; Cadmium sulfides and selenides group
Fiedler & Bayard (1986)

CADMIUM OXIDE

Variable
Generic compound

See: cadmium oxides and hydroxides group.

CADMIUM OXIDES AND HYDROXIDES GROUP

Variable
Group term

Cadmium(II) oxide, CdO, occurs as a brown powder although the colour may vary (to red-yellow or brown-black) according to stoichiometry and particle size. It may be synthesised by oxidizing cadmium hydroxide or by heating cadmium carbonate (*q.v.*); it will also form by oxidation of cadmium sulfide upon heating above 300°C. Cadmium oxide is found naturally as the black mineral monteponite.

Salter (1869) details cadmium white, which he describes as the hydrated oxide (or carbonate) and cadmium brown, which was apparently prepared 'By igniting the white carbonate of cadmium'; this gave 'a cinnamon-brown oxide … of a very clear and beautiful colour'; the latter was apparently quite unstable, said to rapidly revert to white cadmium oxide.

Cadmium oxide has been used as a starting material in the manufacture of cadmium sulfide pigments using the 'dry process' (see Cadmium sulfides and selenides group for further details). It was also added as an adulterant in early cadmium sulfide pigments or as a lightening agent. Fiedler and Bayard (1986, citing Buchner and Church) report that the addition of cadmium oxide led to the discoloration of the pigment.

Cadmium group; Cadmium carbonate; *Cadmium brown*; *Cadmium white*
Buchner (1887); Church (1915) 162–167; Fiedler & Bayard (1986); Salter (1869) 78

CADMIUM RED

Red
Synonym, variant or common name

Early references to cadmium red are probably to an orange hue of cadmium sulfide – Salter (1869), Scott Taylor (1885) and Standage (1887; cf Carlyle, 2001) all mention it, Salter describing it as ‘more orange in hue than vermilion’ (*q.v.*). However, most applications of the term are to cadmium selenide or cadmium sulfide selenide pigments. These were first commercialised in 1910, though according to Gettens and Stout (1966) this type of pigment was mentioned in a patent granted in 1892.

The *Colour Index* (1971) lists two red cadmium pigments, CI Pigment Red 108 and CI Pigment Red 113. Compositionally these relate to cadmium sulfide selenides ($\text{CdS}.x\text{CdSe}$) and pure cadmium selenides (CdSe) as well as cadmium mercury sulfides ($\text{CdS}.x\text{HgS}$) (*q.v.*). Co-precipitates with barium sulfate (*q.v.*) are also known, sometimes referred to as cadmium red lithopone (*Colour Index*, CI 77202).

For more information, see: cadmium sulfides and selenides group.

Cadmium group; Cadmium mercury sulfide; Cadmium sulfide; Vermilion
Carlyle (2001) 505; *Colour Index* (1971) 77202; Gettens & Stout (1966); Salter (1869) 42, 130; Scott Taylor (1885) 92, 118; Standage (1887)

CADMIUM SELENIDE

Red
Generic compound

See: cadmium sulfides and selenides group.

CADMIUM SELENIUM SULFIDE

Red-Orange
Generic compound

See: cadmium sulfides and selenides group.

CADMIUM SULFIDE

Yellow-Orange
Generic compound

See: cadmium sulfides and selenides group.

CADMIUM SULFIDE, AMORPHOUS TYPE

Yellow
Generic compound

Although cadmium sulfide exists in two crystalline forms (hexagonal or greenockite type, and cubic or hawleyite type, *qq.v.*), an amorphous form may also be synthesised. This phase can reportedly coexist with the other crystalline forms at room temperature. According to Budgen (1924), amorphous cadmium sulfide may be formed either by the adding cadmium oxide to molten potassium thiocyanate, or by heating cadmium thiocyanate with acetic acid in a sealed tube at 250°C.

Samples of amorphous cadmium sulfide are described by Fiedler and Bayard (1986) as composed of individual particles or agglomerates which often contain centres with a fused appearance; individual areas of fused material are also observed. Small amounts of crystalline cadmium sulfide are also reported to be present. It is unclear whether the fused material is generated by pressures associated with grinding of the pigment, due to reaction over time, or as part of the synthesis process.

The amorphous form of cadmium sulfide has been identified on many of the paintings by Monet (see the review by Fiedler and Bayard) and it has been noted that the pigment has darkened in some cases where it is mixed with chrome yellow (*q.v.*).

Cadmium sulfides and selenides group; Cadmium sulfide, greenockite type; Cadmium sulfide, hawleyite type; *Chrome yellow*
Budgen (1924); Fiedler & Bayard (1986)

CADMIUM SULFIDE, GREENOCKITE TYPE

Yellow
Generic compound

A hexagonal form of cadmium sulfide, named after the naturally occurring mineral form greenockite (*q.v.*). It is polymorphous with the cubic hawleyite type (*q.v.*), with which it can coexist. According to Fiedler and Bayard (1986), the greenockite form is the most common type of cadmium sulfide pigment encountered. However, Böhm and Niclassen (1924) state that the common historical method of precipitating cadmium sulfide using hydrogen sulfide results in the production of the cubic hawleyite form.

Cadmium sulfides and selenides group; Cadmium sulfide, hawleyite type
Böhm and Niclassen (1924); Fiedler & Bayard (1986)

CADMIUM SULFIDE, HAWLEYITE TYPE

Yellow
Generic compound

A cubic form of synthetic cadmium sulfide, analogous to the naturally occurring mineral hawleyite (*q.v.*). It is polymorphous with the hexagonal form, cadmium sulfide, greenockite type (*q.v.*), to which it may convert during slow heating. According to Böhm and Niclassen (1924), precipitation of cadmium sulfide using hydrogen sulfide following the common historical recipe results in the formation of the cubic type. However, Fiedler and Bayard (1986) report that the hawleyite form of cadmium sulfide is less commonly encountered as a pigment than the hexagonal type.

Cadmium sulfides and selenides group; Cadmium sulfide, greenockite type; Hawleyite
Böhm & Niclassen (1924); Fiedler & Bayard (1986)

CADMIUM SULFIDE LITHOPONE

Yellow-Orange
Synonym, variant or common name

A cadmium sulfide pigment co-precipitated with barium sulfate. According to Fiedler and Bayard (1986), these developed out of economic necessity, pure cadmium sulfide pigments being prohibitive in cost for many industrial purposes. Such lithopones were reputedly introduced by Marston in 1921. The best product was prepared by co-precipitation, with either barium sulfide added to cadmium sulfate solutions, or a soluble barium salt being reacted with sodium sulfate in the solution from which the cadmium sulfide was being prepared. Early lithopones contained only around 5% barium sulfate, but modern examples can contain up to 61.8%, the proportion that results from the barium sulfide/cadmium sulfate reaction. Zinc sulfide can also be used with the barium. No substitution into the cadmium sulfide crystal lattice takes place with these products, the pigment being essentially an intimate mixture.

Cadmium group; *Cadmium lithopone*; *Cadmium orange*; *Cadmium yellow*; *Cadmolith*; *Cadmopone*
Fiedler & Bayard (1986)

CADMIUM SULFIDES AND SELENIDES GROUP

Red-Orange-Yellow
Group term

A group of compounds based around cadmium sulfide forms an important range of yellow to red pigments. Apart from cadmium sulfide itself, various elements may be substituted into the basic structure, replacing the cadmium and/or the sulfur. For example, a series exists from the sulfide to the selenide (Cd(S,Se)) giving a range of yellow through orange to red pigments, while mercury and zinc may be substituted for the cadmium ((Cd,Hg)S and (Cd,Zn)S), giving a variety of orange to maroon shades. Cadmium selenide itself is usually a red powder, but grey to brownish forms are known. In commercial formulation these pigments are also produced in co-precipitates with barium sulfate (as so-called 'lithopone' pigments).

Forms of cadmium sulfide occur in two crystal systems, cubic and hexagonal, as well as an amorphous type; the hexagonal form is sometimes called α-cadmium sulfide, the cubic β-cadmium sulfide. The common historical method of preparing cadmium sulfide that precipitates the pigment using hydrogen sulfide causes the cubic form to be produced (Böhm and Niclassen, 1924), though early studies (Allen and Crenshaw, 1912) also indicated an amorphous variety. However, modern structural studies have shown that most pigments are at least partially crystalline and in fact all forms can coexist at normal temperatures, the cubic transforming to the hexagonal with slow heating. Two cadmium sulfide minerals are also known: the commoner greenockite, which is the analogue of the hexagonal form, and hawleyite (*qq.v.*), which takes the cubic structure.

Fiedler and Bayard (1986) differentiate two basic routes to synthesis of cadmium sulfides, 'dry' and 'wet'. The dry process originally involved heating metallic cadmium, cadmium oxide or carbonate with sulfur in the absence of air at temperatures around 300–500°C. The basic operating parameters for this process – time, temperature, purity, proportion of reactants and oxygen availability – will affect the result, so that the product was quite variable. A wet-grinding stage followed this, which modified the particle morphology and, hence, the final colour. While any shade could, in principle, be produced, according to Zerr and Rübencamp (1906) a dull pigment was frequently the result. The main modern modification to this process is calcination at higher temperatures (700–800°C), which brings about more effectively the structural modification described above.

In the wet process, cadmium sulfide is formed from a soluble cadmium salt and a soluble sulfide. The cadmium compound is normally the chloride, nitrate, sulfate or iodide; the soluble sulfur comes from hydrogen sulfide, barium or sodium sulfide, or a thiosulfate. As with the dry process, reaction conditions are crucial and can significantly affect the colour and permanence of the resulting pigment. Earlier production (pre-1870s) usually employed hydrogen sulfide gas; after that time sodium sulfide was used instead, being a more convenient and controllable source of sulfur. The pH conditions also affect the results, with slightly acidic solutions sometimes being used. The pigment hue varies from lemon yellow to orange red depending not on the arrangement of the atoms in the lattice structure but on secondary factors relating to the structure of the colloidal aggregates largely determined by the valency of the coagulating anion (*Colour Index*, 1971). An interesting summary of the effect of different cadmium salts, reaction temperatures and pH conditions is given by Milligan (1934; reproduced in Fiedler and Bayard, 1986), showing the resulting colour and crystalline forms. Historically, no subsequent calcination step was used.

Patton (1973k) describes modern commercial wet process preparation methods. One starts with a cadmium chloride solution free of iron and nickel impurities; low levels of zinc chloride may be added at this point. Over a period of about an hour or more a solution of barium sulfide is added to precipitate the cadmium/zinc sulfides, the reaction being run at a temperature of around 70–90°C. (To produce lithopone pigments, sodium sulfate would be used at this stage to precipitate the barium sulfate from the by-product barium chloride.) The resulting precipitate was then calcined at about 650°C. In a second method, cadmium chloride or sulfate would be reacted with an alkali metal sulfide (or hydrogen sulfide gas). For selenides, selenium metal was either dissolved in the alkali metal sulfide solution or intimately mixed with the precipitate prior to calcination; a Se-Cd ratio of 10:90 gives orange shades, 20:80 gives bright red and 30:70 dark maroon.

A third route to production of cadmium sulfide is described in the literature, employing electrolytic methods (for example, Zerr and Rübencamp, 1906); this was more costly than other methods and therefore little used. Amorphous forms of cadmium sulfide can be prepared by gradual addition of cadmium oxide to molten potassium thiocyanate, or by heating cadmium thiocyanate with acetic acid in a sealed tube at 250°C (Budgen, 1924, cf. Fiedler and Bayard, 1986).

Considerable issues also surround the earlier production of paler yellows which, while popular, were also of poor stability. Pale shades, for example, could be produced by partial precipitation from cold dilute solutions, or rapid precipitation from acid solutions, or by using cadmium nitrate with sodium sulfide or ammonium thiosulfate; however, these pigments could have up to 20% free sulfur content and they were rarely stable. Other routes involved calcining a mixture of cadmium and zinc sulfides with either zinc or magnesium oxide (Laurie, 1914), mixtures with lead white (*q.v.*; which could rapidly darken from lead sulfide formation), or manufacturing with excess cadmium carbonate or oxalate. Fiedler and Bayard state that in extreme cases 30% of the oxalate might be present with only 1.5% of the sulfide. Modern processes now make use of precipitation modifiers such as cobalt, nickel, phosphate, potassium alum, aluminium hydrate, organic esters or sodium carbonate, though the principal approach is to form cadmium zinc sulfide, $Cd_{1-x}Zn_xS$. Here, cadmium and zinc salts with the same anion are used, with up to about 25% zinc content (Huckle *et al.*, 1966; Patton).

Cadmium sulfide selenides (cadmium sulfoselenide, 'cadmium red') were originally commercialised in 1910, the manufacturing process involving heating cadmium sulfide, sulfur and selenium to about 600°C in an inert atmosphere. An improved process developed by the German company Bayer in 1919 involved the use of aqueous precipitation from solutions of alkaline sulfides and selenides; the precipitate was yellow, the red shade developing on calcination at 300°C.

Moore (1973) describes the preparation of cadmium mercury sulfides whereby the respective sulfides would be precipitated from solutions of their soluble salts, the precipitate being then calcined in a restricted or non-oxidising atmosphere to form the solid solution and cause conversion of the compound from the cubic to the hexagonal crystal structure. HgS-CdS ratios of around 10:90 give orange shades, 26.5:73.5 giving maroon. Cadmium mercury sulfide pigments are said to have been discovered as a result of shortages in selenium in the late 1940s (Moore).

A number of authors (such as Patton) state that cadmium sulfide minerals were used historically as pigments; there is currently no physical or documentary evidence to support this.

Adulteration of cadmium pigments has been rife in the past, to the extent that Fiedler and Bayard comment that 'it was necessary to forewarn the prospective buyer to choose only pure materials and to acquire them from a reliable colorman'. Compounds typically found in cadmium sulfide pigments include zinc oxide, zinc carbonate, zinc sulfide, zinc chromate, ‘arsenic yellow’, lead chromate, gypsum, cadmium carbonate, cadmium oxalate, cadmium oxide, cadmium phosphate, Indian yellow, tin sulfide, free sulfur, antimony, mercury and bismuth compounds, lead iodide and barium sulfate (*qq.v.*). Fiedler and Bayard also report analyses of modern pigments and samples from the Forbes Collection that contain titanium and strontium compounds.

A range of terms surrounds this group of compounds, most notably cadmium yellow, C. orange and C. red (*qq.v.*); cadmium mercury sulfides were generally traded under the commercial name *Mercadmium* (a registered trade mark of Hercules Inc.). The group is also covered by a number of *Colour Index* designations. See the relevant entries for further discussion of terminology.

Cadmium sulfides and selenides as pigments have been reviewed by Fiedler and Bayard (1986) who describe their extensive use in oil and watercolour, particularly after 1840 when production was commercialised. Early forms were often unstable, darkening on exposure to air and light, or bleaching in the presence of moisture (Fiedler and Bayard, citing Friend). Cadmium sulfide pigments are also reported to discolour when used with certain copper- and lead-based pigments (particularly emerald green, *q.v.*), due to the formation of copper and lead sulfides (for example, Church, 1901; Standage, 1883). Chalking may also occur when used in oil, as reported by Curtis and Wright (1954), Whitehouse and Eastaugh (2001) and Asperen de Boer (1994), in these cases the pigment was often found mixed with titanium dioxide white (*q.v.*), zinc or lead. Huigen and Phenix (1997) detail further the stability and deterioration of cadmium pigments. More recently, Duffy and McGlinchey (2001) reported that the exudation of a cadmium red pigment on Youngerman’s *Black, Red, and White* was due to the formation of extensive drying cracks in the overlying black layer, permitting the underlying cadmium red paint, which had remained viscous, to emerge.

Cadmium group; **Tin sulfides group; Zinc chromates group; Zinc sulfides group;** Barium sulfate; Cadmium carbonate; Cadmium mercury sulfide; Cadmium oxalate; Cadmium zinc sulfide; Greenockite; Gypsum; Hawleyite; Lead chromate(VI); Lead iodide; Zinc oxide; *Arsenic yellow*; *Cadmium orange*; *Cadmium red*; *Cadmium yellow*; *Emerald green*; *Indian yellow*; *Lead white*; *Lithopone*; *Mercadmium*; *Titanium dioxide white*

Allen & Crenshaw (1912); Asperen de Boer (1994); Böhm & Niclassen (1924); Budgen (1924) 100–105; Church (1901) 142–148; *Color Index* (1971); Curtis & Wright (1954); Duffy & McGlinchey (2001); Fiedler & Bayard (1986); Friend (1910) 38–39; Huckle *et al.* (1966); Huigen & Phenix (1997); Laurie (1914); Moore (1973); Patton (1973k); Standage (1883); Whitehouse & Eastaugh (2001); Zerr & Rübencamp (1906/1908)

CADMIUM SULFOSELENIDE

Red-Orange

Synonym, variant or common name

See: cadmium sulfides and selenides group.

CADMIUM TUNGSTATE

Unknown

Generic compound

Cadmium tungstate is probably of limited interest although according to the *Colour Index* (1971; CI 77208) it is used in the USA in fluorescent paints.

Cadmium group; **Tungsten group**

Colour Index (1971) 77208

CADMIUM VERMILION

Red-Orange

Synonym, variant or common name

This is a cadmium mercury sulfide (*q.v.*) pigment, ‘analogous to cadmium cinnabar, of orange to red hue’ (de Keijzer, 1990).

Cadmium sulfides and selenides group; Cadmium mercury sulfide; *Mercadmium*

Keijzer (1990)

CADMIUM WHITE

White

Synonym, variant or common name

Mentioned in the texts by Salter (1869) and Muckley (1882; cf. Carlyle, 2001), though not in Field (1835), this was stated to be either a hydrated oxide or a carbonate of cadmium. Salter describes the preparation of cadmium white thus: ‘Provided the metal be freed from iron … a white of considerable beauty may be produced; either directly by precipitation as hydrated oxide or carbonate, or indirectly by exposing the brown anhydrous oxide to air and light – the latter mode yielding a product of greater opacity’.

Cadmium carbonate

Carlyle (2001) 518; Field (1835); Muckley (1882) 29; Salter (1869) 78

CADMIUM YELLOW

Yellow

Synonym, variant or common name

Although some authors, such as Curtis and Wright (1954) and Patton (1973k), suggest that cadmium sulfide in the form of the naturally occurring mineral greenockite (*q.v.*) has been used as a pigment for nearly two millennia, there appears to be no physical or documentary evidence to support this. Synthetic cadmium sulfide was instead suggested as a pigment in 1819 by Stromeyer, although it was not commercially available until the 1840s due to the scarcity of the metal required for its manufacture. For example, Bachhoffner (1837) comments that ‘Its oxide is of an orange colour, and would no doubt form a good pigment did there exist a sufficient supply of the metal’, while Harley (1982) notes that cadmium yellow does not appear on any colour list before 1835.

Early forms of the pigment darkened on exposure to air and light. Fiedler and Bayard (1986, citing Friend) report that exposure to moisture was considered to cause bleaching of the pigment due to the formation of sulfuric acid which would react with the cadmium sulfide to form colourless cadmium sulfate. Exposure to air, moisture and ultra-violet radiation has also been reported to cause bleaching due to the conversion of the sulfide to sulfate, although the effect may be reduced or eliminated if a suitable medium for the pigment is used. Chalking of the pigment has been noted in studies by Whitehouse and Eastaugh (2001), Asperen de Boer (1997) and Curtis and Wright, although in these cases the pigments are frequently mixed with titanium dioxide white (*q.v.*), zinc or lead. Cadmium sulfide is incompatible with copper- and lead-based pigments (particularly copper acetate arsenite, ‘emerald green’, *q.v.*), with discoloration occurring by the formation of copper and lead sulfides, although this is reportedly slower for lead pigments (Church, 1901; Standage, 1883). Further discussion of the stability and deterioration of cadmium pigments is given by Huigen and Phenix (1997).

The use of cadmium yellow as a pigment has been reviewed by Fiedler and Bayard who note that it has been used extensively in oil and watercolour, although its use was limited until the 1840s when production was commercialised.

According to Fiedler and Bayard (1986), from the time of its introduction as an artists' pigment in the earlier nineteenth century cadmium sulfide has been generally known as cadmium yellow, with few exceptions. However, we should note that Stromeyer, the discoverer of cadmium in 1817, used the term sulphuret of cadmium when recommending cadmium sulfide as an artists' pigment (Stromeyer, 1819). Other names dating from the nineteenth century include aurora yellow and *jaune brilliant* as well as Mutrie yellow and orient yellow (Salter, 1869), *Radiant yellow* (trade name of the British colourmen Reeves, late nineteenth century, cf. Carlyle, 2001), neutral orange (Scott Taylor, 1885) and daffodil yellow (Church). Cadmia is also recorded as a term for cadmium yellow by Fiedler and Bayard, though generally it has meant the zinc mineral calamine. By far the largest group of names though are modified or qualified versions of cadmium yellow: cadmium yellow primrose, c.y. lemon, c.y. light, medium and dark. Co-precipitates analogous to the zinc oxide-barium sulfate composite lithopone (*q.v.*) were called cadmium lithopone, cadmopone or *Cadmolith* (the latter a trade name), or described as a 'cadmium-barium shade'.

The *Colour Index* (1971) lists cadmium yellow as CI 77199/Pigment Yellow 37 and the lithopone form as CI 77117/Pigment Yellow 35.

For a fuller discussion of cadmium sulfide and related compounds, see: cadmium sulfides and selenides group.

Cadmium group; Cadmium sulfides and selenides group; Cadmium sulfide; Greenockite; Lithopone; Titanium dioxide white; *Aurora yellow*; *Brilliant yellow*; *Cadmia*; *Cadmium lithopone*; *Cadmium sulfide lithopone*; *Cadmolith*; *Cadmopone*; *Daffodil yellow*; *Emerald green*; *Jaune brilliant*; *Lemon cadmium*; *Mutrie yellow*; *Neutral orange*; *Orient yellow*; *Radiant yellow*
Asperen de Boer (1997); Bachhoffner (1837); Carlyle (2001) 523; Church (1901) 142; *Colour Index* (1971) 77117, 77199; Curtis & Wright (1954); Fiedler & Bayard (1986); Harley (1982); Huigen & Phenix (1997); Patton (1973k); Salter (1869) 87, 92; Scott Taylor (1885) 121; Standage (1883); Stromeyer (1819); Whitehouse & Eastaugh (2001)

CADMIUM YELLOW LITHOPONE

Yellow
Synonym, variant or common name

Marston patented the first cadmium yellow lithopone in 1921 in which approximately 5% barium sulfate (*q.v.*) was present. Fiedler and Bayard (1986, citing Ward, 1927) state that by 1927, cadmium lithopones were being produced with >60% barium sulfate, which greatly reduced the cost of manufacturing pure cadmium sulfide.

For a fuller discussion of cadmium sulfide and related compounds, see: cadmium sulfides and selenides group.

Cadmium group; Barium sulfate; *Cadmium yellow*; *Lithopone*
Fiedler & Bayard (1986); Ward (1927)

CADMIUM ZINC SULFIDE

Yellow-Orange
Generic compound

Developed in response to the need for stable lighter shades of the cadmium pigments, methods involving calcining a mixture of cadmium and zinc sulfides with either zinc or magnesium oxide were used (Laurie, 1914; cf. Fiedler and Bayard, 1986). However, the principal modern approach is to form cadmium zinc sulfide, $Cd_{1-x}Zn_xS$. Here, cadmium and zinc salts with the same anion are used, with up to about 25% zinc content (Huckle *et al.*, 1966; Patton, 1973k).

Cadmium group; *Cadmium orange*
Fiedler & Bayard (1986); Huckle *et al.* (1966); Laurie (1914); Patton (1973k)

CADMOLITH

Yellow-Orange
Synonym, variant or common name

Commercial (trade) name for a cadmium sulfide-type pigment (Fiedler and Bayard, 1986).
See: cadmium sulfides and selenides group.

Cadmium group; Cadmium sulfides and selenides group; Cadmium sulfide; *Cadmium yellow*; *Cadmopone*
Fiedler & Bayard (1986)

CADMOPONE

Red-Orange-Yellow
Synonym, variant or common name

Synonym or manufacturer's term for a cadmium sulfide lithopone-type pigment that may come in yellow to red variants (de Keijzer, 1990). Heaton (1928) lists this as a current term at that time.

Cadmium group; *Cadmium lithopone*; *Cadmium orange*; *Cadmium sulfide lithopone*; *Cadmium yellow*; *Cadmolith*; *Lithopone*
Heaton (1928) 380; Keijzer (1990)

CADMOSELITE

Black
Generic compound

Cadmoselite is a black hexagonal mineral named after its chemical composition, CdSe. Its type locality is Tuva, Siberia, Russia and was discovered by Bur′yanova *et al.* in 1957. It is a rare mineral but its synthetic counterpart, cadmium selenide, which forms a red or grey to brown powder, is known in a pigment context, principally in conjunction with cadmium sulfide to form orange to red cadmium selenide sulfides (*q.v.*).

Cadmium group; Cadmium sulfides and selenides group
Bur′yanova *et al.* (1958)

CAELIN BLUE

Blue
Synonym, variant or common name

See: cobalt blue.

CAERULEUM

Blue
Synonym, variant or common name

According to the classical author Vitruvius *caeruleum* came originally from Alexandria, but that a certain Vestorius had founded a factory in Puteoli (modern Pozzuoli) to make this. Pliny (77 AD) states that there were various sorts of *caeruleum*, though it is clear from his descriptions that they are all essentially forms of the pigment known as Egyptian blue (a synthetic calcium copper silicate pigment, *qq.v.*). Describing it as a sand, he says that there were 'in old days' three varieties, the *Aegyptium* (Egyptian), the *Scythicum* (Scythian) and the *Cyprium* (Cyprian); to these were added a pigment manufactured at Pozzuoli which he calls *puteolanum* and another (which is probably the same) known as *vestorianum* ('vestorian blue'). Finally, *Hispaniense* ('Spanish blue') may be related though the description is unclear. Pliny also comments that 'Every kind however undergoes a dyeing process, being boiled with a special plant and absorbing its juice'; no particular plant is specified and the comment makes little sense unless some tinting process were meant. However, it should also be noted that the Latin word *caeruleum* could sometimes simply mean a blue pigment.

In the nineteenth century the term appears to have been revived, though for a different compound – cobalt stannate (cobalt tin oxide, *q.v.*). The *London Times* of 28 December 1859 carried an advert for 'Cæruleum, a new permanent colour, prepared for the use of artists', while Ure's *Dictionary of Arts* (1875–78) also specifies the composition, describing the pigment as 'Cæruleum … consisting of stannate of protoxide of cobalt, mixed with stannic acid and sulphate of lime.' This is repeated by other authors such as Standage (1887); however, the word afterwards stabilises as cerulean (*q.v.*).

Calcium copper silicate; Cobalt tin oxide; *Cerulean blue*; *Egyptian blue*
Pliny (1st cent AD/Rackham 1952) XXXIII.lvii.161–163; Standage (1887); Ure (1875–78); Vitruvius (1st cent BC/Grainger, 1934) VII.ix.1

Caesalpina
Red
Ure (1875–78)
Common generic composite

See: brazilwood.

Calcined bone
Black-White
Synonym, variant or common name

See: bone, calcined.

Calcite
White
Generic compound

Calcite is a naturally occurring calcium carbonate mineral ($CaCO_3$). It is normally colourless or white, sometimes with impurities that give grey, yellow, blue, red, brown or black tints.

It is chiefly found in sedimentary rocks such as chalk and limestone (including lithographic stone, pisolite and oolite) and in marble (*qq.v.*). These forms are the main sources for pigment production; however, there are in fact many other sources of calcite such as: spars (explicit crystal forms like nail-head, dog-tooth, Iceland and satin spars); stalagmitic forms (stalactites, 'oriental alabaster' and 'Algerian onyx', the latter two being neither alabaster nor onyx); tufa (calc or calcareous tufa, travertine *q.v.*); and anthraconite (stinkstone), a dark coloured limestone containing bituminous matter. Calcite is used as a white pigment (reviewed by Gettens *et al.*, 1993a) as well as an extender or bulking agent for paints. It is also used as a ground for painting when mixed with animal glues. There are several impurities that may be associated with the pigment which include quartz, magnesite, aragonite, dolomite, clays and colouring agents such as hematite (*qq.v.*) and carbon.

There are two related calcium magnesium carbonates which have also been found as pigments: dolomite and huntite (*qq.v.*). Calcite can take up a few per cent of magnesium without changing its crystal structure (limit: Mg/Ca ±1/4.5). This is a solid solution of magnesium in calcite; likewise, some calcium can also substitute for magnesium in dolomite. Finally, magnesian limestones and magnesian marbles are mechanical mixtures of calcite and dolomite.

According to the *Colour Index* (1971), synthetic calcite can be produced industrially in two ways: (1) from conversion of calcium oxide, and (2) as a precipitate of calcium chloride with sodium carbonate. The resultant compound was often used as a base for lake pigments and as an extender for others. However, see calcium carbonates group for a fuller discussion of synthesis. The *Colour Index* designation for this pigment is CI 77220/Pigment White 18. The term 'whiting' also may refer to a synthetic calcium carbonate.

Calcium carbonates group; Calcium group; Aragonite; Calcium carbonate, calcite type; Chalk; Dolomite; Hematite; Huntite; Limestone; Magnesite; Marble; Quartz; Travertine
Colour Index (1971) 77220; Gettens *et al.* (1993a)

Calcium aluminium oxide
White
Generic compound

Heaton (1928) mentions calcium aluminium oxide (calcium aluminate) as forming, with calcium sulfate, the pigment known as satin white (*q.v.*).

Satin white
Heaton (1928) 109

Calcium carbonate, aragonite type
White
Generic compound

See: aragonite and calcium carbonates group.

Calcium carbonate, calcite type
White
Generic compound

See: calcite and calcium carbonates group.

Calcium carbonates group
White
Group term

Calcium carbonate, $CaCO_3$, forms the basis of a number of natural and synthetic compounds used as pigments, notably the minerals calcite and aragonite, the rock varieties chalk, limestone, travertine and marble and direct biogenic precipitates, shells and coral, as well as synthetically produced material such as that prepared historically from lime (*qq.v.*) or by chemical precipitation reactions. Broadly, the calcium carbonates may be divided into four groups based on origin – those of purely mineral origin, calcium carbonates of direct biological production such as shells, those from fossilisation of such material and calcium carbonate produced synthetically.

Calcium carbonate principally takes on the crystal structure of the mineral calcite (trigonal – hexagonal scalenohedral), while the rarer polymorphic forms of aragonite (orthorhombic – dipyramidal) and vaterite (*q.v.*; hexagonal – dihexagonal dipyramidal) may also be encountered. Aragonitic calcium carbonate, for example, predominates in materials from biogenic sources such as shells and coral while the calcite structure is widely found within a geological context; aragonite is in fact relatively less stable than calcite, to which it converts over time, the alteration being generally due to environmental factors such as elevated temperatures. Several calcium magnesium carbonates are also encountered, these being dolomite and huntite (*qq.v.*) along with their synthetic analogues, while dolomite may also occur coincidentally as a component of materials such as dolomitic limestones.

Calcium carbonate is secreted by many marine invertebrates. Organisms belonging to the Phyla *Mollusca* and *Brachiopoda* produce aragonitic shells. The Phylum *Mollusca* includes the class *Cephalopoda*, octopi and squids, some of which produce external shells (nautiloids, argonauta) and others which produce small, internal shells or 'bones' such as cuttlefish (*sepia*) and Loligo. The classes *Bivalvia* and *Gastropoda* are the more familiar seashells, but also include land snails. The rare *Brachiopoda* (lamp shells) are an unimportant group today; however, they are commonly found as fossils. The Phylum *Echinodermata* (including starfish, sea urchins and sea lillies) also produce calcium carbonate shells. Organisms belonging to the Phylum *Cnidaria* are major producers of calcium carbonate in the form of coral reefs. These can be enormous structures (such as the tropical reefs like the Great Barrier Reef), but corals exist in smaller volumes in Mediterranean and temperate seas. These animals also excrete calcium carbonate-rich pellets. Calcareous nannoplankton, coccoliths and other marine algae also possess calcium carbonate tests. These algae bloom in enormous quantities and have been known to do so in the geological past. The rock chalk is primarily composed of such coccoliths. Studies of coccolith assemblages in the chalk grounds of paintings have been published by, for example, Perch-Nielsen (1973).

Marine limestones are produced geologically from the fossilisation of marine organisms. Chalk, as mentioned above, is one variety of limestone. Others include fossilised coral reefs and fossil organism-rich beds. Further varieties of limestones form in warm, shallow tropical seas from precipitated calcium carbonate which has become saturated in the water. Such limestones are called oolitic limestones, because they are composed of roughly one millimetre diameter concentric spheres of calcium carbonate called ooids or ooliths. Other limestones may be composed entirely of carbonate muds derived from excreted pellets. Non-marine limestones are less abundant. They are composed of calcium carbonate which has been dissolved in water due to the weathering of limestone rocks. Non-marine limestones include travertines and speleothems (cave-deposits; flowstones, stalagmites and stalactites). Lithification of limestones over geological time may produce partial recrystallisation and other chemical alterations of the rock; processes generally covered by the term 'diagenesis'. Marble is the metamorphic equivalent of limestone, recrystallised at elevated temperatures and pressures. The variety of limestones is enormous and the interested reader should consult texts such as Tucker and Wright (1990) for further discussion.

Prepared calcium carbonates are purified forms of native material. Conversion of calcium oxide and hydroxide produced from the calcination of material such as limestone and the subsequent absorption of atmospheric carbon dioxide further accounts for the occurrence of pigments such as those sometimes called lime.

The manufacture of 'precipitated' calcium carbonate is thought to have commenced around 1850 when J. & E. Sturge Ltd (Birmingham, UK) reacted calcium chloride with sodium carbonate, a process that continued in use until around 1900 when it was replaced by a direct method; this involves calcium oxide produced from lime-burning being mixed with water and then carbon dioxide from further burning being passed through to re-form calcium carbonate (though of greater purity and uniformity). Modern production methods for precipitated calcium carbonate now follow four main routes (Woerner, 1973). The first method is that just described, which is said to produce the aragonitic form of calcium carbonate with sub-micron particle size. Second, calcium chloride and ammonium carbonate are reacted (as part of the Solvay process to make sodium carbonate) to produce a larger-particle product (1–10 μm), usually of the calcite type. Another stage of the Solvay process allows reaction of calcium chloride and sodium carbonate, giving sub-micron particles and agglomerates of calcite-type calcium carbonate and sodium chloride. Third, the 'lime-soda' reaction between calcium hydroxide and sodium carbonate is used to basically produce sodium hydroxide with calcium carbonate as by-product; it is little used because of residual alkalinity. Finally, a treatment method for water containing calcium hydrogen carbonate hardness involving the action of calcium hydroxide produces calcitic calcium carbonate of relatively large particle size (10–20 μm). Precipitated calcium carbonate is sometimes referred to as precipitated chalk.

The literature citing the use of calcium carbonates as pigments is extensive; this has been largely reviewed by Gettens *et al.* (1993a). Additionally, the calcium magnesium carbonate, huntite is discussed by Heywood in the context of Egyptian artefacts (Heywood, 2001), while Hill (2001) has identified the use of calcium carbonate from certain marine algae (specifically *Halimeda macroloba*) among ethnographic artefacts of Papua New Guinea. Modern industrial uses of natural and synthetic forms of calcium carbonate have been reviewed by Hall (1973) and Woerner (1973). Additional information on the individual varieties and use of related terms may be found in the relevant links.

Calcium group; Aragonite; Calcite; Chalk; Coral; Dolomite; Huntite; Lime; Limestone; Marble; Travertine; Vaterite; *Shell white*; *Whiting*
Gettens *et al.* (1993a); Hall (1973); Heywood (2001); Hill (2001); Perch-Nielsen (1973); Tucker & Wright (1990); Woerner (1973)

CALCIUM CHROMATE(IV) DIHYDRATE

Yellow
Generic compound

This is listed by the *Colour Index* (1971) as one of the compositions ($CaCrO_4.2H_2O$) for Pigment Yellow 33 (CI 77223), the other being calcium chromate hydroxide dihydrate ($Ca_2(OH)_2CrO_4.2H_2O$). Two forms of calcium chromate(IV) dihydrate exist: a monoclinic form, the so-called 'alpha' form and the beta type, which is orthorhombic (MacIntyre, 1992). Although anhydrous forms of calcium chromate are also listed in the chemical literature (for example, calcium chromate(VI), $CaCrO_4$, and calcium chromate hydroxide or basic calcium chromate; cf. MacIntyre), the dihydrate compounds are those most commonly encountered. They are synthesised from mixtures of aqueous solutions of potassium chromate and calcium chloride and higher synthesis temperatures result in products with a deeper hue; the products also dehydrate at 200°C.
See also: calcium chromate(IV) hydroxide dihydrate and calcium chromates group.

Calcium chromates group; Calcium chromate(IV) hydroxide dihydrate
Colour Index (1971) 77223; MacIntyre (1992) 2768, 3078

CALCIUM CHROMATE(IV) HYDROXIDE DIHYDRATE

Yellow
Generic compound

This is one of the formulations ($Ca_2(OH)_2CrO_4.2H_2O$) listed by the *Colour Index* (1971) for Pigment Yellow 33 (CI 77223), with

the other given as calcium chromate(IV) dihydrate (*q.v.*), $CaCrO_4.2H_2O$. The anhydrous forms of these compounds are also listed in the chemical literature (for example, MacIntyre, 1992), but it is the dihydrates which are commonly found. They dehydrate at 200°C and are prepared by mixing aqueous solutions of potassium chromate and calcium chloride, the higher the synthesis temperature the deeper the hue of the product.
See also: calcium chromate(IV) dihydrate and calcium chromates group.

Calcium chromates group; Calcium chromate(IV) dihydrate
Colour Index (1971) 77223; MacIntyre (1992)

CALCIUM CHROMATES GROUP

Yellow
Group term

According to Kühn and Curran (1986), calcium chromate (with composition given as $CaCrO_4$) was first synthesised at the beginning of the nineteenth century. However, it is only mentioned in later nineteenth century sources (for example, Gentele, 1860) as used as an additive to yellow pigments, particularly chrome yellow (*q.v.*). Calcium chromate is listed by the *Colour Index* (1971) as Pigment Yellow 33 (CI 77223), with the composition given as either calcium chromate(IV) dihydrate ($CaCrO_4.2H_2O$) or calcium chromate(IV) hydroxide dihydrate ($Ca_2(OH)_2CrO_4.2H_2O$) (*qq.v.*). Anhydrous forms, commonly calcium chromate(VI), $CaCrO_4$, and calcium chromate hydroxide (or basic calcium chromate), are also listed in the chemical literature (MacIntyre, 1992) although the dihydrate compounds are the most common; further anhydrous forms are calcium chromate(IV), $CaCrO_3$, and calcium chromate(V), $Ca_3Cr_2O_8$. The dihydrate compounds, which dehydrate at 200°C, are prepared by mixing aqueous solutions of potassium chromate and calcium chloride, with higher synthesis temperatures resulting in products with a deeper hue.

The terms *Gelbin* and *Steinbühler Gelb* are listed by Kühn and Curran (1986) as now obsolete terms which were occasionally used in Germany for calcium chromate(VI); Salter (1869) also describes Gelbin's yellow as 'chromate of lime'. Other synonyms include calcium monochromate, calcium chrome yellow and yellow ultramarine (*q.v.*).

The *Colour Index* also indicates that calcium and zinc chromates (*q.v.*) may be co-precipitated to produce CI Pigment Yellow 36 (CI 77959), by the addition of potassium sodium chromate to calcium and zinc chlorides.

Calcium group; Chromates group; Zinc chromates group; Calcium chromate(IV) dihydrate; Calcium chromate(IV) hydroxide dihydrate; *Chrome yellow*; *Gelbin's yellow*; *Yellow ultramarine*
Colour Index (1971) 77223, 77959; Gentele (1860); Kühn & Curran (1986); MacIntyre (1992) 2767–2768, 3078–3079; Salter (1869) 117

CALCIUM COPPER CHLORIDE

Green
Generic compound

Formulations for preparing calcium copper chloride are given by Bersch (1901) and the *Colour Index* (1971; CI 77426). It was commonly known as Kuhlmann's green (*q.v.*).

Calcium group; Copper group; *Kuhlmann's green*
Bersch (1901); *Colour Index* (1971) 77426

CALCIUM COPPER SILICATE

Blue
Generic compound

The pigment known as 'Egyptian blue' – calcium copper silicate – is essentially the synthetic analogue of the mineral cuprorivaite (*q.v.*; $(Ca,Cu)Si_4O_{10}$), a naturally occurring material so rare that the latter's use as a pigment can be largely dismissed. Extensive modern experiments have shown that the compound can be synthesised by mixing silica (such as quartz) with calcium compounds like calcium carbonate, gypsum or calcium hydroxide, and a copper compound such as copper oxide or malachite (a copper carbonate hydroxide mineral, *qq.v.*) in the ratio of $4SiO_2{:}1CaO{:}1CuO$; fluxing agents such as potassium or sodium carbonates may also be added. The mixture is then heated to 900°C (with flux) to 1000°C and then maintained at a temperature of 800°C for a period of 10–100 hours (Riederer, 1997a).

However, in practice, analysis of historical specimens indicates considerable variation in bulk composition, with unreacted synthetic analogue compounds of minerals such as quartz and tridymite, wollastonite and the copper oxides cuprite and tenorite generally being present also (*qq.v.*; Jaksch *et al.*, 1983). Samples of the pigment from artefacts usually consist of the cuprorivaite phase along with unreacted quartz and a copper-bearing wollastonite-like compound of composition $(Ca,Cu)_3(Si_3O_9)$. Variable amounts of alkali-rich glass are also present. Another variant occurs when a bronze was used in partial or complete replacement of copper; in these instances free tin oxide (tin(IV) oxide, cassiterite; *qq.v.*) can be encountered (Jaksch *et al.*, 1983). Finally, pyrite (FeS) and titanomagnetite ($Fe_3O_4.Fe_2TiO_4$) (*qq.v.*) have been detected in some cases. It has also been observed that the colour, in addition to the hardness and texture, depends to a large extent on the initial materials, the microstructure of the sintered product and the final particle size after grinding.

Other compounds found in association include glaucophane and riebeckite, which have been identified in material from Knossos, Crete, dated to 2100 BC, and Thera (Santorini; 1500 BC) (Filippakis *et al.*, 1976; Cameron *et al.*, 1977; Profi *et al.*, 1977). Differences in the compositions of samples from various geographical sources have also been noted in analyses. Tite *et al.* (1984), for example, have shown how Egyptian and Roman specimens have excess calcium oxide and higher alkali levels while Nimrud samples have an excess of copper(II) oxide and low concentrations of potassium and sodium. All samples seem to contain more silicon dioxide than required for stoichiometry.

Calcium copper silicate is a direct analogue of one of the barium copper silicates apparently used in China during the Han dynasty (208 BC to 220 AD; hence the term 'Han blue'; *qq.v.*). There is also a related 'Egyptian green' (*q.v.*), a copper-containing wollastonite-type compound formed by varying the proportion of starting materials and the preparatory conditions used for Egyptian blue.

The composition and use of calcium copper silicate as a pigment has been extensively discussed by Riederer (1997a) and Scott (2002). Terminology surrounding this compound is discussed under Egyptian blue.

Calcium group; Copper group; Barium copper silicate, blue type; Calcium hydroxide; Cassiterite; Cuprite; Cuprorivaite; Glaucophane; Gypsum; Malachite; Pyrite; Quartz; Riebeckite; Tenorite; Tin(IV) oxide; Titanomagnetite; Tridymite; Wollastonite; *Egyptian blue*; *Egyptian green*; *Han blue*
Cameron *et al.* (1977); El Goresy *et al.* (1986); Filippakis *et al.* (1976); Green (1995); Jaksch *et al.* (1983); Le Fur (1990); Profi *et al.* (1977);

Riederer (1974); Riederer (1977a); Riederer (1982); Riederer (1997a); Scott (2002); Tite *et al*. (1984)

Calcium copper silicate, cuprorivaite type

Blue
Generic compound

See: calcium copper silicate and Egyptian blue.

Calcium euxanthate

Yellow
Generic compound

Euxanthic acid, a major constituent of so-called Indian yellow (*q.v.*), will form salts with various elements; however, those of calcium and magnesium are the ones commonly encountered.

Indian yellow

Calcium group

Variable
Group term

This is a large and complex group of compounds including many biogenic forms. Pigments containing calcium form one of the larger groups and include several important categories such as the carbonates and the sulfates as well as a number of phosphorus compounds related to bone. The reader is referred to the relevant group and individual entries for more detailed discussions.

Carbonates: aragonite, calcite and their synthetic analogues. Various biogenic forms such as coral, bone of *Sepia* spp. ('cuttlefish'), eggshell and oyster shell. Calcium carbonate-rich rocks such as chalk, limestone and marble.
Carbonates with Group 1 and 2 elements: ankerite ($Ca(Mg_{0.67}Fe_{0.33})(CO_3)_2$); dolomite ($CaMg(CO_3)_2$); huntite.
Simpler organo-calcium compounds: weddellite ($CaC_2O_4.2H_2O$) and whewellite ($CaC_2O_4.H_2O$).
Oxides and hydroxides: calcium hydroxide and portlandite ($Ca(OH)_2$), calcium oxide and lime (CaO), and calcium aluminium oxide.
Phosphates: the apatite group ($Ca_5[PO_4]_3[F,Cl,OH]$) including dahllite ($Ca_{10}(PO_4)_6(CO_3).H_2O$), calcium phosphate ($CaPO_4$).
Sulfates: anhydrite ($CaSO_4$), bassanite ($CaSO_4.xH_2O$), hemihydrate ($CaSO_4.0.5H_2O$), gypsum ($CaSO_4.2H_2O$) and their synthetic analogues.
Silicates: the amphibole group, the clay minerals group, the feldspar group and the silicates group all contain calcium; the individual minerals or analogues of wollastonite ($CaSiO_3$) and cupro-wollastonite (as wollastonite, with a few % copper), calcium copper silicate (Egyptian blue and cuprorivaite, $[Ca,Cu]Si_4O_{10}$), calcium silicate hydrate ($CaSiO_3.nH_2O$) and lazurite/ultramarine ($[Na,Ca]_8[\{Al,Si\}_{12}O_{24}][S,SO_4]$) belong to the silicates group.

Additionally, there are two chromates (calcium chromate(VI) dihydrate ($CrO_4Ca.2H_2O$) and calcium chromate(VI) hydroxide dihydrate ($Ca_2(OH)_2CrO_4.2H_2O$)), a possible calcium copper chloride known as Kuhlmann's green, a calcium sulphoaluminate ($3CaO.Al_2O_3.3CaSO_4.31H_2O$) and a calcium tungstate. The pigment known as green ashes is a calcium copper arsenic compound. Finally, calcium euxanthate is a major colouring compound in the pigment Indian yellow.

Amphibole group; Apatite group; Calcium carbonates group; Calcium chromates group; Calcium halides group; Calcium oxides and hydroxides group; Calcium phosphates group; Calcium sulfates group; Chromates group; Copper group; Feldspar group; Organo-calcium group; Silicates group; Tungsten group; Alabaster; Anhydrite; Aragonite; Bassanite; Bone; Calcite; Calcium aluminium oxide; Calcium chromate(IV) dihydrate; Calcium chromate(IV) hydroxide dihydrate; Calcium copper chloride; Calcium copper silicate; Calcium hydroxide; Calcium lead oxide; Calcium oxide; Calcium silicate; Calcium sulfate, anhydrite type; Calcium sulfate, bassanite type; Calcium sulfate, gypsum type; Calcium tungstate; Chalk; Coral; Cuprorivaite; Cupro-wollastonite; Cuttlefish bone; Diopside; Dolomite; Epidote; Fluorite; Gypsum; Huntite; Indian yellow; Lazurite; Lime; Marble; Portlandite; Scheelite; Travertine; Vaterite; Weddellite; Whewellite; Wollastonite; *Calcium sulphoaluminate*; *Eggshell*

Calcium halides group

Variable
Group term

Only one calcium halide is known to have been used as a pigment, the calcium fluoride mineral fluorite (*q.v.*). However, it has been suggested that bone (widely known as a pigment and used either as a white calcination product or a black coke) is to be considered a fluorinated calcium phosphate, fluorapatite (*qq.v.*).

Calcium group; Bone; Fluorapatite; Fluorite

Calcium hydroxide

White
Generic compound

Synthetic analogue of portlandite (*q.v.*). It may be found as a residual component of the so-called 'lime white', which is principally calcium carbonate converted from calcium hydroxide. Also known as slaked lime, hydrated lime and calcium hydrate. See also: lime.

Calcium group; Lime; Portlandite; *Lime white*

Calcium lead oxide

Brown
Generic compound

According to the *Colour Index* (1971) calcium orthoplumbate (calcium lead oxide, $CaPbO_4$; CI 77227/Pigment Brown 10) is synthesised by heating calcium carbonate with litharge (*q.v.*). The hue of the product can be varied at will from white to dark reddish buff by very slight variations in the proportions of starting components, the *Colour Index* further stating that these variations in colour cannot be imitated by mechanical mixtures. Any excess lead is present as the reddish brown 'lead calcium plumbate'.

Calcium group; Lead group; Litharge
Colour Index (1971) 77227

Calcium magnesium carbonate

White
Synonym, variant or common name

See: dolomite, huntite and the calcium carbonates group.

Calcium magnesium carbonate, dolomite type

White
Generic compound

See: dolomite.

Calcium magnesium carbonate, huntite type

White
Generic compound

See: huntite.

CALCIUM MANGANATE

Blue
Generic compound

Terry (1893) describes the accidental discovery of this compound by Kuhlmann.
See: Kuhlmann's blue and manganese blue.

Calcium group; Manganese group; *Kuhlmann's blue*; *Manganese blue*
Terry (1893) 49

CALCIUM ORTHOPLUMBATE

Brown
Synonym, variant or common name

See: calcium lead oxide.

CALCIUM OXALATE

White
Synonym, variant or common name

See: weddellite and whewellite.

CALCIUM OXALATE, WEDDELLITE TYPE

White
Generic compound

See: weddellite.

CALCIUM OXALATE, WHEWELLITE TYPE

White
Generic compound

See: whewellite.

CALCIUM OXIDE

White
Generic compound

Calcium oxide, CaO, is generally produced in the form of crystals, white or greyish white lumps or a granular powder. Commercial material may have a yellowish or brownish tint, due to the presence of iron (*Merck Index*, 1996). It is also known as lime (*q.v.*), burnt lime, *calx* and quicklime.

Hill (2001) reports the preparation of a 'partial' quicklime from coral or mollusc shells, producing a white powder containing calcium carbonate and calcium hydroxide phases which is then slaked; this was used on artefacts painted in Papua New Guinea. Calcium oxide is also found as a minor impurity in Egyptian blue (*q.v.*; Tite *et al.*, 1987).

Calcium group; Calcium oxides and hydroxides group; Lime; *Egyptian blue*
Hill (2001); *Merck Index* (1996) 1733; Tite *et al.* (1987)

CALCIUM OXIDES AND HYDROXIDES GROUP

White
Group term

The calcium oxides and hydroxides are primarily produced during the calcination of limestone (calcium carbonate) to form lime (*qq.v.*), CaO, and its subsequent slaking with water to produce calcium hydroxide ($Ca(OH)_2$), slaked lime. Calcium oxide is a very unstable compound and will readily combine with water to form calcium hydroxide. The reaction by which lime cements form, the exchange of atmospheric carbon dioxide for the hydrous component of slaked lime, is a slow process, and unconverted $Ca(OH)_2$ can linger for decades or even centuries. These materials are important as grounds and supports in panel, easel and wall paintings. For the fresco technique, pigments are combined directly with a medium of slaked lime.

The naturally occurring equivalent of $Ca(OH)_2$ is portlandite (*q.v.*). This is rare and confined primarily to volcanic environments. It has been recorded as an admixture to orpiment pigments (*q.v.*; FitzHugh, 1997).

Calcium aluminium oxide is one of the compositions associated with the pigment known as satin white (*q.v.*).

Calcium carbonates group; Calcium group; Calcium aluminium oxide; Calcium hydroxide; Calcium oxide; Lime; Limestone; Orpiment; Portlandite; *Satin white*
FitzHugh (1997)

CALCIUM PHOSPHATES GROUP

Variable
Group term

The principal interest in calcium phosphate(s) derives from their relationship to bone and ivory materials, there otherwise being little expressed interest in the literature for using the synthetic phosphates as pigments. However, 'calcium phosphate' (of an undefined type) is recorded as a component in the pigment known as Dingler's green, reputedly a mixture of chromium and calcium phosphates (Zerr and Rübencamp 1906; *Colour Index*, 1971, CI 77298/Pigment Green 17; see: Arnaudon's Chrome green). Calcium phosphate, $CaPO_4$, is also known to have been used in the early manufacture of titanium dioxide whites (*q.v.*; Laver, 1997). The chemistry of the calcium phosphates appears to be relatively complex with a number of compounds being cited in the scientific literature, including:

1. $CaPO_4$.
2. $Ca(HPO_4)$, plus mono-, 1.5- and dihydrates as well as the mineral analogues monetite and brushite.
3. $Ca(H_2PO_4)_2$, plus mono- and tetrahydrates.
4. $Ca_3(H_2PO_4)_2$ (though this is uncertain and it may either be a unique compound which readily converts to hydroxyapatite or else a mixture of hydroxyapatite and brushite or monetite).
5. $Ca_4(HPO_4)(PO_4)_2$ (considered a precursor phase in bone formation).
6. The apatite group – fluorapatite, chlorapatite and hydroxylapatite – with general formula $Ca_5X(PO_4)_3$, where X = F, Cl and OH respectively.

Additionally, the calcium carbonate phosphate mineral dahllite ($Ca_{10}(PO_4)_6(CO_3).H_2O$) has been identified in ivory (LeGeros *et al.*, 1960; McDonnell, 1965). Several of the phosphates are also known to occur in urinary calculi and may therefore be present in gallstones. A fuller discussion of calcium phosphates and allied compounds as found in bone, ivory and gallstones can be found in the relevant entries.

Apatite group; Calcium group; Bone; Bone, calcined; Chlorapatite; Dahllite; Fluorapatite; Gallstone; Hydroxylapatite; *Arnaudon's chrome green*; *Titanium dioxide white*
Colour Index (1971) 77298; Laver (1997); LeGeros *et al.* (1960); McDonnell (1965); Zerr & Rübencamp (1906/1908) 241

CALCIUM SILICATE

White
Generic compound

Both natural and synthetic calcium silicates have found use as pigments. The synthetic material is a calcium silicate hydrate of composition $CaSiO_3.nH_2O$. It is manufactured by reacting diatomaceous silica with lime in a water suspension under conditions of high temperature and pressure Kranich (1973b). According to Kranich, these synthetic, hydrous calcium silicates are characterised by extremely high absorptive capacity, very small ultimate particle size, high surface area and a varied particle structure. Commercial production of pigments of this type started in 1956, with general acceptance by around 1960; a treated form with reduced absorptive capacity for dispersion media became available in 1964. Typical applications were in paper and board products, rubber and plastics; however, they were also used as carriers for special dyestuffs. The *Colour Index* (1971) lists calcium silicate as CI 77230/Pigment White 28.

Related calcium silicates include the calcium copper silicates, Egyptian blue and wollastonite (*qq.v.*).

Calcium group; Silicates group; Wollastonite; *Egyptian blue*
Colour Index (1971) 77230; Kranich (1973b)

CALCIUM SULFATE, ANHYDRITE TYPE

White
Generic compound

This is a synthetic analogue of the calcium sulfate mineral anhydrite (*q.v.*). Two synthetic forms exist; a soluble variety γ-$CaSO_4$ which is metastable and a stable insoluble variety β-$CaSO_4$ (Bezou *et al.*, 1995). These forms are created through the thermal decomposition of gypsum ($CaSO_4.2H_2O$) during the manufacture of plaster of Paris (*qq.v.*); γ-$CaSO_4$ forms first and reverts to the stable β-$CaSO_4$ at c. 200°C.

According to Heaton (1928), calcium sulfate was also produced as a by-product of the aluminium industry. Alum ($Al_2[SO_4]_3$) was reacted with calcium acetate to produce aluminium acetate; $CaSO_4$ was produced as waste. Heaton goes on to say that this was ground and washed, then used as a pigment called *terra alba* or mineral white (*qq.v.*). The same names were also applied to pigments made from naturally occurring gypsum.

Calcium sulfates group; Anhydrite; Gypsum; *Mineral white*; *Plaster of Paris*; *Terra alba*
Bezou *et al.* (1995); Heaton (1928) 108

CALCIUM SULFATE, BASSANITE TYPE

White
Generic compound

Synthetic analogues of the calcium sulfate subhydrate mineral, bassanite, exist with the general formula $CaSO_4.xH_2O$, where x lies between 0.8 and 0.5 (Bezou *et al.*, 1995). The name hemihydrate is given to compounds with the formula $CaSO_4.0.5H_2O$.

The stable hydrate, gypsum ($CaSO_4.2H_2O$), decomposes when heated, through the subhydrates and finally to anhydrite (β-$CaSO_4$; *q.v.*). The degree of hydration of the intervening phases depends upon the conditions of heating (that is, the water vapour pressure and the surface area of the sample being heated).

The metastable phases formed during the heating of gypsum to temperatures between 70 and 90°C during the production of plaster of Paris (*q.v.*) have been shown to have the hydration states $CaSO_4.0.6H_2O$ and $CaSO_4.0.5H_2O$ (Bezou *et al.*).

Calcium sulfates group; Anhydrite; Bassanite; Gypsum; *Plaster of Paris*
Bezou *et al.* (1995)

CALCIUM SULFATE, GYPSUM TYPE

White
Generic compound

Calcium sulfate, gypsum type has the formula, $CaSO_4.2H_2O$, and is the synthetic analogue of the calcium sulfate hydrate mineral gypsum (*q.v.*).

Calcium sulfates group; Gypsum

CALCIUM SULFATES GROUP

White
Group term

A variety of forms of calcium sulfate are used as pigments, being either naturally occurring minerals (gypsum and anhydrite) or, more commonly, synthetic analogues. All are various hydration states of calcium sulfate, from that with no water – anhydrite ($CaSO_4$) – to that with two molecules of water – gypsum ($CaSO_4.2H_2O$). Hemihydrate contains half a molecule of water per calcium sulfate molecule ($CaSO_4.0.5H_2O$) and the superficially identical bassanite reportedly contains 0.5–0.8 molecules of water per calcium sulfate molecule (Bezou *et al.*, 1995). Hemihydrate and bassanite are not distinguished geologically. For fuller discussion of the geological occurrences of these minerals see the relevant entries.

The hydration states of the calcium sulfates can be changed through heating to low temperatures, and depend upon water vapour pressure and surface areas of the sample being heated. Calcining of the commonly occurring natural gypsum is used for the manufacture of plaster of Paris and related materials such as *gesso*. Calcining gypsum at temperatures of a minimum of 90°C, but usually to temperatures of 150–165°C, produces calcium sulfate subhydrates which are then reconstituted by slaking with water followed by curing (drying) in air to re-form gypsum (Manning, 1995). Heating to temperatures above 200°C produces anhydrite, which is a stable phase.

Gesso in various grades (*gesso grosso*, the coarse, base coat and *gesso sottile*, the fine, top coat) was used as a white ground in Renaissance painting (Bomford *et al.*, 1989; Cennini, 1960; Martin *et al.*, 1992). Recent work by Martin *et al.* (1992) on a large number of thirteenth to sixteenth century Italian paintings on wood has shown that the *gesso grosso* is composed predominantly of anhydrite, either natural or from heated gypsum. They found that this *gesso grosso* had widespread usage in Italian paintings throughout this period (contrasting with the work of Gettens and Mrose (1954) which suggests this practice was more or less limited to the Venetian School). The top coat, *gesso sottile*, now more usually called *gesso a oro*, was a plaster of Paris. This was also used as a base layer for the application of gold leaf.

Calcium sulfate plasters were not widely recommended for the *intonaco* for outdoor fresco painting, 'it swells and decays when exposed to the rain' (Merrifield, 1849). However, it was apparently used for internal wall paintings; 'The quality of the plaister of Paris, is to bind the Colours together' (Sanderson, 1658; cf. *OED*, 2002).

Natural calcium sulphates occur in abundant deposits throughout the Mediterranean basin. Manufacture of these materials was mainly as the by-product of the aluminium extraction industry (see Heaton, 1928 and the entry for calcium sulfate, anhydrite type, above).

Calcium sulfate pigments, both natural and synthetic, are well recognised in ancient Egyptian art of all periods (see Heywood, 2001).

Calcium group; Anhydrite; Bassanite; Gypsum
Bezou *et al.* (1995); Bomford *et al.* (1989); Cennini (c. 1400/Thompson, 1960) 70–74; Gettens & Mrose (1954); Heaton (1928) 108; Heywood (2001); Manning (1995); Martin *et al.* (1992); Merrifield (1849) 792; *OED* (2002) 'plaster of Paris'; Sanderson (1658)

CALCIUM SULPHOALUMINATE

White
Synonym, variant or common name

Composition given by the *Colour Index* (1971; CI 77235/Pigment White 33) as $3CaO.Al_2O_3.3CaSO_4.31H_2O$ (calcium aluminium oxide sulfate hydrate).
See: ettringite.

Ettringite
Colour Index (1971) 77235

CALCIUM TUNGSTATE

Yellow
Generic compound

One of a group of tungsten pigments which includes those based on barium, cadmium, cobalt and lead. Calcium tungstate has a *Colour Index* (1971) designation of CI 77250 and is also known as tungsten yellow (*q.v.*). The preparation is described, for example, by Zerr and Rübencamp (1906): 'Tungsten yellow, a deep lemon-coloured powder, obtained by grinding fine metallic tungsten powder with fused potassium carbonate [...] is precipitated with calcium chloride, whereupon calcium tungstate is formed.' However, it should be noted that calcium tungstate, $CaWO_4$, is normally described as a white compound.
See: scheelite.

Calcium group; Tungsten group; Tungsten oxides and hydroxides group; Scheelite; *Tungsten yellow*
Colour Index (1971) 77250; Zerr & Rübencamp (1906/1908) 155

CALEDONIAN BROWN

Brown
Synonym, variant or common name

Synonym for Vandyke brown (*q.v.*) in the form of a burnt sienna or umber (*qq.v.*). Salter (1869) describes it as a rich powerful colour, however by 1901 Church states that the natural earth is exhausted and substituted by 'a mixture of burnt sienna and bituminous Vandyke brown.'

Burnt sienna; *Burnt umber*; *Vandyke brown*
Church (1901) 231–232; Salter (1869) 341

CALEDONIAN WHITE

White
Synonym, variant or common name

Heaton (1928) lists this as an obsolete or rarely used pigment at that time, a synonym for 'lead chlorosulphite'. It is associated with the product known as Freeman's white (*q.v.*) and may later have come to mean a pigment composed of lead sulfate with zinc oxide (*qq.v.*).
See: lead sulfates group.

Lead group; Lead halides group; Lead sulfates group; Zinc oxide; *Freeman's white; Lead chlorosulfite*
Heaton (1928) 380

CALLIANDRA

Blue
Common generic composite

A species of *Calliandra* (*C. gracilis* Klotsch.) is listed by Wallert (1995c) as forming the basis of an organic blue colourant used for illuminating manuscripts in Mesoamerica.

Wallert (1995c)

CALUMETITE

Blue
Generic compound

Calumetite is a blue orthorhombic hydrated copper chloride hydroxide mineral with composition, $Cu(Cl,OH)_2.2H_2O$. Discovered by Williams, it is named after its type locality at Centennial mine, Calumet, Houghton County, Michigan, USA and is also known from the Tyrol (Austria) and Harz (Germany). Calumetite occurs as a secondary mineral in the oxidising portions of copper deposits where it forms as soft aggregates of spherical or scaly crystals.

It is chemically similar to anthonyite (*q.v.*) and was first identified in paintings on canvas and in fresco by Van'T Hul-Ehrnreich and Hallebeek (1972). Naumova and Pisareva (1994) have also identified calumetite on eighteenth century frescos at the Solovky monastery, Russia, while Most and Hückel (1996) have found it on a French wallhanging of 1818. The presence of calumetite was also suspected among pigments identified on the frame to Carlo Crivelli's *Annunciation* (National Gallery, London, No. 739; Smith *et al.*, 1989).

Copper group; Copper halides group; Anthonyite
Most & Hückel (1996); Naumova & Pisareva (1994); Smith *et al.* (1989); Van'T Hul-Ehrnreich & Hallebeek (1972); Williams (1963)

CAMBRIDGE WHITE

White
Synonym, variant or common name

See: Freeman's white.

CAMPANIA EARTH

Brown
Synonym, variant or common name

A synonym for Vandyke brown (*q.v.*; Feller and Johnston-Feller, 1997). This would therefore appear to be a clay from Campania, Italy. It is also possible that this is a corruption of the term *nero di terra di Campane* which translates literally as 'black from earth of bells' (Armenini, 1587) which Merrifield (1846) states was made from 'a sort of crust which forms on the moulds in which bells and cannons are cast'. Borghini (1584) however adds to the confusion by describing *Terra di campana* as the earth (clay) used to make bell moulds. It was used in fresco painting but Baldinucci (1681) says that 'when exposed to the air … the colour flies'.

Vandyke brown
Armenini (1587/edition of 1823) 122; Baldinucci (1681) 106; Borghini (1584/edition of 1787); Feller & Johnston-Feller (1997); Merrifield (1846) liii

CAMPEACHYWOOD

Blue-Purple
Synonym, variant or common name

See: logwood.

CANDLE BLACK

Black
Synonym, variant or common name

Terry (1893) specifically describes candle black as 'candle smoke condensed on a cold plate'. Eighteenth century French sources apparently distinguish two sorts of lamp black: *noir de fumée* ('smoke black') from combustion of pitch and tar and *noir de bougie* from candles (Watin, 1785).
See: carbon-based blacks group: flame carbons sub-group and lamp black.

Carbon-based blacks group; Flame carbons sub-group; *Lamp black*
Terry (1893) 25; Watin (1773/edition of 1785) 35

CAPPAGH BROWN

Brown
Synonym, variant or common name

Various sources state that the pigment Cappagh brown was derived from the Cappagh mine, on the estate of Lord Audley, ten miles west of Skibbereen in Cork, Ireland. The mine was opened in 1814 and produced a material analysed by Church (1890) which contains 34.4% iron oxide and 27.2% manganese oxide, with trace amounts of silica. Church's analysis shows that this material is convincingly inorganic and very close in composition to an umber (*q.v.*). In addition, Church observes that the pigment closely resembles raw umber but with a 'slightly reddish hue'.

However, other sources describe the pigment as 'a species of bog-earth or peat, mixed with manganese in various proportions, and found on the estate of Lord Audley at Cappagh' (Salter, 1869). Though the provenance cannot be disputed, the pigment described is totally different and more related to a lignite-based pigment similar to Vandyke brown (*q.v.*). More revealing are the comments of Weber (1923). He clearly defines the original material taken from the mine as an umber, in the geological sense, containing manganese and iron oxides. However, he goes on to say that the material 'is today obtained from various sources', and implies that a similar colour (going under the same name) was made from mixing 'bitumen' with burnt umber and burnt sienna (*qq.v.*). Whether the supplies of Lord Audley's mine were exhausted is not clear (although Heaton writing in 1928 believes they had been) but it can be assumed that the 'true' Cappagh brown umber from Cappagh mine was available to artists only from 1814 to the early twentieth century.

The pigment is sometimes spelled Cappah brown. Salter (1869) gives the alternative names euchrome and mineral brown, adding that the pigment was used for 'civil and marine painting'; it is also known as Hibernian umber.

Burnt umber; Burnt sienna; Umber; *Euchrome*; *Mineral brown*; *Vandyke brown*
Church (1890) 233–234; Heaton (1928) 380; Salter (1869) 342; Weber (1923) 31–33

CAPUT MORTUUM

Red-Purple
Synonym, variant or common name

Traditionally *caput mortuum* is associated with a synthetic reddish purple or violet pigment derived from iron(III) oxide. Harley (1982) and sources therein consider the material to be formed as a by-product of sulphuric acid manufacture during the seventeenth and eighteenth centuries. This was probably an early form of the copperas process used for the manufacture of Venetian red and copperas red (*qq.v.*). The synthetic origin of the pigment is also upheld by Church (1901); Weber (1923) also lists it among synthetic red iron oxide pigments.

More recent applications of the term (Bikiaris *et al.*, 1999; Daniila *et al.*, 2002; Oliveira *et al.*, 2002) appear to refer to naturally occurring and heat treated hematite-rich pigments producing a 'violet' colour used in Roman, Byzantine and post-Byzantine art. Here, and perhaps due to the Latin name, *caput mortuum* is directly related to the purple pigments documented by the Roman authors Pliny (77 AD) and Vitruvius (first century BC), although the name was never used by either and in fact is unknown from other classical sources. However, it has been used synonymously with Pliny's and Vitruvius' *usta* and *ostrum* although the link between these materials is, at best, tenuous. The pigments of these names described by Vitruvius refer specifically to Tyrian purple and Pliny's *usta* refers to burnt *cerussa* (red lead; *qq.v.*).

In a recent paper, Oliveira *et al.* (2002) have Raman spectroscopy to characterise various modern purple iron oxide pigments called *caput mortuum*, supplied by Kremer. They note that variation in colour in these samples is related to particle size; the darker hues have the largest particle size. However, they consider 'real' *caput mortuum* to be that used in Roman contexts. In this case (Rushton Roman villa, UK) the pigment is identified as hematite mixed with calcium carbonate and kaolinite (*qq.v.*), and again is unrelated to wet chemically precipitated compounds.

Caput mortuum is broadly synonymous with terms applied to the synthetic red iron oxides including Venetian red, Spanish brown and colcothar (*qq.v.*). *Caput mortuum* violet and *caput mortuum vitrioli* are also used. *Caput mortuum* is Latin for 'death's head'. The phrase, in this context, is *not* of Roman origin and was originally used by early seventeenth century alchemists to refer to the 'worthless' residue left after experiments; it 'is the last element of all bodies which can be no farther altered by any art whatsoever' (Sullivan, 1794). Iron(III) oxide would certainly exist in such contexts, due to its extreme stability. According to Harley (1982) the name first appeared in the eighteenth century referring to a pigment. In view of the alchemical derivation of this term and the fact that it did not appear in the classical literature, the name is best used to refer to synthetic, wet-chemically manufactured forms of iron(III) oxide pigments. The authors do not recommend the use of *caput mortuum* applied to pre-seventeenth century synthetic iron(III) oxide pigments and it is an anachronous term when applied to Roman contexts.

Iron oxides and hydroxides group; Hematite; Iron(III) oxide, hematite type; Kadinite; *Burnt vitriol*; *Cerussa*; *Colcothar*; *Copperas*; *Red lead*; *Spanish brown*; *Tyrian purple*; *Venetian red*
Bikiaris *et al.* (1999); Church (1901) 179; Daniila *et al.* (2002); Harley (1982) 121–122; Oliveira *et al.* (2002); Pliny (1st cent AD/Rackham, 1952) XXXV.xii, XXXV.xx; Sullivan (1794) 135; Vitruvius (1st cent BC/Grainger, 1934) VII.xiii.1; Weber (1923) 64

CARAJURIN

Orange
Generic compound

The xanthone carajurin, anhydro-6,7-dihydroxy-5-methoxy-2-(4-methoxyphenylbenzopyranol), is the main colouring compound of *Bignonia chica* Humb. and Bonpl. (Bignoniaceae) (Schweppe, 1992). It is listed in the *Colour Index* (1971) as CI 75180/ Natural Orange 5.
See: chica.

Xanthones group; *Chica*
Colour Index (1971) 75180; Schweppe (1992) 434, 439

CARBAZOLE VIOLET

Purple

Synonym, variant or common name

See: polycyclic pigments group: dioxazine sub-group.

CARBON BLACK

Black

Synonym, variant or common name

The term carbon black is often used rather loosely to mean any pigment based on carbon. However, Winter (1983) recommends a tighter definition – using it specifically for certain modern forms of black – while proposing 'carbon-based black' as a more suitable umbrella term. There will necessarily be scope for confusion when reading the older literature.

Toch (1916) gives a clear description of the more specific meaning of the term, stating that 'Carbon black is in all respects similar to lampblack [*q.v.*], except that it is intensely black in color, and while it shows no crystalline structure under the microscope it condenses itself so hard on the places from which it is scraped that it is largely interspersed with flakes of black which to all appearance are crystalline and are very refractory in the mill.' Heaton (1928) defines carbon black as specifically 'carbon from natural gas', that is a carbon-based black formed from the incomplete combustion of natural gas (see: gas black). See: carbon-based blacks group.

Carbon-based blacks group; *Gas black*; *Lamp black*

Heaton (1928) 380; Toch (1916) 100; Winter (1983)

CARBÓN DE PIEDRA MOLIDA

Black

Synonym, variant or common name

A term used in the treatise of 1693 by Garcia Hidalgo (1693, cf. Veliz, 1986). Veliz translates *carbón de piedra molida* as coal (*q.v.*).

Coal

Garcia Hidalgo (1693); Veliz (1986) 211, n.9

CARBONATE OF LIME

White

Synonym, variant or common name

See: calcium carbonates group.

CARBONATE-HYDROXYLAPATITE

Variable

Generic compound

Carbonate-hydroxylapatite is synonymous with dahllite (*q.v.*), a calcium phosphate mineral which belongs to the apatite group (*q.v.*).

Apatite group; Calcium group; Calcium phosphates group; Dahllite

CARBON-BASED BLACKS GROUP

Black-Brown

Group term

Following the convention proposed by Winter (1983), the term carbon-based black is used to denote a group of black or brown pigments composed primarily of carbon. This allows distinction from carbon black, a term of more specific (and therefore potentially confusing) meaning as a form of flame carbon. Carbon-based black pigments may be divided into four groups depending primarily on their mode of preparation, the exception being the crystalline carbons; within each group, distinction may be drawn by source material or manufacturing process:

Crystalline carbons: Graphite and its synthetic analogue; chaoite and lonsdaleite.

Chars: Bark chars (such as from *Betula* spp., 'Swedish black', and *Quercus suber*/*occidentalis* spp., 'cork black'), fruitstone chars, paper chars, wood chars (such as from *Vitis* spp., 'Vine black', and *Fagus* spp., 'beech black').

Cokes: Bone, ivory and antler ('horn') cokes; yeast cokes.

Flame carbons: These may be commonly sub-grouped according to criteria such as the precursor material (for example, from hydrocarbon precursors such acetylene black, channel black, lamp black, or from wood precursors such as with 'Chinese ink' and bistre) or according to whether the pigment is quenched on a cool surface (impingement black) or in chimneys (lamp black).

Fullerenes, macromolecular species of carbon (C_{60}, C_{70}), are likely to form under some or most of the conditions used to produce carbon-based black pigments but have not, thus far, been identified in such specific pigment contexts. However, the rare rock-type shungite (*q.v.*) is currently being marketed as a pigment and is known to contain fullerenes. Additionally, although it might be implied above that the latter three groups are 'non-crystalline', in fact different degrees of internal ordering are often present. Studies have shown, for example, that flame carbon particles consist of relatively disordered nuclei surrounded by concentrically deposited carbon layers, the carbon atoms in each layer being arranged in almost the same manner as graphite; the relative position of each layer though is random, giving what is known as a 'turbostratic' structure.

It should also be noted that a very wide variety of source materials can be used to produce carbon-based blacks, particularly when studied, say, at the level of specific plants used in the manufacture of chars. From a study of documentary sources it is clear that certain sources were favoured at particular times and places. Therefore it is also not surprising that significant areas of the terminology surrounding this group relate overtly to manufacturing processes rather than precursor material – terms such as channel black and lamp black, to name but two, are good examples. Winter differentiates practical pigments along these lines, listing those of mineral origin (graphite and black earth/chalk), soots and smokes (carbon black; lamp black and soot, and biste), pigments made from vegetable materials (such as charcoal, fruitstone blacks and cork black) and pigments from animal materials (bone and ivory black).

Carbon-based blacks group: Chars sub-group; Carbon-based blacks group: Cokes sub-group; Carbon-based blacks group: Crystalline carbons sub-group; Carbon-based blacks group: Flame carbons sub-group; Shungite

Winter (1983)

CARBON-BASED BLACKS GROUP: CHARS SUB-GROUP

Black

Group term

Winter (1983) defines chars as carbons formed from solid precursors that remain solid through the carbonisation process. As a result, the end products retain much of the morphology of the starting material, unlike cokes. A common example of this type of relict structure is to be found in wood chars ('charcoal'). Chars are also frequently highly porous, often with chemically active surfaces. At a molecular level, chars tend to have structures that are less readily converted to graphite and therefore generally belong to the class of so-called 'non-graphitisable' or 'hard' carbons. This is because since the material remains in the solid state throughout the conversion process, carbon atoms and atom groups are severely hindered in their ability to rearrange, a process required to assist crystallisation. Several views are taken on the possible structures underlying this. Franklin (1951), for example, postulated crystallites randomly arranged and locked in position by regions of non-organised carbon; Jenkins and Kawamura (1976) on the other hand envisaged polymeric carbon based on tangled, intertwined graphitic ribbons. Whichever structure is involved, the resulting material is physically isotropic.

The first step in carbonisation of wood or similar material is the drying out of the material at 100°C or below to zero moisture content. The temperature of the oven dry wood is then raised to about 280°C. The energy for these steps comes from partial combustion of some of the wood charged to the kiln or pit, which is an energy absorbing endothermic reaction. When the wood is dry and heated to around 280°C, it begins to spontaneously break down to produce charcoal plus water vapour, methanol, acetic acid and more complex chemicals, chiefly in the form of tars and non-condensable gas consisting mainly of hydrogen, carbon monoxide and carbon dioxide. Air is admitted to the carbonising kiln or pit to allow some wood to be burned and the nitrogen from this air will also be present in the gas. The oxygen of the air is used up in burning part of the wood charged. The spontaneous breakdown or carbonisation of the wood above a temperature of 280°C liberates energy and hence this reaction is said to be exothermic. This process of spontaneous breakdown or carbonisation continues until only the carbonised residue of charcoal remains. Unless further external heat is provided, the process stops and the temperature reaches a maximum of about 400°C. This charcoal, however, will still contain appreciable amounts of tarry residue, together with the ash of the original wood. The ash content of the charcoal is about 3–5%; the tarry residue may amount to about 30% by weight and the balance is fixed carbon, about 65–70%. Further heating increases the fixed carbon content by driving off and decomposing more of the tars. A temperature of 500°C gives a typical fixed carbon content of about 85% and a volatile content of about 10%. The yield of charcoal at this temperature is about 33% of the weight of the oven dry wood carbonised (FAO, 1983).

Chars may be formed from a very wide range of materials, most notably cellulosic plant material. While no realistic limit can be placed on the sources that may have been employed historically, certain types have been expressed consistently in the literature. These include bark chars (such as from *Betula* species, 'Swedish black', and *Quercus suber* L., 'cork black'), fruitstone chars, paper chars, wood chars (for example, from *Vitis* species to give 'vine black', and *Fagus* species, giving 'beech black'). The presence of alkali metal carbonates in wood chars has been noted by Winter.

A black pigment has been produced historically by thermal decomposition of various fruit kernels such as those from peach (*Prunus persica*), cherry (*Prunus* spp.), date (*Phoenix dactylifera*), almond (*Prunus amygdalus*), walnut (*Juglans* spp.), coconut (*Cocos nucifera*) and so forth. Botanically most of these are what are known as drupes – fleshy fruit that develop from either one or several fused carpels (the female reproductive organ of a flower) and contain one or more seeds. The seeds themselves are enclosed by the hard protective endocarp, which is the inner part of the pericarp or fruit wall (the part of a fruit which develops from the ovary wall of a flower) of the fruit; thus the stone of a drupe is the endocarp containing the seed. The exception among those fruit mentioned above is the date, which is a berry, the stone being the seed with no additional covering. Therefore it is the endocarp which provides the principal material for the pigment char with drupes, but the seed of the date (Lowson, 1973). Chars may retain some structural features of the material from which they are prepared, so could reflect these distinctions. Different historical authors recommend a range of starting materials. Harley (1982), for example, found among English seventeenth century writers advice to use peach stones (MS 86.EE.69), cherry and date (Hilliard, 1624), almond shells (Lomazzo/Haydocke, 1584, 1598) and walnut shells (Peacham, 1612). Church (1901) listed various blue blacks under the name charcoal black: 'Coconut yields the densest, most velvet-like black; vine shoots a less solid black, having a bluish hue. Washed wine lees yield a rich black – Frankfort black'; he also commented on imitations of lamp black and indigo (*qq.v.*). Among the chars, Yü (1955) mentions 'Rice-paper plant ash'; the stem pith of the plant *Tetrapanax papyrifer* (Hook.) K. Koch is put in an iron tube where it is burned to produce ash; he claims that it was used for painting moths and butterflies.

Numerous analyses of artworks record the use of chars, though these are typically undifferentiated as to source material. A few examples of the many identifications include: Scott and Schilling (1991) noting charcoal as one of the pigments on the Canosa vases (J. Paul Getty Museum); Béarat (1997) found charcoal (as well as flame carbon and bone cokes) among 550 analyses carried out on wall painting fragments and raw pigments from 14 different Roman sites in Switzerland as well as Pompeii, Italy; Scott *et al.* (1998) identified charcoal in the first century AD Moche site of La Mina in the Jequetepeque Valley, Peru, while Scott and Hyder (1993) record charcoal on Chumash Indian rock art. American nomadic Plains Indian tribes used charcoal to decorate tipis (Brasser, 1982). Watchman *et al.* (1993) record charcoal in rock paintings in the Laura region of Cape York Peninsula, Australia; Tworeil-Matuszkiewicz (1989) mentions charcoal as a 'traditional' pigment for the production of Australian Aboriginal bark paintings. Plahter (1990) describes the presence of charcoal black on the capital-lion (carved lion) from Vossestrand (Norway), a polychromed wooden sculpture dated to the late twelfth or early thirteenth century. Howard (1990) documents the production of a blue colour through the use of charcoal in two early English mediaeval wall paintings of the so-called 'Lewis' group. Richter and Härlin (1976) found charcoal as a pigment on mediaeval playing cards from the Württembergisches Landesmuseum in Stuttgart dating from about 1430. As a drawing medium, Finaldi *et al.* (1995) note the use of charcoal by Annibale and Agostino Carracci to execute cartoons (National Gallery, London) for a completed design in the Palazzo Farnese in Rome. Sawicki (1997) found charcoal among pigments used in frescos by the seventeenth century Italian artist Michelangelo Palloni. Bomford *et al.* (1988) record Rembrandt's use of charcoal as a pigment, Kühn (1968) records Vermeer's use of charcoal among 30 paintings he examined, while Butler (1983) found charcoal among ten paintings by or attributed to Jan Steen (1626–79). Cove (1991) found that Constable used charcoal in his paintings throughout his career.

Jirat-Wasiutynski *et al.* (1984) found charcoal in various paintings by van Gogh from his Arles period (1888–89).

Charcoal is also a suitable material for radiocarbon dating and several measurements have been reported on examples from rock art sites (for example, Geib and Fairley, 1992; Hyman and Rowe, 1997).

Carbon-based blacks group; *Blue black*; *Frankfort black*; *Grape black*; *Indigo*; *Lamp black*; *Noir de vigne*; *Rebenschwartz*; *Vine black*
Béarat (1997); Bomford *et al.* (1988); Brasser (1982); Butler (1983); Church (1901) 243; Cove (1991); FAO (1983) 4.1; Finaldi *et al.* (1995); Franklin (1951); Geib & Fairley (1992); Harley (1982) 158; Hilliard (1624/Thornton & Cain, 1981) 92; Howard (1990); Hyman & Rowe (1997); Jenkins & Kawamura (1976); Jirat-Wasiutynski *et al.* (1984); Kühn (1968); Lomazzo/Haydocke (1584/1598); Lowson (1973) 378–379; MS 86.EE.69 (nd); Peacham (1612); Plahter (1990); Richter & Härlin (1976); Sawicki (1997); Scott & Hyder (1993); Scott & Schilling (1991); Scott *et al.* (1998); Tworeil-Matuszkiewicz (1989); Watchman *et al.* (1993); Winter (1983); Yü (1955/trans. Silbergold & McNair, 1988) 15

CARBON-BASED BLACKS GROUP: COKES SUB-GROUP

Black
Group term

Cokes may be defined as any carbonised product for which the precursor was in a liquid or plastic state immediately before carbonisation (Winter, 1983). Typically the precursor will be a solid material that fuses on heating, such as gelatin or sugar, though many bituminous coals (*qq.v.*) undergo a similar plastic transition during the pyrolysis process that forms the ‘coke’ of commerce. By implication, the resulting material bears little morphological relationship to the original microstructure, this being lost during the plastic flow involved in formation. Cokes have structures on a molecular level which allows them to be converted to crystalline graphite; hence they are sometimes known as ‘graphitisable’ carbons. Various sources of starting material are reported in the historical literature, notably bone (this includes antler and ivory) and yeast, and according to the *Colour Index* (1971; CI 77268/Pigment Black 8), grade black or coke black is a fine product obtained from the coke produced in the Thuringian lignite (coal) industry.

The yeast coke, yeast black (sometimes also referred to as wine lees black or vine black, though this can mean a wood char of *Vitis* spp.), is prepared by carbonising spent yeasts and wine lees; it was once favoured for printing inks (Harley, 1982). Vitruvius (first century BC) and others mention that a colour akin to indigo (*q.v.*) may be produced by burning the lees of the finest wines. A plausible interpretation of this is that an ‘optical’ blue is being produced, where mixtures of finely-divided black pigments with white appear blue to an observer. Pliny (77 AD) states that the Athenian painters Polygnotus and Micon prepared a vine black which they called *tryginon* (grape lees). Tingry (1804) states that dried lees produce a coarser black than that produced using lees which have been washed and burnt with tartar (according to the *Oxford English Dictionary*, 2002, tartar is a ‘bitartrate of potash [acid potassium tartrate], present in grape juice, deposited in a crude form in the process of fermentation, and adhering to the sides of wine-casks in the form of a hard crust’). This pigment was produced in France and on a large scale in Germany, thus it is also called Frankfort black and German black.

The bone cokes are essentially calcined bone, the organic phase – collagen – forming a black to brown coke on an inorganic hydroxylapatite (*q.v.*) substrate. Toch (1916) describes a preprocessing step in which the inorganic carbonate is dissolved using a mineral acid such as hydrochloric acid; this allowed a much more intense black to be prepared, which Toch calls ‘black toner’, since it was used as an additive to other blacks. Deterioration of bone blacks in fresco painting (attributed to the action of calcium on residual collagen) has been discussed by Marzetti and Scirpa (2000).

Numerous identifications of bone/ivory black are reported in the literature. Oellermann (1993) found it used for painting of the thirteenth century tomb of the Count Palatine Henry II. McGrath (1984) reports bone black in Irish twelfth to sixteenth century wall paintings. Bortolaso and Appolonia (1992) found it in materials used for St Orso’s Cloister in Aosta, Italy. Orna and Mathews (1981) have identified bone black used on the Armenian Glajor Gospel book. Plesters (1978) reported bone/ivory black in Bellini’s *Blood of the Redeemer*, Dunkerton and Roy (1986) on Cima’s *The Incredulity of S. Thomas*, Bomford *et al.* (1986) in two paintings by Dieric Bouts and Wyld *et al.* (1979) on Gerard David’s *The Virgin and Child with Saints and Donor* (all paintings National Gallery, London). Groen (1978) identified bone black among five polychrome stone sculptures of the late fifteenth century in Utrecht. Bone black was found in the paintings of Vermeer by Kühn (1968), by Butler (1983) on paintings by Jan Steen and by Gifford (1983) on several paintings by Jan Van Goyen and Salomon van Ruysdael. Talley and Groen (1975) found bone black in their examination of the materials of the eighteenth century artist and writer on painting Thomas Bardwell. Bomford and Roy (1982) found bone black among pigments used by Hogarth for his *Marriage à la Mode* series. Bone black has been reported by Albertson and Coddington (1981) from an examination of two paintings by Francesco Guardi, and by Ashworth *et al.* (1988) among seven paintings by Charles Wilson Peale (1721–80). Richter and Härlin (1974a) found bone/ivory black in a nineteenth century pigment collection and bone black was found among watercolour pigments on Audubon’s *The Birds of America* by Adair and Young (1981). Finally, Seurat’s *La Grande Jatte* reportedly contains bone black (Fiedler, 1984) while Butler (1984) identified bone black when investigating the materials of Paul Cézanne.

A large group of related terms indicates the relative importance of bone black pigments. These include *atramentum*, which could refer to an ivory or wine lees black; ivory black (*noire d’ivoire*); bouju b.; Frankfort b. and Paris b.

Carbon-based blacks group; Antler; Antlerite; Bitumen; Bone; Coal; Indigo; Hydroxylapatite; Yeast; *Animal black*; *Atramentum*; *Black toner*; Borja black; *Drop black*; *Frankfort black*; *German black*; *Ivory black*; *Paris black*; *Wine lees black*
Adair & Young (1981); Albertson & Coddington (1981); Ashworth *et al.* (1988); Bomford & Roy (1982); Bomford *et al.* (1986); Bortolaso & Appolonia (1992); Butler (1983); Butler (1984); *Colour Index* (1971) 77268; Dunkerton & Roy (1986); Fiedler (1984); Gifford (1983); Groen (1978); Harley (1982); Kühn (1968b); Marzetti & Scirpa (2000); McGrath (1984); *OED* (2002); Oellermann (1993); Orna & Mathews (1981); Plesters (1978); Pliny (1st cent AD/Rackham, 1952) XXXV.xxv.42; Richter & Härlin (1974a); Talley & Groen (1975); Tingry (1804) 349; Toch (1916) 97–98; Vitruvius (1st cent BC/Grainger 1934) VII.x.4; Winter (1983); Wyld *et al.* (1979)

CARBON-BASED BLACKS GROUP: CRYSTALLINE CARBONS SUB-GROUP

Black
Group term

Of the forms of crystalline carbon which exist in nature, only graphite (*q.v.*), as natural and synthetic material, appears to have been used to any extent as a pigment. Other crystalline carbons (chaoite and lonsdaleite) are sufficiently rare to be unlikely to be encountered, though presumably their synthesis is possible. However, it should be noted that other forms of carbon-based blacks are not necessarily without internal order; for example flame carbons may have what is known as 'turbostratic' structure, consisting of sequentially random layers of carbon atoms arranged graphitically.

Carbon-based blacks group; Chaoite; Graphite; Lonsdaleite

CARBON-BASED BLACKS GROUP: FLAME CARBONS SUB-GROUP

Black
Group term

Flame carbons are defined by Winter (1983) as comprising any carbon produced in the gas phase, arising from the incomplete combustion of hydrocarbon precursors. Typically they are formed from flames that give rise to soot, although some industrial forms are made by gas-phase pyrolysis rather than by combustion. Soot as a by-product of combustion is a poorly defined material that often contains, besides the carbon black particles, significant amounts of ash and high levels of polycyclic aromatic hydrocarbons (PAH), perhaps as much as 30% (Buxbaum, 1998).

Structural studies have shown that flame carbon particles consist of relatively disordered nuclei surrounded by concentrically deposited carbon layers, the carbon atoms in each layer being arranged in almost the same manner as graphite (*q.v.*); the relative position of each layer though is random, giving what is known as a 'turbostratic' structure. The surfaces of these carbon blacks also contain certain amounts of polynuclear aromatic compounds that are strongly adsorbed and difficult to extract. Up to perhaps 15% oxygen can additionally be present in modern flame carbons, its presence having a huge impact on the properties of the pigments since it is bound to the surface in the form of acidic and basic functional groups. The level of oxygen is dependent on the atmosphere at the time of formation; reducing atmospheres, such as occur with 'furnace' and 'thermal' blacks, will lead to low oxygen levels and vice versa; oxidising environments such as occur with 'gas' and 'channel' blacks lead to high oxygen levels.

Flame carbons may be conveniently differentiated on the basis of source material and/or the formative process. For example, hydrocarbon sources are used to prepare acetylene black, channel black and lamp black; from combustion of wood, products as 'Chinese ink' (by combustion of pine wood) and bistre are obtained.

Lamp black is prepared by burning oils, resins and, more specifically, rosin and pitch, the soot being collected when these are set on fire; coal can also be the source. French eighteenth and nineteenth century sources distinguish two other sorts: *noir de fumée*, from the combustion of pitch and tar, and *noir de bougie*, from candle wax (Carlyle, 2001). Yü (1955) describes what he calls 'chimney ink' or 'pan-bottom soot', the black soot obtained from burning wood or vegetable matter; in Chinese art this was apparently 'always' used for painting beards, hair, feathers and fur.

Modern techniques of carbon black manufacture are highly refined with a great degree of control over the final product. Buxbaum differentiates methods of 'incomplete' combustion, covering the furnace black, gas black, channel black and lamp black processes, and 'thermal cracking', which includes thermal black and acetylene black processes. The furnace black process was developed in the US in the 1920s and involves injecting an atomised feedstock (petrochemical or coal tar oils) into a high-temperature reactor furnace. The channel black process, used in the US since the late nineteenth century, involved the use of natural gas as feedstock, the carbon black particles collecting on specially designed iron channels; in the related gas black, so-called Degussa process, the feedstock is partially vaporised, then carried by a combustible carrier gas, mixed with air and pyrolysed. Other processes for producing carbon black, such as the thermal and acetylene black processes, are based on the thermal decomposition of lower gaseous hydrocarbons such as natural gas or acetylene in the absence of air. The thermal black process, developed in the 1930s, differs from other methods in that the production of carbon is discontinuous, the furnace being heated prior to introduction of the gaseous material for conversion. In the acetylene black process use is made of the fact that, unlike other hydrocarbons, the decomposition is exothermic (that is, it generates heat rather than absorbing it); the reaction is therefore self-maintaining.

Carbon-based blacks group; Bistre; Graphite; *Acetylene black*; *Channel black*; *Furnace black*; *Gas black*; *Lamp black*; *Thermal black*
Buxbaum (1998) 143–179; Carlyle (2001) 185; Winter (1983); Yü (1955/trans. Silbergold & McNair, 1988) 15

CARDENILLO

Green
Synonym, variant or common name

The eighteenth century Spanish author Palomino lists verdigris (*q.v.*) as *verdete* or *cardenillo* (Palomino, 1715–24; cf. Kühn, 1993).

Verdigris
Kühn (1993); Palomino (1715–24)

CARMINE

Red
Synonym, variant or common name

This term was applied generally to the scale insect lakes; however, due to the predominance of cochineal (*q.v.*) as an insect lake source by the seventeenth century it was by then commonly understood to mean a cochineal lake, and was in use as such generally toward the end of the seventeenth century (Harley, 1982). Field (1835) also states that it was 'A name originally given only to the fine feculences of kermes and cochineal tinctures, denotes generally at present any pigment which resembles them in beauty, richness of colour, and fineness of texture. Hence we hear of blue and other coloured carmines, though the term is principally confined to the crimson and scarlet colours produced from carmine by the agency of tin.' Salter (1869) adds that it was sometimes mixed with starch, vermilion (*qq.v.*) or extra alumina.

For a fuller discussion see: cochineal, kermes and lac.

Insect-based reds group; Cochineal; Kermes; Lac; Starch; Vermilion
Field (1835) 100–101; Harley (1982) 135; Salter (1869) 133–134

CARMINE ALIZARINE

Red
Synonym, variant or common name

See: alizarin.

Carmine lake
Red
Synonym, variant or common name

According to Field (1835), although the name carmine was originally only given to cochineal- or kermes-based lakes (*qq.v.*), it became used for any pigment 'which resembles them in beauty, richness of colour, and fineness of texture; hence we hear of blue and other coloured carmines, though the term is principally confined to the crimson and scarlet colours produced from cochineal by the agency of tin'.

Carlyle (2001) also notes a number of terminological forms listed by English colourmen for cochineal lakes such as carmine, crimson lake, crimson lake extra, extra carmine lake, and crimson lake extra fine. Further, combinations of vermilion (*q.v.*) and carmine were given names such as carmine vermilion and Florentine and Chinese lake.

Cochineal; Kermes; Vermilion; *Vienna lake*
Carlyle (2001) 506–507; Field (1835) 100–101

Carminic acid

Carminic acid, 7-a-D-glucopyranosyl-9,10-dihydro-3,5,6,8-tetrahydroxy-1-methyl-9,10-dioxo-2-anthracenecarboxylic acid, is the principal dyestuff in cochineal, which is obtained by extraction from the insects of the *Porphyrophora* and *Dactylopius* species. An essential constituent of carmine, it is a complex polyhydroxylated carboxylic acid ($C_{21}H_{20}O_{13}$) comprising three fused carbocylic rings (based on anthracene, see anthraquinones group) which is a dark, purplish-brown mass or bright red powder decomposing at 136°C. For a discussion of the various cochineal insects see: cochineal. Listed in the *Colour Index* (1971) as CI 75470.

Anthraquinones group; Cochineal
Colour Index (1971) 75470

Carnagione
Pink
Synonym, variant or common name

See: carnation.

Carnation
Pink
Synonym, variant or common name

A term covering those mixtures of pigments used for flesh tints rather than any particular pigment *per se*. For example, Harris (1704–10) says that 'Carnation, is a Term in Painting, signifying such Parts of an Human Body as are drawn naked … or what express the bare Flesh; and when this is done Natural, Bold, and Strong, and is well coloured, they say of the Painter, that his Carnation is very good' (cf. *OED*, 2002). The Italian form *carnagione* is also sometimes encountered, with essentially the same meaning. Veliz (1986) defines the Spanish *encarnación* as 'the painted flesh tones for a sculpted figure and the colour tempered for this purpose'.

Harris (1704–10); *OED* (2002) 'Carnation'; Veliz (1986) xvii

Carotene, β-
Red
Generic compound

Strictly β,β-carotene, is the most important of the provitamins A and is widely distributed in plants and animals (*Merck Index*, 1996). As a dyestuff it may be derived from various *Cuscuta* species (*C. tinctoria* Mart., *C. americana* Lin. and *C. odontolepis* Engelmann), where it occurs almost always together with chlorophyll (*q.v.*).
See: cuscuta.

Carotenoid group; Chlorophyll; Cuscuta
Merck Index (1996) 1902

Carotenoid group
Variable
Group term

Carotenoids are a class of hydrocarbons (carotenes) and their oxygenated derivatives (xanthophylls) consisting of eight isoprenoid units joined in such a manner that the arrangement of isoprenoid units is reversed at the centre of the molecule so that the two central methyl groups are in a 1,6-positional relationship and the remaining non-terminal methyl groups are in a 1,5-positional relationship. All carotenoids may be formally derived from the acyclic $C_{40}H_{56}$ structure, having a long central chain of conjugated double bonds (IUPAC, 1974). For structure, see below.

Specific carotenoid compounds found in pigments include:

Bixin, from stamens of *Bixa orellana* L.
β-carotene, from *Cuscuta* species (*C. tinctoria* Mart., *C. americana* Lin. and *C. odontolepis* Engelmann).
Crocetin, 'Saffron', from stamens of *Crocus sativus* L. and other *C.* spp., and seeds of *Gardenia jasminoides* Ellis.

Bixa; Bixin; Carotene, β-; Crocetin; Cuscuta; Saffron; *Gardenia seed*
IUPAC (1974)

Carphosiderite
Yellow
Synonym, variant or common name

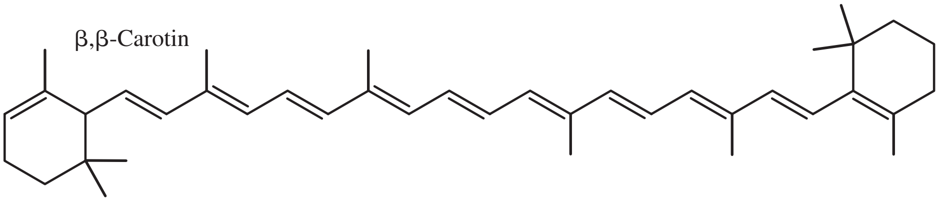
See: hydronium-jarosite.

Carthame
Red-Orange-Yellow
Synonym, variant or common name

See: safflower.

Carthamin
Red
Generic compound

Carthamin (6-β-D-glucopyranosyl-2-[[3-β-D-glucopyranosyl-2,3,4-trihydroxy-5-[3-(4-hydroxyphenyl)-1-oxo-2-propenyl]-6-oxo-1,4-cyclohexadien-1-yl]methylene]5,6-dihydroxy-4-[3-(4-hydroxyphenyl)-1-oxo-2-propenyl]-4-cyclohexene-1,3-dione) is a


β,β-Carotin

red benzoquinone dye that exists as geometric isomers in dyer’s saffron (*Carthamus tinctorius* L.; Compositae) (*Merck Index*, 1996). It is designated by the *Colour Index* (1971) as CI 75140.
See: safflower.

Quinones group; Saffron
Colour Index (1971) 75140; *Merck Index* (1996) 1918

Casali’s green
Green
Synonym, variant or common name

Apparently a variety of viridian (Zerr and Rübencamp, 1906). However, Bersch (1901) discusses a method for producing a chromium oxide pigment (that is, not the hydrate) according to A. Casali, involving calcination of potassium bichromate with burnt gypsum, then boiling with dilute hydrochloric acid to remove the lime formed. Coffignier (1924) also states that Casali’s green is a chromium oxide.
See: viridian and chromium oxide.

Chromium group; Chromium oxide hydrate; Gypsum; *Viridian*
Bersch (1901) 261; Coffignier (1924) 456; Zerr & Rübencamp (1906/1908) 241

Cashew lake
Red
Synonym, variant or common name

See: mahogany lake.

Cassel earth
Brown
Synonym, variant or common name

A humic earth, typically associated with the so-called Vandyke brown (*qq.v.*). Salter (1869), for example, describes it as ‘an earth containing bitumen … [d]eposited at the bottom of seas, lakes, or rivers, and subsequently covered up by the accumulations of clay and sand, the organic tissue undergoes a kind of fermentation by which the bodies in question are slowly produced.’ It could also be calcined to give a darker colour.

Alternate terms cited in the literature include *Terre de Cassel* and castle earth (Salter, 1869) also Kassel earth (Feller and Johnston-Feller, 1997). Heaton (1928) gives Cassel earth as an obsolete term.

Humic earth; *Vandyke brown*
Feller & Johnston-Feller (1997); Heaton (1928) 380; Salter (1869) 343–344

Cassel green
Green
Synonym, variant or common name

Gentele (1860) lists Kassel green as one of the names applied to emerald green (*q.v.*). Mayer (1991) lists Cassel green as a synonym for manganese green (*q.v.*), a term of uncertain nature.

Emerald Green; *Manganese green*
Gentele (1860) 253; Mayer (1991) 41

Cassel yellow
Yellow
Synonym, variant or common name

Heaton (1928) lists Cassel yellow as an obsolete or rarely used pigment synonymous with Turner’s yellow (lead chloride oxide; *q.v.*).

Lead chloride oxide; *Turner’s yellow*
Heaton (1928) 390

Casselmann’s green
Blue-Green
Synonym, variant or common name

Casselmann’s green is reportedly copper hydroxide sulfate hydrate $CuSO_4.3Cu(OH)_2.\frac{1}{2}H_2O$, a synthetic analogue of the mineral brochantite (*q.v.*). According to the *Colour Index* (1971) the commercial product – Casselmann’s green – contains some arsenious oxide. The discoverer, Arthur Casselmann, was born in Felsberg near Cassel in 1828 and died in St Petersburg, Russia, in 1872. He was a student of the renowned chemist Wohler.

Copper group; Brochantite; Copper hydroxide sulfate hydrate
Colour Index (1971)

Cassia fistula
Yellow-Brown
Synonym, variant or common name

This pigment is best described by quoting Field (1835) in full: ‘Cassia fistula is a native vegetal pigment, though it is more commonly used as a medicinal drug. It is brought from the East and West Indies in a sort of cane, in which it is naturally produced. As a pigment it is deep, transparent, and of an imperfect citrine colour, inclining to dark green – diffusible in water, without grinding, like gamboge and sap green: it is, however, little used as a pigment, and that only in water, as a sort of substitute for bistre [*qq.v.*].’

Cassia fistula L. (‘pudding-pipe tree’, ‘purging cassia’, ‘Indian laburnam’ and ‘golden shower’) is widely cultivated in tropical Asia, the fruits growing to 60 cm with seeds embedded in a laxative pulp (Mabberley, 1998). There are a number of other *Cassia* spp. (Leguminosae) known to produce anthraquinone dyes, so that, apart from *Cassia fistula* L. itself, Schweppe (1992), for example, lists *C. angustifolia* Vahl., *C. auriculata* L., *C. senna* L. and *C. tora* L. as sources. However, current botanical terminology is more complex and, while *C. fistula* L. remains, others have been reassigned to a *Senna* spp., so *C. Senna* is now, for example, *S. alexandrina Miller* and *C. auriculata* = *S. auriculata* (L.) Roxb. The chemistry of *C. fistula* has been studied by Lee *et al.* (2001), who identified some 27 distinct compounds extractable from the bark; these included eight anthraquinones such as chrysophanol and emodin; Schweppe lists aloe-emodin, chrysophanol, rhein (*qq.v.*), rheidin and sennosides A–D.

Aloe-emodin; Bistre; Chrysophanol; Emodin; Gamboge; Rhein; *Sap green*
Field (1835) 142; Lee *et al.* (2001); Mabberley (1998) 132; Schweppe (1992) 200, 211–215, 252

Cassiterite
Black-Brown
Generic compound

Cassiterite is a common brown-black tin oxide mineral with composition SnO_2, found in acid igneous rocks or in associated high temperature hydrothermal veins with Bi-bearing minerals (such as Cambourne, Cornwall, England; Erzgebirge, Saxony, Germany; Luina, Tasmania). It is often associated with minerals such as lepidolite and fluorite (*qq.v.*). Alluvial deposits derived from the degradation of tin-silver veins of volcanic origin (such as Selangor, Malaysia; Chunju, South Korea) are also important sources of cassiterite. It forms as twinned tetragonal prisms, fibrous or botryoidal masses, or as rounded grains in fluvial placer deposits. The name of the mineral is derived from the Greek word for tin (*καςςιτερος*) and cassiterite is the most important source of tin (Rutley, 1988).

Use of natural cassiterite as a pigment in its own right is currently unknown but tin(IV) oxide is used as a component for making pigments such as lead tin yellow and cerulean blue (*qq.v.*; Church, 1890). Hence it may be found as a relict phase in these pigments.

Tin group; Fluorite; Lepidolite; Tin(IV) oxide; *Cerulean blue*; *Lead tin yellow*
Church (1890); Rutley (1988) 270

CASSYTHA
Yellow
Common generic composite

A species of *Cassytha* (*C. filiformis*) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *zacatlaxcalli*.

Flavonoids group
Wallert (1995c)

CASTILE EARTH
Brown
Synonym, variant or common name

Term used in association with Vandyke brown (*q.v.*; Feller and Johnston-Feller, 1997).

Humic earth; *Vandyke brown*
Feller & Johnston-Feller (1997)

CASTILIAN BLUE
Blue
Synonym, variant or common name

A term for azurite (*q.v.*) ashes found in the early seventeenth century Portuguese treatise by Nunes *Arte poetica* (1615). According to Veliz (1986), Spanish sources always qualify this material as coming from Seville; the difference seems to be one of geographical and political perspective.

Azurite
Nunes (1615) 59; Veliz (1986) 193, n.12

CASTLE EARTH
Brown
Synonym, variant or common name

Synonym for Vandyke brown (*q.v.*; Feller and Johnston-Feller, 1997).

Vandyke brown
Feller & Johnston-Feller (1997)

CATASOL
Green
Synonym, variant or common name

A recipe for catasol is given in the early seventeenth century Portuguese treatise by Nunes (1615): 'Crush a lily well and put it into a porringer. The lily should be left like that for six days. When these days have passed, pour some alum into it and let it stand thus without mixing for two days. When these days have passed, squeeze it and then absorb some of the juice by wetting cloths with it, and dry them in the air until they have body; and when you wish to work with it, use it with gum water' (tr. Veliz). It is very similar to a recipe given shortly after for lily green. Irises were often called *Lillium* and thus these recipes most likely refer to a colour made from Iris.
See: iris green.

Iris green
Nunes (1615) 64ff–65; Veliz (1986) 11

CATECHIN
Unknown
Generic compound

Catechin is a gallotannin dyestuff extracted from *Accacia catechu* L. (*Merck Index*, 1996; Schweppe, 1992).
See: catechu brown

Tannins group; Catechu brown
Merck Index (1996) 1950; Schweppe (1992) 495

CATECHU BROWN
Brown
Synonym, variant or common name

Salter (1869) lists catechu brown(s) prepared from extracts of *Acacia catechu* L. Various salts were used to give a range of colours from greenish brown (iron), brownish yellow (tin) and brick coloured (lead); copper acetate and potassium bichromate gave brown residues. These were apparently speculative pigments although another brown prepared from catechu bark is recorded that was recommended for painting 'if not too thinly applied'.

Acacia catechu (L.f.) Willd. produces condensed tannins that have been used as dyestuffs, notably the gallotannin *catechin* with *epicatechin* and the flavonoid *quercetin* (*q.v.*; Schweppe, 1992).

Quercetin
Salter (1869) 354–355; Schweppe (1992) 503–506

CAUK
White
Synonym, variant or common name

See: baryte.

CEDER GREEN
Green
Synonym, variant or common name

Ceder green is a synonym for chrysocolla (*q.v.*). Harley (1982) states that it is probably a corruption of the word solder and was the term used by Hilliard (1624) and Norgate (early 17th century), chrysocolla being called gold solder in the middle ages. Goeree (1670) mentions *seifergreen* as distinct from malachite. Other related terms are Dutch *severgroen* and German *Schifergrün* (Agricola, 1556).
See: chrysocolla.

Agricola (1556/trans. Hoover & Hoover, 1950) 221; Goeree (1670) 287; Harley (1982) 77; Hilliard (1624/Thornton & Cain, 1981) 94; Norgate (early 17th c./Thomton & Cain, 1981)

CELADON GREEN
Green
Synonym, variant or common name

See: green earth.

CELADONITE

Green
Generic compound

Celadonite (seladonite) is a green ferromagnesian silicate mineral of composition $K(Mg,Fe^{2+})(Fe^{3+},Al)Si_4O_{10}(OH)$ which belongs to the mica group (*q.v.*). It is similar to glauconite (*q.v.*), but contains more Mg and less Al and Fe^{3+} and forms in a different environment (Zhukhlistov *et al*., 1977). Celadonite is commonly found in the vesicle lining and coatings of altered volcanic rocks of basic to intermediate compositions. It is known from Monte Baldo, near Verona, Italy and Kern County, California. Its name was proposed by Glocker in 1847 from the French *céladon*, meaning 'sea-green', in allusion to its common colour.

Celadonite is a primary component of so-called green earth (*q.v.*; Grissom, 1986), which has been extensively used as a pigment. Celadonite has been specifically identified (with glauconite) by Odin and Delamare (1986) as the green phyllite material used on certain Roman wall paintings in Gaul. It is also listed by Price *et al*. (1998) as occurring on paintings by Vincenzo Foppa (1427/30–1515/16).

Aluminium group; Iron group; Magnesium group; Mica group; Silicates group; Glauconite; Green earth
Glocker (1847); Grissom (1986); Odin & Delamare (1986); Price *et al.* (1998); Walsh *et al.* (2004); Zhukhlistov *et al.* (1977)

CELESTIAL BLUE

Blue
Synonym, variant or common name

Similar to so-called Brunswick blue (*q.v.*) in being Prussian blue struck onto a base such as baryte or barium sulfate (*qq.v.*), though this is a pale tint of 5–10%. Seemingly, according to Heaton (1928), synonymous with 'daylight blue' and, according to Davidson (1880), with 'celestial blue'.

Hexacyanoferrate group; Barium sulfate; Baryte; *Brunswick blue*; *Celestial blue*; *Daylight blue*; *Prussian blue*
Davidson (1880) 83; Heaton (1928) 160

CELESTINE

White
Synonym, variant or common name

See: celestite.

CELESTITE

White
Generic compound

Celestite (or celestine) is a naturally occurring strontium sulfate mineral with chemical composition $SrSO_4$. Pure celestite is white or colourless, but it may vary in colour from red to green or brown due to the presence of impurities such as iron (Deer *et al*., 1992). The most common coloured variety is pale blue, thought to be caused by irradiation, and the mineral name is in fact derived from the Latin *caelestis*, referring to the sky. Celestite is structurally similar to the barium sulfate mineral, baryte (*q.v.*). Although complete solid solution does exist between the two minerals, natural celestite rarely contains more than 2–3% $BaSO_4$. Celestite is a relatively common mineral and usually occurs as tabular vitreous crystals or as fibrous aggregates. It is most commonly found in cavities in dolomites or dolomitised limestones (for example, Bristol, England; Tuscany, Italy) and in hydrothermal veins where it is associated with strontium carbonate (strontianite), to which it alters, dolomite and fluorite (*qq.v.*). It is also found in evaporite deposits with gypsum and halite (*qq.v.*) and has been identified in volcanic deposits at Mount Etna, Sicily. Important deposits also exist in Iran (Walter *et al*., 1998).

Mayer (1991) implies that celestite and its synthetic analogue, strontium sulfate (*q.v.*), have been used as a white pigment commonly known as strontium white. Identification of celestite has been made during analysis of 22 Greek stèles in the Louvre (Rouveret and Walter, 1998; Walter *et al*., 1998), used as a background layer, either alone or mixed with cerussite (*q.v.*).

Zerr and Rübencamp (1906) record that 'Attempts have been made to make a white pigment from another alkaline earth allied to barium, namely, strontium. The raw material in this case is the native strontium sulphate, cœlestine, which is treated in the same way as barytes.' They also state that strontium sulfate has been used in combination with zinc sulfate to form an analogue of lithopone (zinc sulfate + barium sulfate) and sulfopone (zinc sulfate + calcium sulfide (*qq.v.*)). Heaton (1928) discusses what he terms strontium white at much greater length, again noting the production methods similar to baryte, but also recording the discovery of commercially viable deposits of celestite: 'in March, 1927, extensive deposits at Yate, near Bristol, were opened up, and its use has been established on a considerable scale, chiefly as a substitute for barytes, to which it is closely similar in properties'.

Strontium group; Baryte; Cerussite; Dolomite; Fluorite; Gypsum; Halite; Strontianite; Strontium sulfate; Lithopone; *Strontium white*; *Sulfopone*
Deer *et al.* (1992) 610–611; Heaton (1928) 105; Mayer (1991) 57; Rouveret & Walter (1998); Walter *et al.* (1998); Zerr & Rübencamp (1906/1908) 85

CELITE

White
Synonym, variant or common name

See: diatomite.

CENDRES BLEUES

Blue
Synonym, variant or common name

A French term covering both natural and synthetic copper carbonate blues; probably the basis of the English term sanders blue (*q.v.*) by corruption. The French drew a distinction between the natural (azurite, *q.v.*) and synthetic (blue verditer, *q.v.*) form by sometimes calling the manufactured form *cendres bleues d'Angleterre*, as this was an English specialism (Harley, 1982).

Copper carbonates group; Azurite; Copper carbonate hydroxide, azurite type; *Blue verditer*
Harley (1982) 50

CENERE D'AZZURRO

Blue
Synonym, variant or common name

Although Merrifield (1849) indicates that '*cenneri azzuri*' signified artificial blue copper carbonate pigments it is entirely clear from sources such as Baldinucci (1681) that in fact the term he gives as *Cenere d'azzurro* meant ultramarine ashes (that is, lower grades of natural ultramarine, lazurite, *qq.v.*); he states: '*Cenere d'Azzurro (è) un Azzurro di lapis lazzulo di cattivo colore, il quale si cava dopo il buono, quando la pietra, con la quale si fece l'Azzurro, fu venusa e mescolata con Marmo o marca sita*' ('Cenere d'Azzurro is a lapis lazuli blue of an ugly colour, which is recovered after the good colour, when the stone, with which azure is made, was veined and contained marble or marcasite [*qq.v*].')

Lapis lazuli; Lazurite; Marble; Marcasite; Ultramarine; *Ultramarine ash*
Baldinucci (1681) 31; Merrifield (1849) cc

CENOBRIUM

Red
Synonym, variant or common name

Historical term for vermilion (*q.v.*) found, for example, in the treatise *De Diversis Artebus* by Theophilus (c. twelfth century; numerous MSS, for which see: Clarke, 2001, 15–16).

Vermilion
Clarke (2001) 15–16; Theophilus (c.12th cent/Hawthorne & Smith, 1963) 14, n.3

CERIUM OXIDE

Yellow-Orange
Generic compound

Used as cerium yellow, an orange-yellow pigment (*Colour Index*, 1971, CI 77280).

Cerium yellow
Colour Index (1971) 77280

CERIUM SULFIDE

Red-Orange-Yellow
Generic compound

A range of coloured pigments based on the sulfide of the rare earth element cerium have been recently introduced (industrial production since 1997), with colours ranging from yellow to red. Cerium sulfide itself has an intense red colour; however, by the introduction of an alkaline element (lithium, sodium) in small proportions, the dark red colour is transformed into a light red to orange.

The colour of these cerium-based compounds can be further modified by introducing fluorine. The resulting crystal networks are two dimensional (rare earth fluorosulfides) and more stable in acid environments and more resistant to temperature than their sulfide counterparts. By partially replacing cerium with another smaller rare earth such as samarium, intense red colours are obtained. Samarium fluorosulfides, much like their sulfide counterparts, also produce intense yellow colours and may prove to be viable pigments in the future.

Cerium sulfide pigments apparently have some role in replacing cadmium sulfides, heavy metal compounds now being limited by increasingly stringent environmental standards. Cerium sulfide is sold under the trade name of *Neolor* (Rhône-Poulenc).

Demourges (2001)

CERIUM YELLOW

Yellow-Orange
Synonym, variant or common name

Cerium oxide was used as an orange-yellow pigment (*Colour Index*, 1971, CI 77280).

Cerium oxide
Colour Index (1971) 77280

CERULEAN BLUE

Blue
Synonym, variant or common name

There is some confusion in the literature between the terms 'cerulean' and 'ceruleum' (both also *cæ*-; additionally: coelin, cœruleum). Cerulean, a general colour term derived from the Latin *cæruleus* and meaning 'dark blue' or 'dark green', appears in English as early as the seventeenth century; for example, we find Primatt (1677; cf. *OED*, 2002) advertising products 'For Painting the best Cerulian or Blew colour in Oyl.' However, the earliest references to the pigment we now generally know under this name were in fact to ceruleum blue. The London *Times* of 28 December 1859 carried an advert for 'Cæruleum, a new permanent colour, prepared for the use of artists', while Ure's *Dictionary of Arts* (1875) also specifies the composition, describing the pigment as 'Cæruleum … consisting of stannate of protoxide of cobalt, mixed with stannic acid and sulphate of lime'; this is repeated by other authors immediately following such as Standage (1887), who again identifies it as 'stannate of cobalt', noting that 'sulphate of lime' was sometimes present. (A 'factitious' version was also said to exist, made from ultramarine, Naples yellow and lead white (*qq.v.*).) Church (1901) refers to it as being called cœruleum (his main heading), cerulium or cerulean blue. Coffignier (1924) calls it *bleu cœruleum*, mentioning also the common French term for it, *bleu céleste* ('celestial blue'). By 1935, Doerner gives cerulean as the main term, cœruleum as a synonym, while omitting cerulium altogether. Most modern references are to 'cerulean', though 'ceruleum' can still be found to some extent.

As with the terminology, so the origin is unclear from the literature. A number of sources credit the introduction to the British colourmen George Rowney, this being perpetuated as late as Coffignier (1924), who also states that this took place 'about 1850'. However, Carlyle (2001) has shown that this is in truth unlikely to have been before about 1862–63, and that immediately prior to that the British firm of Roberson was purchasing 'Blue No. 58 (Cerulium)' from the German firm of Frauenknecht and Stotz. The German origin is consistent with Salter's comment (1869) that 'Under the name Coelin there has of late years been imported from Germany the cobalt blue with a tin base … which likewise contains or is mixed with gypsum, silica, and sometimes magnesia.' In this context it is interesting to note that the 1860 edition of Gentele's influential *Lehrbuch der Farbenfabrikation* does not mention cerulean blue, while the 1880 edition does.

In fact there are precursors from the late eighteenth century, notably that known as Höpfner blue. The earliest publication of this appears to be that by Höpfner himself in 1789, though more commonly the modern literature cites the listing of the compound by Schreger as 'a beautiful blue painter's colour' in 1805 (Höpfner, 1789; Schreger, 1805). The original process involved mixing the filtered solution of one part cobalt and *aqua regia* with two or more parts of tin into the same solution, then precipitating it with potash, washing, drying and calcining it in a crucible. This pigment appears to have then been largely forgotten until the 1850s–60s, when it was seemingly reintroduced as described above. For example, Rose (1916) says that Höpfner developed a blue pigment made of cobalt oxide and tin oxide 'before 1805', but that this was soon forgotten and only in 1860 was a similar pigment developed, this time consisting of cobalt oxide, tin oxide, calcium sulfate and silica. Mierzinski (1881) on the other hand quotes the original Höpfner recipe in some detail.

Pamer has identified chromium cobalt aluminium oxide in samples of modern acrylics labelled 'cerulean blue', but this appears to be otherwise rare (Pamer, 1978). Mayer (1991) also mentions a 'cerulean blue cobalt'. Other associated terms include *Cölinblau* (for example, Linke and Adam, 1913).

Cobalt group; Tin group; Chromium aluminium cobalt oxide; Cobalt tin oxide; *Bleu celeste*; *Caeruleum*; *Coelin*; *Coeruleum*; *Höpfner blue*; *New blue*
Carlyle (2001) 472; Church (1901) 212; Coffignier (1924) 378; Doerner (1935) 81; Gentele (1860); Höpfner (1789); Linke & Adam (1913) 60; Mayer (1991) 73; Mierzinski (1881) 231; *OED* (2002); Pamer (1978); Rose (1916) 281, 289; Salter (1869) 190; Schreger (1805); Standage (1887); Ure (1875–78) I, 570

CERULEAN BLUE COBALT

Blue
Synonym, variant or common name

Said to be a variant of cerulean blue (*q.v.*; Mayer, 1991).

Cerulean blue
Mayer (1991) 73

CERULEUM BLUE

Blue
Synonym, variant or common name

See: cerulean blue.

CERUSA

White
Synonym, variant or common name

Historical synonym for a lead-based white pigment, probably lead carbonate hydroxide (*qq.v.*).
See: cerussa.

Lead carbonate hydroxide; *Lead white*

CERUSE

White
Synonym, variant or common name

Dossie (1764) states that ceruse is 'lead corroded […] by the acid of grapes (vinegar)', that brought from Italy far surpassing the white lead made in England. By 1804, however, Tingry states that it is inferior to lead oxide as it is mixed with white tobacco pipe clay, Spanish white, Troyes white or washed chalk (*qq.v.*). He further remarks that the heaviest (containing the highest proportion of lead oxide) and that which does not effervesce in the presence of acids should be preferred. Salter (1869) describes this as 'A French variety [*of lead white, q.v.*], not necessarily, but not unfrequently, mixed with different chalky earths in various proportions'; Watin (1785) also mentions ceruse as mixed with chalk from Holland, Crems and Rome. Osborn (1845) lists ceruse as the least pure of his three grades of lead white.

It may also refer to 'tin white', which is probably tin(IV) oxide and the term may have been used indiscriminately for either lead or tin white (*qq.v.*). It is further probable that for a short period in the seventeenth century the term was applied to a mixture of lead white and chalk (Harley, 1982).

Calcite; Chalk; Lead carbonate; Lead carbonate hydroxide; Lead oxide; Tin(IV) oxide; *Ceruse de Venise*; *Lead white*; *Pipe clay*; *Spanish white*; *Tin white*; *Troyes white*
Dossie (1764) 131; Harley (1982) 165–166; Osborn (1845) 2; Salter (1869) 74; Tingry (1804) 292; Watin (1773/edition of 1785) 18–19

CERUSE DE VENISE

White
Synonym, variant or common name

Of uncertain composition although Harley (1982), writing about British documentary sources, suggests that this term may have referred to a mixture of lead white and chalk before the late seventeenth century but that it appeared to be an equal mixture of barytes and lead white (*qq.v.*) after that time.
See: ceruse.

Baryte; Chalk; *Ceruse*; *Lead white*; *Tin white*
Harley (1982) 165–166, 175

CERUSSA

White
Synonym, variant or common name

Cerussa apparently refers to lead white (*q.v.*). Pliny (77 AD) states that *cerussa* is 'now all manufactured', indicating that a once-known naturally occurring source existed on the estate of Theodotus of Smyrna (cf. Vitruvius, first century BC); this may indicate some confusion, however, as Pliny also mentions red lead (*q.v.*) as being 'burnt *cerussa*'.

Lead white; *Red lead*
Pliny (1st cent AD/Rackham, 1952) XXXV.xix–xx; Vitruvius (1st cent BC/Grainger, 1934) VII.xii.1

CERUSSITE

White
Generic compound

Cerussite is a natural white lead carbonate mineral, with composition $PbCO_3$. It forms as prismatic crystals, or as granular or massive aggregates in which individual crystals cannot be distinguished. Cerussite is a secondary mineral, common worldwide, formed by the alteration of galena (*q.v.*), via the precipitation of anglesite (*q.v.*). It occurs in the oxidising portion of lead ore deposits (such as in Cornwall and Derbyshire, England; Tsumeb, Namibia; Tyrol, Austria; Minas Gerais, Brazil; Tuscany, Italy) and is named from the Latin *cerussa* (Rutley, 1988).

The synthetic analogue of cerussite, lead carbonate, commonly known as 'lead white' (*qq.v.*), has been known as a pigment since antiquity and is of widespread occurrence in paintings. Although cerussite has been used as a pigment itself (Wallert, 1995a has reported finding neutral lead carbonate (cerussite) in the polychromy on a fourth century BC Greek basin), literature citations of this mineral in the context of lead-based pigments generally refer to the synthetic form.

Lead carbonates group; Lead group; Anglesite; Galena; Lead carbonate; *Lead white*
Rutley (1988); Wallert (1995a)

CHALCANTHITE

Blue-Green
Generic compound

Chalcanthite is a blue or blue-green hydrated copper sulfate mineral with chemical formula $CuSO_4.5H_2O$. It forms as vitreous tabular crystals or more commonly as fibrous, reniform, stalactitic or crust-like masses. It forms as a secondary mineral in the near-surface oxidising zone of copper ore deposits (e.g. at Cornwall, England; Champion Copper Mine, New Zealand). It is soluble in water and commonly forms by the evaporation of sulfate-rich ground waters which have leached copper from other copper-bearing minerals such as chalcopyrite (Hey, 1993). Hence, in arid climates it forms much larger deposits where it may become an important copper ore (e.g. Chuquicamata, Chile). Discovered by Kobell in 1853, chalcanthite was named from the Greek words *khalkos* and *anthos* meaning ‘copper’ and ‘flower’. It has also historically been termed blue vitriol or copper vitriol, and is commonly found in association with brochantite, malachite, aragonite and calcite (*qq.v.*). Other related hydrated copper sulfate minerals are langite and posnjakite (*qq.v.*).

Copper group; Copper sulfates group; Aragonite; Brochantite; Calcite; Langite; Malachite; Posnjakite
Hey (1993)

CHALCONATRONITE

Blue-Green
Generic compound

Chalconatronite is a blue-green hydrated copper-sodium carbonate mineral ($Na_2Cu(CO_3)_2.3H_2O$). It forms as soft platy crystals or as encrusting masses and was first identified on bronze Egyptian artefacts at the Fogg Art Museum which had been buried close to natron-mummified bodies (Frondel and Gettens, 1955). Chalconatronite has since been found at locations such as the Carr Boyd Deposit, Australia and at Harz and Rheinland-Pfalz in Germany.

Banik (1989) observed this mineral on a sixteenth century illuminated manuscript, in association with pseudomalachite (*q.v.*). Magaloni (1996) has also identified chalconatronite on a wall painting at two Mayan sites. The synthetic analogue of this mineral – copper sodium carbonate, chalconatronite type (*q.v.*) – was found by Scott (2002) to be formed by a Chinese recipe cited by Needham (1974).

Copper carbonates group; Copper group; Copper sodium carbonate, chalconatronite type; Pseudomalachite
Banik (1989); Frondel & Gettens (1955); Magaloni (1996); Needham (1974); Scott (2002), 118

CHALK

White
Generic variety

Chalk is a specific variety of limestone (*q.v.*) formed entirely from microscopic, fossilised phytoplanktonic algae, coccolithophores (Phylum prymnesiophyta). A coccolith is a disc-shaped, calcite (*q.v.*) plate which interlocks with others to form the spherical plankton body, the coccosphere. Coccoliths first evolved 230 million years ago and still exist today and are thus widely used as a diagnostic fossil flora for dating and provenancing chalk and other fine-grained limestone deposits (Young *et al*., 1992, 1997).

Chalks are very fine grained and generally pure and white rocks, though calcium carbonate macrofossils and silica (flints) may be present. Chalks may develop very thick and extensive deposits, notably those of Cretaceous age in the UK and western continental Europe (France, Denmark, Sweden) and Tertiary age deposits in the eastern Mediterranean (that is, the Lefkadia Formation of Cyprus). Chalk deposits also occur in the USA across Nebraska, Arkansas and Texas. Chalk’s whiteness, softness and fine-grained nature makes it an ideal white pigment, being both abundant and easily processed. Chalk is prepared by crushing the natural material and then separating out the coarse material by levigation. Various grades of the pigment are obtained at this stage of the process. The pigment is then dried by controlled heating, though calcium oxide (lime, *q.v.*) may form with overheating. Chalk is relatively transparent in most paint media and is therefore often found as an extender for other pigments and employed with animal glues as a ground for painting rather than as a principal pigment in its own right although exceptions exist where the transparency was desirable (such as some Dutch ‘tonal’ landscapes of the seventeenth century; see: Gifford, 1983).

Chalk is known to have been used as a pigment since earliest times and has been recognised, for example, from Greek and Roman art (Caley, 1946; Augusti, 1967). Since that period use has been both persistent and widespread; Gettens *et al*. (1993a), for example, have reviewed the use of chalk in paintings, documenting examples from the early mediaeval period through to the early nineteenth century, primarily in the context of Northern European easel paintings. Some care should be taken when interpreting the identification of ‘chalk’ in paintings since the term may be used generically and the presence of coccoliths is a diagnostic feature. Specific examples of the identification of coccoliths include the studies by Kozlowski (1950), who found them in *The Last Supper* by Dieric Bouts, by Coremans *et al*. (1952) and on Rubens’ *The Gerbier Family* by Feller (1973). Perch-Nielsen (1973) has provenanced chalk from various European sources on thirteenth and fourteenth century paintings in Norway, where chalk is not locally available.

Due to chalk’s widespread occurrence and use the terminology describing it can be confusing, though much of the nomenclature seems to refer to the place of occurrence or preparation. Earliest references are to the Latin *creta* and this term is used by the classical authors, and was probably applied to other white earths including clays and diatomaceous earths (*q.v.*). A corruption of *creta* (or perhaps referring to deposits on Crete) is Crete white.

Many authors say that the best whiting is Paris white (Terry, 1893; Heaton, 1928) and note its high purity with 95% calcium carbonate. The regions surrounding the French Massif Central have thick and extensive chalk deposits and many pigments derive their names from these sources, for example Meudon white. Harley (1982) also lists Rouen white and Bougeval (or Bougival) white. Tingry (1804) mentions ‘White of Troyes’, white chalk often mixed with sand and silex (ground flint). Synonyms for this pigment are Troy white and Troyes white. As Troyes is in Champagne, this variety is probably synonymous with the term Champagne white. Chalk whites from deposits in the South of England are known as English white. *Rügener kriede* or Rügener chalk comes from northern Rügen Island in northern Germany.

Heaton (1928) and Tingry (1804) among many authors refer to Spanish white (*q.v.*). Confusingly the term Spanish white is generally thought not to refer to a place of manufacture or source but is used as a general term (Riffault *et al*., 1874, however, do state that this refers to its source). Tingry (1804) says that Spanish white is a clay and chalk pigments are substituted for it. Peacham (1634), Norgate (early seventeenth century; cf. Harley, 1982) and Dossit (1764) say it was chalk mixed with alum, and was best mixed with lead white (*q.v.*). In fact it would appear that there was a tradition of adulterating lead white with chalk and so the use of the latter material may be underestimated. Clark *et al*. (1995) have recognised this combination commonly occurring on nineteenth century East Asian manuscripts.

China white was also a chalk, but according to Harley this was a rare pigment. Briançon chalk (synonymous with French chalk) is the name given by Tingry (1804) to the mineral talc (*q.v.*), used as a base with carmine (*q.v.*) for cosmetic rouge. The term ‘chalk’ has also been applied to synthetic precipitated calcium carbonate; however, the term is probably best reserved for the natural form.

Calcium carbonates group; Calcium group; Calcite; Calcium carbonate, calcite type; Lime: Limestone; *Bougival white*; *Carmine*; *Champagne chalk*; *Creta*; *Crete white*; *Diatomaceous earth*; *English white*; *Lead white*; *Meudon white*; *Paris white*; *Rügener chalk*; *Spanish white*; *Troyes white*; *Whiting*
Augusti (1967); Caley (1946); Clark *et al.* (1995); Coremans *et al.* (1952); Dossit (1764) 137; Feller (1973); Gettens *et al.* (1993a); Gifford (1983); Harley (1982) 156; Heaton (1928) 106; Kozlowski (1950); Norgate/Thomton & McCain (early 17th c./1981); Peacham (1634); Perch-Nielsen (1973); Riffault *et al.* (1874) 53–54; Terry (1893) 246; Tingry (1804) 287, 295, 333; Young *et al.* (1992); Young *et al.* (1997)

CHALON’S BROWN

Brown
Synonym, variant or common name

Chalon’s brown is decribed by Salter (1869) who gives no direct information about its composition. However, he groups it between Cassel and Cologne earths, so that it was probably a humic earth (*qq.v.*).

Humic earth; *Cassel earth*; *Cologne earth*
Salter (1869) 344

CHAMOIS

Yellow
Synonym, variant or common name

Mayer (1991) lists *Chamois* as an obsolete term for yellow ochre (*q.v.*).

Yellow ochre
Mayer (1991) 41

CHAMOSITE

Green
Generic compound

Chamosite is an iron-rich aluminosilicate mineral with ideal composition $Fe_{10}Al_2(Si_6A)_2O_{20}(OH)_{16}$. It is a member of the chlorite group (*q.v.*) and is named after Chamoson (Switzerland) from where good samples may be obtained. It has been suggested (see Deer *et al.*, 1992 and Bailey, 1988) that the term chamosite be applied to any iron-rich variety of chlorite, with the terms clinochlore and pennantite (*qq.v.*) used to indicate Mg-rich and Mn-rich varieties, respectively. As with other chlorites, chamosite occurs as green tabular crystals and scaly masses, which may vary in colour to yellow or brown according to composition (Dana, 1932); chamosite also occurs in association in ironstones (Damyanov and Vassileva, 2001) often with spherulitic form (Franceschelli *et al.*, 2000). Chlorites occur as alteration products of ferromagnesian minerals (such as biotite and amphibole group minerals, *qq.v.*) in igneous rocks and are important components of low-grade metamorphic rocks; chlorites are also found in sediments with clay minerals (*q.v.*). Chamosite is common worldwide and known from areas such as Alpi Alpuane and Sardinia (Italy), Hermanovice (Czech Republic), Zamora (Spain), Schmiedefeld (Germany) and Crede (Colorado, USA).

Grissom (1986) mentions the presence of chlorite minerals in green earth (*q.v.*) pigments.

Amphibole group; Chlorite group; Clay minerals group; Earth pigments group; Silicates group; Biotite; Clinochlore; Green earth; Pennantite
Bailey (1988); Damyanov & Vassileva (2001); Dana (1932) 673; Deer *et al.* (1992) 333; Franceschelli *et al.* (2000); Grissom (1986)

CHAMPAGNE CHALK

White
Synonym, variant or common name

According to Riffault *et al.* (1874), ‘prepared chalk’ was called White of Bougival, Meudon, Champagne or Troyes, according to the place of manufacture. Troyes is located in the Champagne region of France and these whites are therefore synonymous.

Calcite; Chalk; *Troyes white*
Riffault *et al.* (1874)

CHANNEL BLACK

Black
Synonym, variant or common name

Gas blacks (*q.v.*) were produced by the incomplete combustion of gaseous hydrocarbons, commonly involving the ‘channel’ process – a method where the pigment was collected on iron channels – thereby giving rise to the term ‘channel black’ (Heaton, 1928).
See: carbon-based blacks group: flame carbons sub-group.

Carbon-based blacks group: Flame carbons sub-group; *Gas black*
Heaton (1928) 173

CHAOITE

Black
Generic compound

Chaoite is a black or dark grey naturally occurring form of crystalline carbon. It is a rare mineral requiring high pressures for its formation. It has only been encountered in meteorites (e.g. Goalpur and Dyalpur meteorites) and impact craters (such as Ries Crater, Germany). Discovered by El Goresy (1969) and named after the petrologist E.C.T. Chao (1919–), chaoite is reported to be a soft mineral and occurs as thin lamellae intercalculated with graphite (*q.v.*). On account of its rarity, it is unlikely to be encountered as a pigment and has generally only been discussed in reviews of pigments for completeness.
See entry under carbon-based blacks group: crystalline carbons sub-group for further information.

Carbon-based blacks group: Crystalline carbons sub-group; Graphite
El Goresy (1969)

CHARCOAL

Black
Synonym, variant or common name

See: carbon-based blacks group: chars sub-group.

CHARCOAL GREY

Grey
Synonym, variant or common name

Supplied by the British colourmen Winsor & Newton and Reeves in the 1890s, this was made from charcoal (Carlyle, 2001).
See: carbon-based blacks group: chars sub-group.

Carbon-based blacks group: Chars sub-group
Carlyle (2001) 498

CHARLTON WHITE

White
Synonym, variant or common name

This is apparently a ‘silico-aluminous’ white (Carlyle, 2001). There are various natural and synthetic aluminium silicates encountered as pigments; it is not clear precisely which this is. Heaton (1928) lists this as a term current at that time for lithopone (*q.v.*).

Aluminium silicates group; *Lithopone*
Carlyle (2001) 518; Heaton (1928) 380

CHESSYLITE

Blue
Synonym, variant or common name

Church (1901) included a description of chessylite, which he states was the same as azurite and blue verditer (*qq.v.*). It is an alternative mineral name for azurite (a copper carbonate hydroxide mineral), occurring, among other places, at Chessy in France.

Azurite; Copper carbonate hydroxide, azurite type; *Blue verditer*
Church (1901) 224.

CHESTNUT BROWN

Brown
Synonym, variant or common name

Salter (1869) refers to hypocastanum or chestnut brown, apparently as an extract being used to form a lake pigment; for more information on this, see the entry for hypocastanum. Mayer (1991) also gives this as a synonym for 'raw' (that is, uncalcined) umber (*q.v.*); it is probably a colour variant name in this context.

Hypocastanum; *Raw umber*
Mayer (1991) 41; Salter (1869) 357

CHICA

Red-Orange-Yellow
Synonym, variant or common name

Salter (1869) discusses what he calls *Chica Marrone*, 'chica' being the 'red colouring matter … extracted from the *Bignonia chica*, by boiling its leaves in water, decanting the decoction, and allowing it to cool, when a red matter falls down, which is formed into cakes and dried.' The same author states that there was also another variety 'from Para in Brazil, and known as crajuru, carajuru, or caracuru'. Bersch (1901) notes that 'beautiful red lakes' can be formed with chica and aluminium and tin.

According to Schweppe (1992), *Bignonia chica* Humb. et Bonpl. (Bignoniaceae) produces the xanthone dye carajurin. This is dye designated by the *Colour Index* (1971) as CI 75180 Natural Orange 5.

Carajurin
Bersch (1901) 379; *Colour Index* (1971) 75180; Salter (1869) 367–368; Schweppe (1992) 439

CHICORY BROWN

Brown
Synonym, variant or common name

Terry (1893) provides the following description of chicory brown: 'This vegetable pigment is rich-coloured but lacks permanence. It is prepared by calcining roots, such as those of chicory, in vessels to which air is not admitted, from which then results a fine brown powder. This is boiled in water, and the solution is evaporated to dryness, yielding a brown pigment, which, being soluble in water, is sometimes employed by water-colour artists.'

Chicory root (Chichorium intybus) continues to be used in certain specialist applications, such as for a stain in the restoration of stringed instruments.

Terry (1893) 102

CHINA CLAY

White
Synonym, variant or common name

China clay, or kaolin, is a soft earthy hydrous material consisting of a mixture of kaolinite, smectite and mica group minerals, quartz (*qq.v.*) and amorphous silicates (Rutley, 1988). It is derived from the weathering of feldspar group (*q.v.*) minerals, principally plagioclase feldspar, so that small relict feldspar grains may also be present in the clay mixture. China clay deposits are commonly white and derived from granitic parent material which has a high feldspar content; however, coloured varieties do occur due to compositional variations in the original rock type. China clay is perhaps best known from St Austell (Cornwall, England), where it occurs as a primary deposit derived from the *in situ* hydrothermal alteration of granite (Deer *et al.*, 1992). It is the largest deposit in the world and is worked extensively for use in the manufacture of bone china. China clay can also form as a secondary deposit, after transportation away from the site of feldspar degradation (e.g. at Atlanta, Georgia). China clay deposits are also known worldwide from localities such as Chaibasia Bihar (India) and Macedonia (Greece).

China clay is used extensively in the modern ceramics, paints, plastics and cosmetic industries. It is listed in the *Colour Index* as Pigment White 19 (CI 77004) together with bentonite (*qq.v.*).

Clay minerals group; Clay minerals group: Kaolinite sub-group; Clay minerals group: Smectite sub-group; Feldspar group; Mica group; Sheet silicates group; Kaolinite; Quartz; *Bentonite*; *Kaolin*; *Pipe clay*; *White bole*
Colour Index (1971) 77004; Deer *et al.* (1992) 362; Rutley (1988) 410–411

CHINESE BLUE

Blue
Synonym, variant or common name

Term used to denote a high quality Prussian blue (*q.v.*; Berrie, 1997). Heaton (1928) states that tin is also invariably found in Prussian blue of this quality, it being added as stannous chloride for its reducing ability (that is, to change the iron from the iron(III) to the iron(II) – 'ferric' to 'ferrous'-state).

The name Chinese blue has also been applied to the synthetic barium copper silicate pigment described elsewhere here as Han blue (*q.v.*; Bouherour *et al.*, 2001; Wiedemann *et al.*, 1998).

Hexacyanoferrate group; *Han blue*; *Prussian blue*
Berrie (1997); Bouherour *et al.* (2001); Heaton (1928) 159; Wiedemann *et al.* (1998)

CHINESE GREEN

Green
Synonym, variant or common name

A green lake pigment which, according to Terry (1893), was 'Another name for the vegetable pigment known in China as *Lokao*' (*q.v.*). Lokao is produced from the roots and bark of *Rhamnus chlorophorus* and *R. utilus.*

In 1874 Charvin of Lyon found the same colouring matter could be derived from *Rhamnus cathartica* L. (common buckthorn). Thus this is also *Charvin's grün* in German (Mierzinski, 1881; Bersch, 1901; Schweppe, 1992).
See entries for *Lokao, Buckthorn* and *Rhamnus*.

Flavonoids group; Rhamnus; *Lokao*
Bersch (1901) 412–413; Mierzinski (1881) 128; Schweppe (1992) 542–543; Terry (1893) 129

CHINESE INK

Black
Synonym, variant or common name

See: carbon-based blacks group: flame carbons sub-group.

CHINESE LAKE

Red
Synonym, variant or common name

According to Salter (1869), this was a form of cochineal (*q.v.*) lake. He briefly mentions it along with Florentine lake (*q.v.*) indicating that these both differed from scarlet lake (*q.v.*) in the way that they were prepared, also implying that both were prepared from dye extracted from scarlet cloth.
See: cimatura.

Cochineal; *Cimatura*; *Florentine lake*; *Scarlet lake*
Salter (1869) 137

CHINESE ORANGE

Orange
Synonym, variant or common name

Salter (1869) identifies this as a 'coal tar' colour (*q.v.*; that is, a synthetic dyestuff), though indicating it was used as a pigment rather than a dye; he was clearly unaware of the exact composition. However, Seward (1889) states that it was prepared from dragon's blood (*q.v.*), while the British firm of colourmen Reeves & Sons classed it with vermilions (cf. Carlyle, 2001).

Dragon's blood; *Coal tar colours*; *Vermilion*
Carlyle (2001) 499–500; Salter (1869) 246–248; Seward (1889)

CHINESE PURPLE

Purple
Synonym, variant or common name

Name used by Bouherour *et al.* (2001) to describe a barium copper silicate listed elsewhere here as Han purple (*q.v.*).

Han purple
Bouherour *et al.* (2001)

CHINESE RED

Red
Synonym, variant or common name

Listed as a synonym for chrome red (*q.v.*) by Heaton (1928), and as an older term for basic lead chromate by Kühn and Curran (1986); Schiek (1973) also lists it as an older name for a chrome orange pigment (lead chromate oxide) (*qq.v.*).

Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*
Heaton (1928) 380; Kühn & Curran (1986); Schiek (1973)

CHINESE ROUGE

Red
Synonym, variant or common name

Field (1835) lists a number of related terms including *rouge végétale*, Chinese rouge and pink saucers, all of which he says were prepared from safflower (*q.v.*).

Safflower
Field (1835)

CHINESE VERMILION

Red
Synonym, variant or common name

Term for a mercury(II) sulphide pigment (i.e. either the mineral cinnabar or perhaps a synthetic analogue vermilion, *qq.v.*), properly from China.

Salter (1869) provides the synonym carmine vermilion for this term.

Cinnabar; Mercury(II) sulfide, cinnabar type; *Vermilion*
Salter (1869) 156

CHINESE WHITE

White
Synonym, variant or common name

Chinese white is a variety of zinc oxide (*q.v.*) pigment characterised by a particularly fine particle size. Introduced by the British firm of Winsor & Newton in 1834, it established the use of zinc oxide as a white pigment. Salter (1869) says of it that 'this peculiar preparation of oxide of zinc [is used by watercolour painters who] … formerly had no white which combined perfect permanency with good body'.

The term is still in current usage.

Zinc oxide; *Zinc white*
Salter (1869) 75–76

CHINESE YELLOW

Yellow
Synonym, variant or common name

See: orpiment.

CHIRANJEE

Red
Synonym, variant or common name

See: aal and madder.

CHLORAPATITE

Variable
Generic compound

Chlorapatite is a chlorine-rich calcium phosphate mineral with chemical composition $Ca_5(PO_3)_4Cl$. It belongs to the apatite group (*q.v.*) of minerals and is the common chlorine-rich member, as its name suggests. It is isomorphous with fluorapatite, hydroxylapatite and dahllite (*qq.v.*; Deer *et al.*, 1992). Biogenic calcium phosphates are essential components of bone (*q.v.*); they may convert to mineral chlorapatite during diagenetic alteration. Hence, while no occurrences of this compound are currently known as pigments, the mineral analogues for these materials are included here for comparison. Chlorapatite, first described by Rammelsberg in 1860 (Dana, 1868), is found in most types of sedimentary and metamorphic rocks and is particularly common where rocks have undergone chlorine metasomatism (e.g. Skaergaard, Greenland). Chlorapatite is also found worldwide as an accessory mineral in many rocks (Deer *et al.*, 1992).

Apatite group; Calcium group; Calcium phosphates group; Bone; Dahllite; Fluorapatite; Hydroxylapatite
Dana (1868); Deer *et al.* (1992) 663–669

CHLORINATED PARA RED
Red
Synonym, variant or common name

See: para red.

CHLORITE
Green
Synonym, variant or common name

See: chlorite group.

CHLORITE GROUP
Green
Group term

The chlorite group is a suite of hydrous sheet silicate minerals containing essential magnesium, iron and aluminium. They can be described by the general chemical formula $(Mg,Al,Fe,Mn)_{12}[(Si,Al)_8O_{20}](OH)_8$ and may additionally contain elements such as lithium, nickel, zinc, chromium and boron. The different members of the group are distinguished by their chemical composition and are given names such as clinochlore (Mg rich), baileychlore (Zn rich), cookeite (Li rich), sudoite (Al rich), pennantite (Mn rich), chamosite (Fe rich) and kammererite (Cr rich). The most common chlorites of these are clinochlore, chamosite and pennantite (*qq.v.*), and Deer *et al.* (1992) have suggested that only these terms be used to distinguish between Mg-rich, Fe-rich and Mn-rich chlorites, respectively. The members of the chlorite group are difficult to distinguish between visually, and hence the term chlorite is applied to any member of this group when differentiation cannot be made. The common chlorites are generally green and monoclinic, and are characterised by flexible prismatic, flake-like crystals which have a greasy feel. The chlorites are a relatively large and common group of minerals and are important components of certain metamorphic rocks. They also occur as primary minerals infilling vesicles in volcanic rocks, in argillaceous sedimentary rocks where they occur with clay minerals (*q.v.*), and as secondary minerals in igneous rocks via the alteration of minerals rich in iron and magnesium, such as biotite, actinolite and aegirine (*qq.v.*).

As pigments, members of the chlorite group may occur as components within so-called green earths (*q.v.*).

Clay minerals group; Sheet silicates group; Actinolite; Aegirine; Biotite; Chamosite; Clinochlore; Green earth; Pennantite
Bailey (1988); Deer *et al.* (1992) 332–343

CHLOROPHYLL
Green
Generic compound

Chlorophylls are familiar as the cause of the green coloration in most plants. There are in fact several kinds of chlorophyll, though chemically each contains a porphyrin ring structure surrounding a magnesium ion and a long hydrocarbon tail attached. The most important of these is chlorophyll a, which all plants, algae and cyanobacteria that photosynthesise contain. A second kind of chlorophyll, chlorophyll b, occurs only in green algae and in plants, while a third form of chlorophyll, chlorophyll c, is only found in the photosynthetic members of the Chromista (a broad taxonomic group that includes diatoms, kelps and mildews) as well as single-celled organisms known as dinoflagellates. Chlorophyll a contains a $—CH_3$ side-group, while in chlorophyll b this is replaced by a —CHO group. The molecular structure of the chlorophylls is similar to that of the haem portion of hemoglobin (*q.v.*), except that the latter contains iron in place of magnesium.

Mills and White (1994) list this as a major component of the pigment known as sap green (*q.v.*). Thompson (1956) speculates that the primary colouring matter of iris green (*q.v.*) is probably chlorophyll. Bersch (1901) provides a series of recipes for chlorophyll pigments, including some described as aluminium lakes.

Porphyrins group; Hemoglobin; *Iris green*; *Sap green*
Bersch (1901) 409–410; Mills & White (1994) 146; Thompson (1956) 172–173

CHOCOLATE LEAD
Red-Brown
Synonym, variant or common name

Listed by Salter (1869), he states that this chocolate maroon-coloured pigment is prepared 'by calcining oxide of lead with about a third of copper oxide, and reducing the compound to a uniform tint by levigation'. Presumably a copper-lead oxide is formed. Salter does not indicate the extent to which it might have been used by artists.

Copper oxides and hydroxides group; Lead oxides and hydroxides group
Salter (1869) 368

CHROMATE OF MERCURY
Red-Orange
Synonym, variant or common name

See: mercury chromate.

CHROMATE OF SILVER
Red
Synonym, variant or common name

See: silver chromate.

CHROMATES GROUP
Variable
Group term

The chromates group encompasses a wide compositional range of compounds in which different elements combine principally with the chromate (CrO_4) or dichromate (Cr_2O_7) ion to produce a series of pigments which vary in colour from yellow, orange, red and purple to brown and green. The first studies of chromates and their potential use as pigments were reported by Berthollet and Vauquelin in the early part of the nineteenth century after the latter's discovery of chromium metal in 1797. The popularity of the chromates as pigments was significantly affected by the availability of the raw materials required for their manufacture, with chromium usually obtained from the common mineral chromite ($FeCr_2O_4$). Synthesis of chromates is generally achieved by adding a metal salt (commonly a chloride, nitrate or acetate) solution to an alkali chromate solution (usually sodium or potassium). The largest group of chromates used as pigments are those based on lead, with zinc, calcium, barium and strontium chromates also important. Reviews of chromate pigments may be found, for example, in Kühn and Curran (1986) and Wormald (1975).

The chromates used as pigments are categorised here according to the elements involved and the Periodic Groups from which they come:

Chromates with group 1–2 elements (Ca, Sr, Ba): barium chromate(VI) ($BaCrO_4$); barium potassium chromate (formula unknown); calcium chromate(VI) ($CaCrO_4$); calcium chromate(IV) dihydrate ($CaCrO_4.2H_2O$); calcium chromate(IV) hydroxide dihydrate ($Ca_2(OH)_2CrO_4.2H_2O$); strontium chromate(VI) ($SrCrO_4$).

Chromates with group 3–11 elements (Mn, Fe, Co, Cu, Ag, Th): cobalt chromate ($CoCr_2O_4$); copper chromate(III) ($CuCr_2O_4$); copper chromate(VI) ($CuCrO_4$); copper chromate hydroxide ($CuCrO_4.Cu(OH)_2$; $CuCrO_4.2Cu(OH)_2$; $2CuCrO_4.3Cu(OH)_2$); copper chromate hydroxide hydrate ($CuCrO_4.2CuO.2H_2O$); iron chromate ($Fe_2(CrO_4)_3$); iron chromate hydroxide ($Fe(OH)CrO_4$); iron dichromate ($Fe_2(Cr_2O_7)_3$); manganese chromate ($2MnO.CrO_3.2H_2O$); silver chromate(VI) (Ag_2CrO_4); thallium chromate ($Tl_2(CrO_4)_3$ or Tl_2CrO_4).

Chromates with group 12 elements (Zn, Cd, Hg): cadmium chromate ($CdCrO_4$); cadmium chromate, basic ($Cd(OH)_2CrO_4$); mercuric(II) chromate ($HgCrO_4$); mercury(I) chromate (Hg_2CrO_4); zinc chromate(VI) hydroxide ($ZnCrO_4.4Zn(OH)_2$); zinc dichromate hydrate ($ZnCr_2O_7.3H_2O$); zinc potassium chromate ($\sim K_2O.4ZnCrO_4.3H_2O$; $K_2CrO_4.3ZnCrO_4.Zn(OH)_2$).

Chromates with group 14–15 elements (Sn, Pb, Bi): lead chromate(VI) ($PbCrO_4$); crocoite ($PbCrO_4$); lead chromate(VI) oxide ($PbCrO_4.PbO$); lead chromate hydroxide, ($PbCrO_4.Pb(OH)_2$); lead chromate(VI) sulfate, monoclinic type ($PbCrO_4.xPbSO_4$); lead chromate(VI) sulfate, orthorhombic type ($PbCrO_4.xPbSO_4$); lead chromate molybdate ($PbCrO_4.PbMo_4.PbSO_4$); lead dichromate ($PbCr_2O_7$); bismuth chromate(VI) ($\sim Bi_2O_3.2CrO_3$); bismuth chromate(VI) oxide ($\sim Bi_2O_3.2CrO_3$); bismuth dichromate ($\sim Bi_2O_3.2CrO_3$); tin(IV) chromate ($Sn(CrO_4)_2$); tin chromate, basic (composition unknown).

While some of these chromate pigments are well characterised, others are principally known from documentary sources and are therefore of unclear composition. Only one mineral form (that of crocoite) is closely enough related to be included.

Bismuth chromates group; Calcium chromates group; Copper chromates group; Iron chromates group; Lead chromates group; Zinc chromates group; Barium chromate(VI); Barium potassium chromate; Cadmium chromate; Crocoite; Manganese chromate; Mercury chromate; Silver chromate; Strontium chromate; Thallium chromate; Tin chromate
Berthollet & Vauquelin (1804); Kühn & Curran (1986); Vauquelin (1809); Wormald (1975)

CHROMBLAUGRUN

Blue-Green
Synonym, variant or common name

Synonym for chromium aluminium cobalt oxide (*q.v.*), a rarely encountered pigment of blue-green hue.

Chromium aluminium cobalt oxide

CHROME ARSENIATE

Green
Synonym, variant or common name

According to Salter (1869), 'Chrome Arseniate is an agreeable apple-green colour, prepared from arseniate of potash and salts of chromic oxide.'

Arsenic group; Chromates group
Salter (1869) 284

CHROME BLACK

Black
Synonym, variant or common name

See: aniline black.

CHROME BLUE

Blue
Synonym, variant or common name

Bersch (1901) gives a recipe for chrome blue according to Garnier, whereby a mixture of 48.62 parts potassium chromate, 65 parts fluorspar and 157 parts of silica are fused in a crucible lined with coal dust. The extent of use of this pigment is unknown.

Bersch (1901) 267

CHROME BROWN

Brown
Synonym, variant or common name

According to the *Colour Index* (1971), this is copper chromate oxide hydrate (CI 77403) with composition $CuCrO_4.2CuO.2H_2O$, produced by mixing aqueous potassium chromate and a copper salt.

Salter (1869) also lists 'chrome browns', 'produced by various methods of several hues, tints, and shades, both by wet and dry processes'; the author seemed to think them wholly superfluous, however.
See: copper chromates group.

Colour Index (1971) 77403; Salter (1869) 355

CHROME CINNABAR

Red-Orange
Synonym, variant or common name

In their review of chrome orange and chrome red (*qq.v.*) pigments, Kühn and Curran (1986) list chrome cinnabar as an older term for basic lead chromate (lead chromate(VI) oxide, *q.v.*).

Lead chromates group; Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*
Kühn & Curran (1986)

CHROME GREEN

Green
Synonym, variant or common name

The term chrome green is most commonly applied to a composite pigment where Prussian blue is precipitated on chrome yellow (*qq.v.*; that is, a lead chromate or similar) (Gettens and Stout, 1996). Terry (1893) gives the more general definition that this term 'often applied to any green in which chrome enters as an element', though he then relates it to Brunswick green (*q.v.*) as Prussian blue/chrome yellow formulations, as do earlier authors such as Field (1835). Field adds that this term is used for 'compounds of chromate of lead with Prussian and other blue colours' and that it makes a fine green but the chromate in time destroys the blue, rendering the compound 'unfit for fine art'. Salter (1869) gives a simple recipe for preparing chrome green: 'To a solution of Prussian blue in oxalic acid, first chromate of potash is added, and then acetate of lead'; he then addresses the deterioration problem just mentioned and adduces a method of making similar compound pigments substituting 'chloride of barium or nitrate of bismuth' for the lead acetate commonly used thus making 'superior and more permanent chrome greens'. An interesting aqueous formulation for the related ‘green cinnabar’ (*q.v.*) is given by Riffault *et al.* (1874). Green cinnabar is used as a main term for these mixed greens by a number of sources, particularly German sources, as mixed greens under this term may not always be based on a chrome pigment. Other mixed chrome greens are English green (Salter), *verts solides*, Victoria green, permanent g., bronze g., moss g., Nürnberg g., silk g., leaf g., oil g., olive g. (Linke and Adam, 1913), Berendt’s g. (Mierzinski, 1881), royal g. (Heaton, 1928), milori g. (*qq.v.*; Riffault, 1874), nitrate g., myrtle g., leek g. (Mayer, 1991). Linke and Adam (1913) give a useful summary of the various combinations which form this group of pigments.They define cinnabar green as a mixture of either (a) Paris blue (*q.v.*) with yellow pigments or (b) smaragd green (in this context another term for viridian (*qq.v.*) or chromium oxide hydrate) with yellow pigments or (c) ultramarine (*q.v.*) with yellow pigments. The yellow pigments are listed as: cadmium yellow, zinc yellow, strontium yellow, chrome yellow, gamboge (*qq.v.*), and ‘yellow laquers’. This was the most universally used green pigment in protective and decorative coatings prior to 1940 (Robinson, 1973a).

Various authors also describe chrome green as referring to chromium oxide (*q.v.*); for a fuller discussion of that meaning see the relevant entry.

Chromates group; Hexacyanoferrate group; Chromium oxide; Gamboge; Ultramarine; *Acetate green*; *Behrendt green*; *Bronze green*; *Brunswick green*; *Cadmium yellow*; *Chrome yellow*; *Green cinnabar*; *Leaf green*; *Milori green*; *Moss green*; *Nürnberg green*; *Paris blue*; *Permanent green*; *Prussian blue*; *Royal green*; *Smaragd green*; *Strontium yellow*; *Verts solides*; *Victoria green*; *Viridian*; *Zinc yellow*

Gettens & Stout (1966) 106; Field (1835) 129; Heaton (1928) 683; Linke & Adam (1913) 69–70; Mayer (1991); Mierzinski (1881) 185; Riffault *et al.* (1874) 553; Robinson (1973a); Salter (1869) 267–268, 279–281; Terry (1893) 118–119

CHROME ORANGE

Orange

Synonym, variant or common name

The first mention of chrome orange appears to be that by Vauquelin (1809) in his early nineteenth century examination of chrome compounds, although the history of its introduction as a pigment is not well known. Field, writing in 1835, mentions that two varieties of chrome orange were available, one based on lead chromate, the other on mercury chromate (*qq.v.*). Heaton (1928) describes chrome orange as a term current at that time for ‘basic lead chromate’. Schiek (1973) and Kühn and Curran (1986) define chrome orange more specifically as the basic lead chromate, lead chromate(VI) oxide (*q.v.*), $PbCrO_4.PbO$. Although in some cases the composition has also been given as $Pb(OH)_2.PbCrO_4$, Pollack and Feller (1976) have shown that there is no structurally bound hydroxyl present.

A variety of shades of chrome orange can be produced, ranging from yellow-orange to deep red (termed chrome red, *q.v.*) and synthesis is by adding a solution of a soluble lead salt to an alkali chromate (potassium or sodium) or dichromate solution. As reported in the review by Kühn and Curran, the product colour is based on the synthesis conditions: chrome orange may be precipitated from alkaline solutions at higher synthesis temperatures (Hurst, 1913), while more yellow shades are associated with an excess of lead in solution; the redder shades are formed during syntheses with an excess of alkali chromate; the orange shade may also be formed by treating neutral lead chromate with alkalis. Chrome orange (CI. 77601) is listed by the *Colour Index* (1971) as Pigment Orange 21 (a yellowish orange colour) and Pigment Orange 45 (reddish orange); a variant, designated CI Pigment Orange 21:1, has a similar composition but is precipitated onto a silica base.

Hurst (1913) states that chrome oranges and red considered to be pure were still likely to contain lead sulfate, whereas the more commonly available products often contained adulterants such as china clay, gypsum or baryte (*qq.v.*). According to Bearn (1923, cf. Kuhn & Curran), red lead (*q.v.*) was added to pure chrome orange to give a product described as ‘Genuine orange chrome’. Synonyms and associated terms listed by Kühn and Curran and Schiek, for chrome orange and chrome red include American vermilion (*q.v.*), Australian cinnabar, Austrian red, Austrian cinnabar, Chinese red, chrome cinnabar, chrome scarlet, Derby red, garnet chrome, golden orange yellow, orange paste, Persian red (*q.v.*) or (*rouge de Perse*), ruby red chrome, Victoria red and Vienna red. According to Salter (1869), laque mineral also refers to a form of chrome orange.

According to Kühn and Curran chrome orange is more lightfast than chrome yellow, which is prone to darkening on exposure to light. However, chrome orange has declined in popularity due to the increasing manufacture of molybdate orange and red (*qq.v.*) pigments.

Lead chromates group; Baryte; Gypsum; Lead chromate(VI) oxide; Mercury chromate; *American vermilion*; *China clay*; *Chrome red*; *Molybdate orange*; *Molybdate red*; *Persian red*; *Red lead*

Bearn (1923) 65–79; *Colour Index* (1971) 77601; Field (1835); Heaton (1928) 380; Hurst (1913); Kühn & Curran (1986); Pollack & Feller (1976); Salter (1869) 258; Schiek (1973); Vauquelin (1809)

CHROME OXIDE

Green

Synonym, variant or common name

See: chromium oxide.

CHROME PRIMROSE

Yellow

Synonym, variant or common name

Heaton (1928) lists chrome primrose as a then current term for a ‘chromate and sulphate of lead’.
See: lead chromate(VI) sulfate.

Heaton (1928) 380

CHROME RED

Red

Synonym, variant or common name

Although Kühn and Curran (1986) give the composition of chrome red as lead chromate(VI) oxide (*q.v.*), $PbCrO_4.PbO$ (isochemical with chrome orange, *q.v.*), Gettens and Stout (1966) and others list it as $PbCrO_4.Pb(OH)_2$. However, analysis by Pollack and Feller (1976) suggests that there is no structurally bound hydroxyl present and that the latter composition is incorrect. The *Colour Index* (1971) gives a variable composition of $xPbCrO_4.yPbO$ (or $xPbCrO_4.yPb(OH)_2$), giving rise to various shades with designations of CI Pigments Orange 21, 21:1 and 45, CI Pigment Red 103 (CI 77601) and as a component of Pigment Green 15.

Chrome red was first described in 1809 by Vauquelin, and although its early history as a pigment is not well known, Gettens and Stout suggest that it probably came into use in the early part of the nineteenth century. In British sources, Carlyle (2001) found that it was first listed by Salter (1869), who noted that it was ‘a bright chromate of lead of an orange-red colour’. However, he goes on to note that ‘the recent introduction of cadmium red (*q.v.*) renders the use of this unnecessary’.

As reported by Kühn and Curran, synthesis of chrome red is by boiling a solution of a soluble lead salt with a strong alkali chromate or dichromate solution, so that an excess of alkali chromate forms. Detailed recipes vary; for example, according to Bearn (1923; cf. Gettens and Stout, 1966) the pigment is made ‘by boiling a strong solution of potassium dichromate with white lead and a small amount of caustic soda’. Harley (1982), citing Bodams (1825), describes a further method of boiling chrome yellow (*q.v.*) with potash. By varying the synthesis conditions (and also particle size), a range of colours can be produced; for example, an excess of lead in solution results in the precipitation of more yellow shades. According to Hurst (1913), in their ‘purest’ forms, commercial chrome red and orange pigments were likely to contain lead sulfate, with the less pure products often containing adulterants such as china clay, gypsum or baryte (*qq.v.*).

Kühn and Curran state that chrome red is basically lightfast, unlike the chrome yellows which tend to darken on exposure to light; the chrome oranges are reported more light stable than the chrome yellows (Brown, 1944). However, chrome red is reported to be unstable in the presence of sulfur gases, presumably due to the formation of lead sulfide.

Older synonyms for chrome red and chrome orange as listed by Kelly and Judd (1976) include American vermilion (*q.v.*): Australian cinnabar, Austrian red, Chinese red; chrome cinnabar, chrome scarlet (*q.v.*), Derby red, garnet chrome, Persian red (*q.v.*) or *rouge de Perse*, ruby red chrome, Victoria red and Vienna red. Seward (1889) apparently also identifies chrome red with pigments called Palladian red and Palladian scarlet.

Chromates group; Baryte; Gypsum; Lead chromate(VI) oxide; *American vermilion*; *Cadmium red*; *China clay*; *Chrome orange*; *Chrome scarlet*; *Chrome yellow*; *Persian red*
Bearn (1923) 74; Bodams (1825) 303–305; Brown (1944); Carlyle (2001) 499, 503–505; *Colour Index* (1971) 77601; Gettens & Stout (1966) 106; Harley (1982) 130; Hurst (1913) 137; Kelly & Judd (1976); Kühn & Curran (1986); Pollack & Feller (1976); Salter (1869) 151; Seward (1889); Vauquelin (1809)

CHROME SCARLET

Red
Synonym, variant or common name

Variant of chrome red (*q.v.*). According to Harley (1982), chrome scarlet is listed in an early catalogue of the British colourmen Winsor & Newton (c. 1840–42) but is not found in later editions. Kühn and Curran (1986) also mention chrome scarlet in their review of chrome orange (*q.v.*) and chrome red pigments. Kelly and Judd (1976) cite midnight sun as a synonym.

Chrome orange; *Chrome red*
Harley (1982) 130; Kelly & Judd (1976); Kühn & Curran (1986)

CHROME SESQUIOXIDE

Green
Synonym, variant or common name

Numerous late nineteenth and early twentieth century sources refer to chromium(III) oxide (Cr_2O_3) by this term. It is listed in the *Colour Index* (1971) as 77288, CI Pigment Green 17.

See: chromium oxide.
Chromium oxide
Colour Index (1971) 77288

CHROME YELLOW

Yellow
Synonym, variant or common name

Pigments termed chrome yellow are those which have a composition of lead chromate(VI), $PbCrO_4$, or lead chromate(VI) sulfate (*qq.v.*), $PbCrO_4.xPbSO_4$ (Gettens and Stout, 1966; Kühn and Curran, 1986). They vary in colour from light yellow to orange-yellow (Harley, 1982), with the lighter shades generally containing more lead sulfate. The pure form of lead chromate is listed in the *Colour Index* (1971) as Pigment Yellow 34 (CI 77600), with the lead chromate-lead sulfate solid solution compositions listed as CI 77603. Lead chromate was first recognised as a potential pigment in 1804 by Berthollet and Vauquelin, with its preparation and shade variation later reported by Vauquelin in 1809. Synthesis is by adding a neutral solution of a soluble lead salt (acetate or nitrate) to an alkali (usually potassium or sodium) chromate or dichromate solution (Bearn, 1923); Kittel (1960) states that chrome yellow may also be made directly by adding lead monoxide to chromates in paste form. From the work of Vauquelin (1809), Kühn and Curran suggest that lead chromate was introduced as a pigment between 1804 and 1809.

According to the ASTM Standard (D211-67), chrome yellow pigments may be classified into three types according to their $PbCrO_4$ content: Type I (‘primrose’) contains >50% $PbCrO_4$; Type II (‘lemon’ or ‘light’) contains >65% $PbCrO_4$; and Type III (‘medium’) contains >87% $PbCrO_4$ and therefore includes pure $PbCrO_4$; the remainder of the pigment is usually composed of lead sulfate although other compounds such as lead carbonate or phosphate (*qq.v.*) may also be used (Schiek, 1973). The lead chromate(VI) sulfates vary in crystal structure (monoclinic or orthorhombic), although additives must be added to orthorhombic forms to stabilise the structure (see relevant entry for further details).

Although lead chromate was first synthesised in 1804, it is generally agreed that chrome yellow was not immediately widely available due to the lack of suitable raw materials (the mineral chromite, $FeCr_2O_4$, was usually used). Harley (1982), citing Field (1835), states that by 1814–15 there were several sources supplying chrome yellow, and Bollman (1769–1821) is credited as the first to manufacture chrome yellow commercially in England, starting between 1814 and 1816. Raft (1973) mentions the purchase of chrome yellow (‘*jaune de chrôme*’) in 1815 by the Danish painter Eckersberg (1783–1853), and this appears to be the earliest mention of the pigment in the art literature (Kühn and Curran). Kühn (1969) reports the earliest use of chrome yellow on a painting as that by Sir Thomas Lawrence dated prior to 1810. According to Kühn and Curran, chrome yellow began to be used widely from the second quarter of the nineteenth century onwards (see their review for further details). However, Liebig *et al.* (1842) state that it was an expensive pigment and was sold under the name ‘Cologne yellow’, after being extended with lead sulfate, baryte and gypsum (*qq.v.*). Zerr and Rübencamp (1906) further discuss a number of adjuncts mixed with lead chromates, noting that these are ‘usually limited to barytes, gypsum, or china clay (kaolin, more rarely calcined diatomaceous earth)’, though they also mention chalk (*qq.v.*); moreover, these mixed pigments are ‘put on the market under the names new yellow, Paris yellow, Baltimore yellow, American yellow, &c.’. There are many synonyms for chrome yellow in the literature, some of which refer to extended varieties, although the names have not been used consistently. Salter (1869) states that 'Jaune Minéral, Jaune de Cologne or Cologne yellow, Pale Chrome, and Deep Chrome, are chromates of lead', while Kühn and Curran give the following terms: *amarillo de cromo*; American chrome yellow (*q.v.*) (*Amerikanisches Chromgelb*), Baltimore chrome yellow (*q.v.*) (*Baltimorechromgelb*), *chromato de plomo*, *Chromgelb*, *Citrongelb* (*Zitrongelb*), French chrome yellow (*Französisches Chromgelb*), *Giallo de cromo*, Golden chrome yellow, *Gothaergelb*, *Jaune d'or*, *Jaune de chrôme*, *Jaune de chrôme jonquille* (Jonquille chrome yellow), King's yellow (*q.v.*) or *Königsgelb*, Leipzig yellow (*Leipzigergelb*), Lemon yellow, New chrome yellow (*Neuchromgelb*), New yellow (*Neugelb*), Paris yellow (*Parisgelb*), Spooner's chrome yellow (*Jaune de chrôme Spooner*), Vienna yellow (*Wienergelb*) and *Zwikauergelb*. They also state that various shade terms have also been used in the literature (such as extra bright, bright, medium bright, sulfur yellow, canary yellow) although these do not consistently designate composition. Schiek additionally lists primrose chrome, lemon chrome, golden chrome and middle chrome, with further French terms given in *Fiche Technique*.

Chrome yellow tends to discolour on exposure to light (for example, Haug, 1951; Watson and Clay, 1955; Weber, 1923; Doerner, 1935) due to photochemical effects, with darkening also occurring in the absence of oxygen or moisture. According to Haug, the monoclinic forms of chrome yellow tend to show the greater lightfastness. As reported by Kühn and Curran, modern lightfast pigments (based on the monoclinic form) are made by the addition of stabilising agents such as zinc salts, by encapsulating the pigment with silica (Feller, 1972) or by producing a coating of lead sulfate over the lead chromate during synthesis. According to Church (1901), lead chromates also darken upon exposure to hydrogen sulfide gas, with the discoloration more prevalent when the pigment is used with an water-based vehicle. Gettens and Stout note that when chrome yellow is mixed with organic pigments, chromium oxide (*q.v.*) is produced which causes the pigment to become green. It was considered unsuitable for use in fresco painting as it would react with alkalis.

Chrome yellow has also been used extensively in conjunction with blue compounds to produce green pigments. For example, it is combined with Prussian blue to form chrome green or green cinnabar (Gettens and Stout), or with phthalocyanine blue (*qq.v.*) in modern applications (Kühn and Curran). Martel (1859) also identified it as mixed with vermilion in orange vermilion (*qq.v.*).

Chromates group; Chromium oxides and hydroxides group; Lead carbonates group; Lead chromates group; Lead phosphates group; Lead sulfates group; Baryte; Chalk; Chromium oxide; Gypsum; Lead chromate(VI); Lead chromate(VI) sulfate; *American chrome yellow*; *Baltimore chrome yellow*; *China clay*; *Chrome green*; *Cologne yellow*; *Diatomaceous earth*; *French chrome yellow*; *Green cinnabar*; *Jonquille chrome yellow*; *Kaolin*; *King's yellow*; *Leipzig yellow*; *Lemon yellow*; *New chrome yellow*; *New yellow*; *Orange vermilion*; *Paris yellow*; *Phthalocyanine blue*; *Prussian blue*; *Spooner's chrome*; *Vermilion*; *Vienna yellow*

ASTM (1977); Bearn (1923); Berthollet & Vauquelin (1804); Church (1901) 162–163; *Colour Index* (1971) 77600, 77603; Doerner (1935); Feller (1972); Fiche Technique (1966); Field (1809); Field (1835) 77; Gettens & Stout (1966) 106; Harley (1982) 101–102; Haug (1951); Kittel (1960) 279; Kühn (1969); Kühn & Curran (1986); Liebig *et al.* (1842); Martel (1860); Raft (1973); Salter (1869) 93; Schiek (1973); Vauquelin (1809); Watson & Clay (1955); Weber (1923); Zerr & Rübencamp (1906/1908) 148–149

CHROMIUM ALUMINIUM COBALT OXIDE

Blue-Green
Generic compound

Kühn (1969) identified this in an 1862 painting by Eduard Schleich the Elder. Pamer (1978) identified a similar pigment in certain modern acrylic paints referred to as Cerulean blue (*q.v.*) and has reported an unindexed X-ray diffraction pattern for it. Several German sources give this colour the name turquoise or Turkish green (*q.v.*). Zerr and Rübencamp (1906) comment that this colour is very bluish. The *Colour Index* (1971; CI 77343) gives a formulation to produce a chromium-aluminium-cobalt oxide by 'igniting a mixture of aluminium hydroxide, chromium oxide and cobalt carbonate at white heat'.
See also: Turkish green.

Aluminium group; Chromium group; Cobalt group; Cerulean blue; *Turkish green*; *Turquoise green*
Colour Index (1971) 77343; Kühn (1969); Pamer (1978); Zerr & Rübencamp (1906/1908) 241

CHROMIUM BORATE

Green
Generic compound

In early studies on the element chromium by its discoverer Louis-Nicolas Vauquelin, he described a beautiful green colour produced by heating the metal with a blowpipe and borax (Vauquelin, 1798; cf. Newman, 1997).

Listed by the *Colour Index* (1971, CI 77292) it appears to be a rare pigment.

Chromates group
Colour Index (1971) 77292; Newman (1997); Vauquelin (1798)

CHROMIUM CHLORIDE

Purple
Generic compound

Apparently 'chromic chloride' was a violet pigment discovered by Wohler (1800–82), Professor of Chemistry at the Chemical University of Göttingen (cf. *Colour Index*, 1971; CI 77295). In practice this compound generally occurs either as an anhydrous chromium(III) chloride ($CrCl_3$) or as a hexahydrate (chromium(III) chloride hexahydrate, $Cl_3CrH_{12}O_6$, probably as $[Cr(OH_2)_6]Cl_3$). The anhydrous compound is red-violet, while the hydrated form has greenish black to violet crystals; it is unclear which is the basis of the pigment. Chromium(II) and chromium(IV) chlorides also exist.
See: chromium halides group.

Chromium group; Chromium halides group
Colour Index (1971) 77295

CHROMIUM GROUP

Variable
Group term

Named from the Greek for colour (*χρομα*), chromium perhaps unsurprisingly forms an enormous range of compounds that have found importance as pigments. Most significant among these are the various chromates and the green oxide and oxide hydrate. Given the number of compounds it is also convenient to separate the chromates according to the periodic group of the second element.

Halides: chromium chloride ($CrCl_3$); chromium(III) chloride hexahydrate ($[Cr\{OH_2\}_6]Cl_3$).

Simple oxides and hydroxides: chromium oxide and eskolaite (Cr_2O_3); chromium oxide hydrate ($Cr_2O(OH)_4$).

Chromates with group 1–2 elements (Ca, Sr, Ba): barium chromate(VI) ($BaCrO_4$); barium potassium chromate (formula unknown); calcium chromate(VI) dihydrate ($CaCrO_4.2H_2O$); calcium chromate(VI) hydroxide dihydrate ($Ca_2(OH)_2CrO_4.2H_2O$); strontium chromate(VI) ($SrCrO_4$).

Chromates with group 3–11 elements (Mn, Fe, Co, Cu, Ag, Th): cobalt chromate ($CoCr_2O_4$); copper chromate hydroxide ($CuCrO_4.Cu[OH]_2$); copper chromate hydroxide ($CuCrO_4.2Cu(OH)_2$); copper chromate hydroxide ($2CuCrO_4.3Cu(OH)_2$); copper chromate oxide hydrate ($CuCrO_4.2CuO.2H_2O$); iron dichromate ($Fe_2(Cr_2O_7)_3$); iron chromate hydroxide ($Fe(OH)CrO_4$); manganese chromate (according to the *Colour Index*, 1971, the formula is '$2MnO.CrO_3.2H_2O$'); silver chromate(VI) (Ag_2CrO_4); thallium chromate ($Tl_2[CrO_4]_3$ or Tl_2CrO_4).

Chromates with group 12 elements (Zn, Cd, Hg): cadmium chromate ($CdCrO_4$); cadmium chromate, basic ($Cd(OH)_2CrO_4$); mercury(I) chromate (Hg_2CrO_4); mercuric(II) chromate ($HgCrO_4$); zinc dichromate hydrate ($ZnCr_2O_7.3H_2O$); zinc chromate(VI) hydroxide ($ZnCrO_4.4Zn(OH)_2$); zinc potassium chromate ($K_2O.4ZnCrO_4.3H_2O$).

Chromates with group 14–15 elements (Sn, Pb, Bi): lead chromate(VI) ($PbCrO_4$); crocoite and lead dichromate ($PbCr_2O_7$); lead chromate(VI) oxide ($PbCrO_4.PbO$); lead chromate hydroxide ($PbCrO_4.Pb(OH)_2$); lead chromate sulfate ($PbCrO_4.xPbSO_4$); bismuth chromate ($Bi_2O_3.2CrO_3$); tin chromate(VI) ($Sn[CrO_4]_2$).

Tertiary and quaternary oxides (Al + Co, Sn; Cu, Fe): chromium aluminium cobalt oxide; chromium iron oxide ($(Fe,Cr)_2O_3$); chromium copper iron oxide ($CuO.Cr_2O_3.Fe_2O_3$).

Phosphates: chromium phosphate hydrate ($CrPO_4.xH_2O$).

Sulfates: chromium sulfate ($Cr_2[SO_4]_3$); chromium sulfate hydrate ($Cr_2[SO_4]_3.15H_2O$ and $Cr_2[SO_4]_3.18H_2O$).

A chromium borate is also thought to exist in a pigmentary context.

Calcium chromates group; Chromates group; Chromium halides group; Chromium oxides and hydroxides group; Chromium phosphates group; Chromium sulfates group; Copper chromates group; Iron chromates group; Lead chromates group; Zinc chromates group; Chromium aluminium cobalt oxide; Chromium borate; Chromium chloride; Chromium iron oxide; Chromium oxide; Chromium oxide hydrate; Chromium oxide hydroxide; Chromium tin oxide; Cobalt chromate; Copper chromate hydroxide; Copper chromate oxide hydrate; Copper chromate(III); Copper chromate(VI); Crocoite; Eskolaite; Iron chromate hydroxide; Iron dichromate; Lead chromate hydroxide; Lead chromate molybdate; Lead chromate(VI); Lead chromate(VI) oxide; Lead chromate(VI) sulfate; Lead dichromate; Manganese chromate; Mercury chromate; Silver chromate; Strontium chromate(VI); Thallium chromate; Tin chromate; Zinc chromate hydroxide; Zinc dichromate hydrate; Zinc potassium chromate hydrate
Colour Index (1971)

CHROMIUM(III) CHLORIDE

Red-Purple
Generic compound

See: chromium halides group.

CHROMIUM(III) CHLORIDE HEXAHYDRATE

Purple
Generic compound

See: chromium halides group.

CHROMIUM HALIDES GROUP

Variable
Group term

According to the *Colour Index* (1971) 'chromic chloride' was a violet pigment discovered by Wohler. The stated preparation technique was to form pure chromic oxide into balls with charcoal, starch and water, bring to white heat, pass chlorine through and then condense the pure chromic chloride, which sublimes off. Heating and passing of chlorine is continued until a sample of the mass no longer gives a green aqueous solution (Wohler, cf. *Colour Index*, CI 77295).

The principal chromium(III) chloride is the red-violet $CrCl_3$ (CAS 10025-73-7) and the various forms recognised of the hexahydrate ($Cl_3CrH_{12}O_6$; CAS 10060-12-5):

(a) $[CrCl_2(OH_2)_4]Cl.2H_2O$, which is dark green (CAS 29563-34-6);
(b) $[CrCl(OH_2)_5]Cl_2.H_2O$, which is pale green (CAS 36179-36-9);
(c) $[Cr(OH_2)_6]Cl_3$, which is violet (CAS 13820-88-7).

According to Cotton *et al.*, $CrCl_3$ can be sublimed in a stream of chlorine at ~600°C, though it decomposes to the Cr^{2+} chloride if the chlorine is absent (Cotton *et al.*, 1999). Further, the hexahydrates reportedly dissolve in water to give green solutions when concentrated, violet when dilute (*Merck Index*, 1996). The chloride itself apparently has only low aqueous solubility unless some Cr^{2+} ions or other reducing agents are present; $CrCl_2$ may of course be present during Wohler's method through incomplete reaction or inadequate supplies of chlorine, giving rise to the stated test for completeness.

No other chromium halides seem to have had pigment use or association.

Colour Index (1971) 77295; Cotton *et al.* (1999) 739; *Merck Index* (1996) 2278

CHROMIUM IRON OXIDE

Brown
Generic compound

Listed by the *Colour Index* (1971) under CI 77500/CI Pigment Brown 29 as 'chromium iron brown' (chromium(III) iron(III) oxide, ($(Fe,Cr)_2O_3$), and described as 'a mixed phase pigment based on iron oxide-chromium oxide'.

Chromium group
Colour Index (1971) 77500

CHROMIUM OXIDE

Green
Generic compound

Chromium oxide is an opaque dull olive green pigment generally known by its chemical name or variants such as chrome sesquioxide or chrome oxide. Coffignier (1924) reports that there were several different manufacturing processes, one of these leading to the term Casali's green (*q.v.*). (It must be noted that this term has also been applied to the hydrated form, generally called viridian, *q.v.*) Other terms include green oxide of chromium, native (chrome) green, true chrome green and opaque oxide of chromium, while MacIntyre (1992) also gives chromic trioxide, ultramarine green and green cinnabar (*qq.v.*); however, ultramarine green is generally considered to be an intermediate product in the manufacture of synthetic ultramarine and green cinnabar generally refers to a mixed green based on

Prussian blue and a yellow chromate (*qq.v.*). The mineral form is eskolaite (*q.v.*); Salter (1869) states that '[oxide of chromium] is found native in an impure state as chrome ochre, but is always artificially prepared for artistic use'.

Manufacture of the pigment was through the 'decomposition of iron chromate' (Vauquelin, 1809; cf. Newman, 1997). Later, two further methods are recorded: calcining mercury chromate or a mixture of mercury chromate and sulfur (Vergnaud, 1831; cf. Newman). More economical processes were also developed which included calcining potassium chromate with sulfur, or with ammonium chloride and then washing and calcining again, or calcining potassium bichromate with starch and washing and recalcining. The starch process produced a pigment called Lamorinière green (*q.v.*). There are further so-called 'wet' processes where viridian (hydrated chromium oxide) is formed and then dried and calcined (Church, 1901). Modern processes use a reduction of sodium or potassium dichromates with carbon or sulfur, or simply by heating ammonium dichromate (Robinson, 1973a).

It was generally believed that this pigment was not introduced until 1862; however, chromium oxide has been found on a painting by Turner dated to 1812 (Newman) and a sample of this colour made by the early nineteenth century British colourman Field was entered in his *Practical Journal 1809* after 1815 (cf. Harley, 1982). The pigment has also been identified on ten paintings analysed by Kühn (1969) in the Schack Gallerie in Munich. It is probable that this colour had limited use as it was very expensive compared to chrome greens (*q.v.*; pigment mixtures).

It is listed in the *Colour Index* as CI 77288/Pigment Green 17.

Chromium oxides and hydroxides group; Eskolaite; *Casali's green*; *Chrome green*; *Chrome sesquioxide*; *Chrome yellow*; *Green cinnabar*; *Lamorinière green*; *Native green*; *Prussian blue*; *Ultramarine green*; *Vert de chrome*

Church (1901) 192–193; Coffignier (1924) 456–457; *Colour Index* (1971) 77288; Harley (1982) 86; Kühn (1969); MacIntyre (1992); Newman (1997); Robinson (1973a); Salter (1869) 267; Vauquelin (1809); Vergnaud (1831)

CHROMIUM OXIDE HYDRATE

Green

Generic compound

A transparent green colour with various different names, but most commonly known by the name viridian (*q.v.*) (Newman, 1997).

Chromium group; Chromium oxides and hydroxides group; *Casali's green*; *Chrome sesquioxide*; *Emerald oxide of chromium*; *Guignet's green*; *Pannetier's green*; *Transparent oxide of chromium*; *Veronese green*; *Viridian*

Newman (1997)

CHROMIUM OXIDE HYDROXIDE

Green

Generic compound

An inaccurate composition given in some sources for chromium oxide hydrate.

See: chromium oxides and hydroxides group.

CHROMIUM OXIDES AND HYDROXIDES GROUP

Variable

Group term

Various chromium oxides and hydroxides are known to exist. The chromium oxides comprise a group of pigments collectively known as chromium oxide greens based on chromium(III) oxide (Cr_2O_3), chromium sesquioxide. This is listed by the *Colour Index* (1971) as CI 77288/Pigment Green 17. There is also a hydrated form, hydrated chromium sesquioxide ($Cr_2O(OH)_4$, or mixtures of $Cr_4O_3(OH)_4$ and $Cr_4O(OH)_{10}$ with Cr_2O_3 and 0.5–10% boric acid), listed as *Colour Index* CI 77289/Pigment Green 18.

There are no chromium hydroxide pigments.

Eskolaite is a chromium oxide mineral with composition Cr_2O_3 (Newman, 1997).

Chromium group; Chromium oxide; Eskolaite; *Arnaudon's chrome green*; *Chrome sesquioxide*; *Viridian*

Colour Index (1971) 77288, 77289; Newman (1997)

CHROMIUM PHOSPHATE

Green

Generic compound

See: chromium phosphates group.

CHROMIUM PHOSPHATE, BASIC HYDRATED

Green

Generic compound

See: chromium phosphates group.

CHROMIUM PHOSPHATE HYDRATE

Green

Generic compound

See: chromium phosphates group.

CHROMIUM PHOSPHATES GROUP

Green

Group term

Several chromium phosphates can be formed, notably the various hydrated forms ($CrPO_4.xH_2O$). There are also a number of manufacturing variants such as those known as Arnaudon's chrome green (*q.v.*), Dingler's g., (Mathieu) Plessy's g. and Schnitzer's g., which were prepared as follows:

Arnaudon's green: heating ammonium phosphate with potassium dichromate.
Dingler's green: formed from a mixture of chromic and calcium phosphates.
Plessy's green: made by treating aqueous potassium dichromate with acid calcium phosphate and cane sugar dissolved in hydrochloric acid.
Schnitzer's green: by treating an aqueous solution of potassium dichromate with sodium phosphate and tartaric acid (Zerr and Rübencamp, 1906).

The authors Church (1901) and Coffignier (1924) describe a 'basic hydrated chromium phosphate of variable composition'. The manufacturing process and possibly the specific chemical composition of these various pigments were in some cases different (Champetier *et al*., 1956). Hurst has described the precipitation of chromium phosphates from chromium chloride solutions, or in a mixture of potassium dichromate and sodium phosphate (Hurst, 1913). Windholz (1983) gave the composition of Arnaudon's green or Plessy's green as the hemiheptahydrate of $CrPO_4$. No pigments of this type appear to have been identified on paintings. A short review of the pigment is given in the article on chromium oxide greens by Newman (1997).

A violet chromic phosphate ($CrPO_4.6H_2O$) is precipitated when a cold solution of chrome alum and disodium hydrogen phosphate are mixed; on boiling it is converted to the green $CrPO_4.4H_2O$.

Chromium group; *Arnaudon's chrome green*; *Mathieu-Plessy's green*; *Plessy's green*; *Schnitzer's green*; *Vert Dingler*; *Vert Schnitzer*
Champetier *et al.* (1956); Church (1901) 195; Coffignier (1924) 455–456; Hurst (1913); Newman (1997); Windholz (1983); Zerr & Rübencamp (1906/1908) 239

CHROMIUM RUTILE YELLOW

Yellow
Synonym, variant or common name

Chromium rutile yellow pigments are described by the *Colour Index* (1971; CI 77310/Pigment Brown 24) and have a typical composition of $Ti_{0.90}Sb_{0.05}Cr_{0.05}O_2$. Depending on particle size the colour varies from light to medium ochre. It is also related to nickel rutile yellow (*q.v.*; Buxbaum, 1997).

Nickel rutile yellow
Buxbaum (1998) 100; *Colour Index* (1971) 77310

CHROMIUM STANNATE

Red-Purple
Synonym, variant or common name

See: chromium tin oxide.

CHROMIUM SULFATE

Red-Purple
Group term

See: chromium sulfates group.

CHROMIUM SULFATE HYDRATE

Green
Generic compound

See: chromium sulfates group.

CHROMIUM SULFATES GROUP

Variable
Group term

According to the *Colour Index* (1971; CI 77305), chromium sulfate ($Cr_2(SO_4)_3$) is said to occur in three forms: (a) a violet or red anhydrous form; (b) $Cr_2(SO_4)_3.15H_2O$, which is dark green; (c) $Cr_2(SO_4)_3.18H_2O$. It is prepared by treating chromium hydroxide with sulfuric acid and then crystallising, and has been used in green paints, varnishes and inks.

Chromium group
Colour Index (1971) 77305

CHROMIUM TIN OXIDE

Red-Purple
Generic compound

Chromium tin oxide ('chromium stannate') is stated to be a red to violet pigment which can be synthesised via an aqueous route. Otherwise, the *Colour Index* (1971; CI 77302/Pigment Red 121) describes so-called tin violet or mineral lake (*qq.v.*) as being prepared by fusing tin(IV) oxide with chromium oxide.

Chromium oxides and hydroxides group; *Mineral lake*; *Tin violet*
Colour Index (1971) 77302

CHRYSEAN

Yellow
Synonym, variant or common name

According to Bersch (1901), a compound known as chrysean, similar in appearance to mosaic gold (*q.v.*; a tin(IV) sulfide), was said to have been developed in the late nineteenth century. Apparently discovered by Wallach, it was obtained by passing hydrogen sulfide through saturated aqueous potassium cyanide to precipitate a compound of stated formula '$C_4H_5N_3S_3$'. Cost and lack of significant advantage appear to have meant it was not used.

Mosaic gold
Bersch (1901) 162

CHRYSOCOLLA

Green
Generic compound

Chrysocolla is a soft and fragile copper silicate hydroxide hydrate mineral with chemical composition $(Cu,Al)_2H_2Si_2O_5(OH)_4.n(H_2O)$. It is named after the Greek words *χρυσος* (*chrysos*), meaning 'gold', and *κολλα* (*kolla*), meaning 'glue', as it was one of the ingredients used to solder gold. It is commonly blue-green in colour, although the presence of impurities may produce black-brown varieties. Chrysocolla is usually poorly crystalline and is found with botryoidal, stalactitic, encrusting or earthy habits. It forms as a secondary mineral in the upper oxidising zones of ore deposits and is found in association with azurite, malachite, chalcopyrite, tenorite, cuprite and quartz (*qq.v.*). Chrysocolla is also known as bisbeeite or beaumontite and is found in locations such as Cornwall and Cumbria (England), Saxony (Germany), Attica (Greece), Tyrol (Austria), Piedmont (Italy), Arizona (USA, Sun Ming-Shan, 1963) and New Mexico (USA), Ural Mountains (Russia), Broken Hill (New South Wales, Australia), Shaba (Congo) and Tsumeb mine (Otavi, Namibia). The German literature generally treats chrysocolla as coming from Hungary, Agricola (1556) discussed the occurrence of native chrysocolla in veins, as 'grains', as thin layers upon metal surfaces, or settling as a powder from waters washing over copper minerals. He describes how chrysocolla, deposited as sediment in reservoirs filled by water draining from surrounding copper deposits, was collected annually in the Carpathian mountains and sold as a pigment. The Carpathian sources are given by Burmester and Resenberg (2003) as the modern Spania Dolina, Banska bystrica, Kremnitz and Banska Stiavnica from whence it was exported toward the south, particularly to Venice.

However, chrysocolla was also used historically as a term for malachite in classical and mediaeval literature such as the texts by Theophrastus (c. 315 BC), Vitruvius (first century BC) and Pliny (77 AD). For example, Vitruvius describes chrysocolla as coming from the copper mines of Macedonia.

Harley (1982) found that in seventeenth century literature several sources gave two samples, one which was obviously malachite (termed green bice or berggrün) and the other therefore distinct and clearly chrysocolla (termed sedergreen, ceder green, *q.v.*). Boltz (1549) also gives descriptions of both colours, using the German term *Schifergrün* to describe chrysocolla which he considered to be more beautiful than 'the other' (malachite), '*Schifer grein … schöner dann das ander*'. It has also been suggested that this term may refer to the 'spherical' form of malachite (Heydenreich, 2003). Veliz (1986) suggests that the *verde granillo* mentioned by Carducho in his *Diálogos* (1633) might be chrysocolla, though this view does not appear to be supported by other authors of that period or by current analyses. Other names given to this pigment are gold solder, *severgroen* (Dutch) and *siefer-grün* (German). The terminology for chrysocolla appears, however, to be far from clear cut. Recent research by Burmester and Resenberg into the historical terminology as found in early mining, alchemical, taxation, pharmacological and travel literature, particularly that from Germany, indicates that *viride montis*, *viride montanum*, *berck grün*, *schieffergrien*, *chrysicolla vera*, *chrysocolla metallica*, *chrysocolla nativa*, *terra viridis*, *steingrün*, *auriglutinum*, *gluten auri* and *diphryges* were all used to describe this mineral. The use of mountain or Berg green (*q.v.*) is particularly open to confusion as other literature clearly indicated malachite for this term, and *terra viridis* would normally indicate a green earth (*q.v.*).

This pigment apears to have fallen into disuse in Europe during the seventeenth century, possibly due to some disruption of trade (Harley).

Chrysocolla has been identified in a pigment context on ancient wall paintings at Bamiyan in Afghanistan and Kizil in Chinese Turkestan by Gettens (1938a,b) and by Bontinck (1945). Further identifications include those on XII dynasty tombs at El-Bersha and at Kahun, Egypt (Spurrell, 1895) and in Moche wall painting pigments from La Mina, Jequetepeque, Peru (Scott *et al.*, 1998).

Copper silicate group; Azurite; Cuprite; Green earth; Malachite; Quartz; Tenorite; *Berggrün*; *Ceder green*; *gold solder*; *Mountain green*; *Verde granillo*

Agricola (1556/trans. Hoover & Hoover, 1950) 221, 584; Boltz von Ruffach (1549/Benziger, 1913) 76; Bontinck (1945); Burmester & Resenberg (2003); Carducho (1633); Gettens (1938a); Gettens (1938b); Gettens & FitzHugh (1993b); Harley (1982) 77–79; Heydenreich (2003); Pliny (1st cent AD/Rackham, 1952) XXXV.xxix; Scott *et al.* (1998); Spurrell (1895); Sun Ming-Shan (1963); Theophrastus (c. 315 BC/Caley & Richards, 1956) 39; Veliz (1986) 198, n. 10; Vitruvius (1st cent BC/Grainger, 1934) VII.ix.6

CHRYSOPHANIC ACID

Yellow

Generic compound

See: chrysophanol.

CHRYSOPHANOL

Orange

Generic compound

Chrysophanol, 1,8-dihydroxy-3-methyl-9,10-anthracenedione, an anthraquinone, occurs in the free state and as a glucoside in various plants, notably *Aloe* species and *Rheum* species. It is listed by many sources as synonymous with chrysophanic acid (*Merck Index*, 1996; WHO, 1999) and is listed by the *Colour Index* (1971) as CI 75400.
See: aloe and rhubarb.

Anthraquinones group

Colour Index (1971) 75400; *Merck Index* (1996) 2318; WHO (1999) 231–240

CHRYSOTILE

White

Generic compound

Chrysotile is a white fibrous mineral of composition $Mg_3Si_2O_5(OH)_4$ (Warren and Bragg, 1931; Rutley, 1988). It forms part of the serpentine group (*q.v.*) of minerals and has several polymorphs (ortho-, clino- and parachrysotile, *qq.v.*). The name chrysotile is derived from the Greek words χρυςος (*chrysos*) meaning ‘gold’ and τιλος (*tilos*) meaning fibre. The mineral occurs as veins in serpentinite and as masses in metamorphosed or hydrothermally altered ultramafic and carbonate rocks. Chrysotile is found in areas such as Cassiar, British Columbia; Thetford, Quebec; Transvaal, South Africa; Cornwall, UK and Cyprus where it has been extensively mined.

It is a toxic asbestiform material and its modern use in artwork is therefore limited. However, there is evidence of historical use of asbestos materials as additives to paint and it may therefore be encountered; no identifications are currently known in this context.

Serpentine group; Silicates group; Orthochrysotile; Parachrysotile

Rutley (1988) 396; Warren & Bragg (1931)

CICERCULUM

Brown

Synonym, variant or common name

See: brunus.

CIMATURA

Red

Synonym, variant or common name

Pliny (1st century AD) describes the process of making a purple pigment using purple dyed cloth soaked in water with chalk (see the entry: Tyrian purple) and many mediaeval manuscripts describe a method for making *lacca di cimatura* and *cimatura di grana* (translated as ‘shearings’, ‘scowrings’ [Neri, 1612/Merret, 1662] or ‘clippings of grain’), a red lake used in manuscript illumination. The colour was produced using tailoring waste cloth, usually wool, which had been dyed with *grana* (*q.v.*). The fifteenth century Bolognese manuscript (Clarke MS 160, cf. Merrifield, 1849) gives a typical description: ‘Take the clippings of cloth … Put them into ley made from the ashes of bean stalks, and let the ley be strong … Then put the cloth into the ley, and the colour will then be dissolved. Strain it and let it settle; and if you wish to give body to the lake, take roche alum and mix with the lake.’ The *Experimenta de Coloribus* (c. 1341; Clarke MS 2790, cf Merrifield) gives three different methods for producing lake colours from clippings. However, the general process was to use lye (potassium carbonate) to break the bonds between the cloth and the dyestuff and then to lake this dyestuff by the reaction of potassium aluminium sulfate with the lye. This produces an aluminium hydroxide (*q.v.*) precipitate onto which the dyestuff is attached (Wallert, 1991b).

Both indigo and Tyrian purple were also extracted for pigment use in this way, as was madder (*qq.v.*). Wallert further suggests that brazilwood (*q.v.*) lakes could have been prepared from textiles prior to about 1450. It has been postulated that this indirect method of preparation is the reason for there being very little mention of madder in documentary sources in Europe until the late sixteenth century (Kirby and White, 1996). It is also quite possible that cimatura lakes could have been made with mixtures of dyestuffs, as the textile sources could have been from mixed dyes, as, for example, kermes (*q.v.*) and madder were mixed in dyings called *meza grana*, *demy-graines* or *demy-cramoisis* (Kirby and White). Ploss (1962) cites a number of mediaeval German manuscripts which also describe this method, the shearings being called *Vlocken*, where the alkali appears to have been used in a stronger form than in Italy, reducing the material to an amorphous gelatinous mass. French seventeenth century descriptions for *bourre* appear to be similar (de la Hyre, 1730; cf. Kirby and White).

Evidence of this technique has been found by the present authors in a sample of a pink pigment containing textile fibres and tannins excavated from Pompeii, dating to the second century AD (Walsh *et al.*, 2004) and fibres have also been found within a sample of red lake from Titian’s *Venus and Adonis* (c. 1560) analysed at the J. Paul Getty Museum (Birkmaier *et al.*, 1995).

Other terms relating to the use of dyed cloth include the Italian *pezzette*, corrupted to *bisetus*, or *biseto folii* and *bezetta seu turnasolis* (Merrifield, 1849) and the Spanish trapilo blue (*q.v.*), which means 'blue from little rags' (Veliz, 1986); however, these relate to a different method of extraction.
See: turnsole.

Insect-based reds group; Aluminium hydroxide; Brazilwood; Cochineal; Indigo; Kermes; Lac; Madder; *Grana*; *Trapilo blue*; *Turnsol blue*; *Turnsole*; *Tyrian purple*
Birkmaier *et al*. (1995); Hyre (1730); Kirby & White (1996); Merrifield (1849) 457; Neri (1612/Merrit 1662) 347; Pliny (1st cent AD/Rackham, 1952) xxxv.xxxvi; Ploss (1962) 113; Veliz (1986) 198; Wallert (1991b); Walsh *et al*. (2004)

CINABRESE

Red
Synonym, variant or common name

According to Montagna (1993), cinabrese was said to be a mixture of two parts *sinopia* (*q.v.*) and one of *bianco sangiovanni* and used in fresco and tempera painting.

Sinoper
Montagna (1993)

CINNABAR

Red
Generic compound

The early eighteenth century chemist Boerhaave says of cinnabar in his *Elementa Chemiae* that it is 'A hard, ponderous, metallic, and beautifully red stoney substance, that breaks into shining, bright, angular pieces.' Cinnabar is a soft red mercury(II) sulfide mineral with ideal composition α-HgS, although impurities of bitumen and members of the clay minerals group (*qq.v.*) are often present. It commonly occurs with massive form and as granular crusts, although prismatic or tabular crystals may be found, occasionally with interpenetrant twins. Cinnabar commonly forms in veins and small impregnations associated with volcanic activity and hot spring action, often replacing quartz (*q.v.*) and other sulfide minerals. It is often found in association with stibnite, pyrite, marcasite, gypsum, quartz and calcite (*qq.v.*; Rutley, 1988). The most important source of cinnabar in Europe is Almaden (Spain) where it is found in veins in quartzite, with other important localities being Idria (Italy), California (USA), Saxony (Germany), Attica (Greece), Durango (Mexico), Russia, Yugoslavia and in China: Hunan Province (Chenzhou, Fenghuang, Huangxian, Mayang, Gancheng), Guizhou Province (Yuping, Bijie, Guizhu, Anshun), Sichuan Province (Xiyang, Xiushan, Pengshui) and Yunnan Province (Baoshan and Dali). Cinnabar is the trigonal form of HgS and two other polymorphs are known to exist: metacinnabar, α'-HgS, the high temperature black cubic form, and hypercinnabar (*qq.v.*), β-HgS, a less stable form. The term cinnabar is currently used to refer to the natural mineral form; the synthetic form, normally termed vermilion (*q.v.*) and manufactured since the eighth century AD in Europe, is derived indirectly from the native material.

The fourth century BC Greek author Theophrastus describes Spanish (*Ιβυριαν*) cinnabar (*κινναβαρις*) and that from Colchis, both of which he says are of natural origin. (For more regarding Spain, see below. Geographically, ancient Colchis comprised the land bounded by the Black Sea to the west, the Caucasus Mountains to the north, the Surami Range to the east and the Meskhetian Mountains to the south; it corresponds to the present-day region of Mingrelia in the Georgian SSR.) Theophrastus also records cinnabar from Ephesus and was artificial, produced from a washed sand, adding that it glowed 'like kermes berries'. However, it would seem that the ore was actually finely disseminated in a sediment and was concentrated through washing and sieving. The present authors are currently unaware of cinnabar deposits in the region of Ephesus. Cinnabar has also been described by the classical Roman authors who consistently refer to it, however, as *minium*, a term which of course is now appropriated to red lead (*qq.v.*). Pliny (77 AD) states that the Greeks called (the Latin) *minium* 'cinnabar' (*κινναβαρις*) to differentiate it from ochre and *miltos* (*qq.v.*). The main source of this in the Mediterranean world was the mines in the Betic Mountains of south-west Spain (now called from the Moorish, Almaden).

Both Vitruvius (first century BC) and Pliny note that pure cinnabar pigment (*minium*) was unsuitable for painting outside as it turns black in the sunlight (and moonlight); however, it could be protected by a coat of oil and wax. It is well known, however, that this discoloration did not happen with *all* cinnabar-based paints and it has been recently shown (McCormack, 2000) that it occurs only in cinnabars containing traces of chlorine or in pigments exposed to the halogens.

Minium was perhaps the Roman's most valuable pigment and it was used in ambitious works and demonstrated great wealth. Perhaps the most spectacular use is in the 'Frieze of the Mysteries' in *Oecus V* of the Villa of the Mysteries at Pompeii. This prized Spanish *minium* was very expensive. The price was indeed capped by law at 70 sesterces per pound to stop it rising out of all proportion. All the same, this was still ten times more expensive than high quality red ochre (*q.v.*) from Sinope. The 'Frieze of the Mysteries' demonstrates lavish expenditure on behalf of the patron. For those with tighter purse strings, Pliny says that *minium* may be adulterated with goat's blood, red lead ('second rate' or *secundarium minium*) or crushed berries (he is probably referring here to Kermes, *q.v.*). The 'burnt' cinnabar also mentioned in classical texts was a calcined yellow ochre (*q.v.*). Finally, the *cinnabaris* of Pliny is generally interpreted as referring to so-called dragon's blood (*q.v.*), which usually describes a red resinous tree exudate; however, here it is described as the 'mingled blood of the elephant and the dragon'.

Merrifield (1846) cites several authors who describe a hard red mineral called *amatito* (*q.v.*) or *Lapis amatito*. She does not believe that these terms refer to cinnabar although Borghini (1584), for example, does. Yü (1955) records that cinnabar was also known as *Chensha* cinnabar, from the name of a production site Chenzhou, Hunan Province, China, and Field (1835) names other sources which geologically are unlikely to contain cinnabar deposits.

Cinnabar, and vermilion, are known in many different art contexts, and the similarity of the natural and synthetic versions will undoubtedly lead to inaccuracies in determinations. Synthetic cinnabar has been manufactured in the west since the Roman period. Natural cinnabar occurs frequently in Roman art and in East Asian (especially Chinese) art. Gettens *et al.* (1993b) review identifications on Roman wall paintings, fifteenth to eighteenth century Persian and Indian illuminated manuscripts, a seventeenth century Indian wall painting, second millennium BC early Chinese oracle bone inscriptions, tenth century Chinese wall paintings and nineteenth century Spanish wall paintings (see references therein). More recent identifications include the appearance of cinnabar on a fourth century BC marble basin (Wallert, 1995a), in first century Roman wall paintings (Bugini *et al.*, 2000), on the Salerno Exultet (Bicchieri *et al.*, 2000), on fourteenth century Maltese manuscripts (Szczepanowska and FitzHugh, 1999) and on Byzantine paintings (Chiavari *et al.*, 1999). The red ink on the Dead Sea Scrolls has been identified as mercury sulfide, possibly cinnabar (Nir-El and Broshi, 1996). Cinnabar has been identified on Raphael's *La Loggia di Amore e Psiche* (Varoli-Piazza, 2002).

Cinnabar and vermilion have been reviewed by Gettens *et al.* (1993b).

Clay minerals group; Mercury group; Calcite; Dragon's blood; Gypsum; Hypercinnabar; Kermes; Lead(II,IV) oxide; Marcasite; Mercury(II) sulfide, cinnabar type; Metacinnabar; Minium; Ochre; Pyrite; Quartz; Stibnite; *Amatito*; *Miltos*; *Red lead*; *Red ochre*; *Vermilion*; *Yellow ochre*
Bicchieri *et al.* (2000); Boerhaave (1727); Borghini (1584/edition of 1787); Bugini *et al.* (2000); Chiavari *et al.* (1999); Field (1835) 93; Gettens *et al.* (1993b); McCormack (2000); Merrifield (1846) xii–xxii; Nir-El & Broshi (1996); Pliny (1st cent AD/Rackham, 1952) XXXIII,xxxviii; Rutley (1988) 243–244; Szczepanowska & FitzHugh (1999); Theophrastus (c. 315 BC/Caley & Richards, 1956) 58; Varoli-Piazza (2002); Vitruvius (1st cent BC/Grainger, 1934) VII.xi.2; Wallert (1995a); Yü (1955/trans. Silbergold & McNair, 1988) 4–5

CINNABAR GREEN

Green
Synonym, variant or common name

See: green cinnabar.

CINNABARIS

Red
Synonym, variant or common name

Classical authors use the term *cinnabaris* in several contexts, making it possibly equivalent to the mercury(II) sulfide mineral cinnabar and/or the tree resin known as dragon's blood (*qq.v.*). For example Pliny (77 AD), in a discussion of what was then termed *minium* (*qq.v.*), but by which we understand as cinnabar, states that the 'Greeks call red of that colour *cinnabarim*'. Elsewhere Pliny lists *cinnabaris* as a 'florid' colour (one which the client pays for at his own expense).

Cinnabar; Dragon's blood; Minium
Pliny (1st cent AD/Rackham, 1952) XXXV.xii.30

CINQUASIA PIGMENTS

Red
Group term

Cinquasia pigments are various formulations based on quinacridone reds. For more information on quinacridone pigments, see polycyclic pigments group: quinacridone sub-group.

Polycyclic pigments group: Quinacridone sub-group

CINTRA UMBER

Brown
Synonym, variant or common name

See: sintra umber and umber.

CIOCCHI

Red
Synonym, variant or common name

A sixteenth century Italian term for madder (*q.v.*; Schweppe and Winter, 1997).

Madder
Schweppe & Winter (1997)

CISSUS

Blue
Common generic composite

A species of *Cissus* (*C. sicyoides*) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as (possibly) *matlali*.

Wallert (1995c)

CITRINE BROWN

Yellow-Brown
Synonym, variant or common name

Salter (1869) describes a pigment he calls citrine brown, produced, he states, 'From boiling, hot, or cold solutions of bichromate of potash and hyposulphite of soda in excess … it is a hydrated oxide of chromium.' It had not, apparently, been introduced as a commercial pigment.

Chromium group; Chromium oxides and hydroxides group
Salter (1869) 317–318

CITRINE LAKE

Yellow-Brown
Synonym, variant or common name

Field (1835) describes citrine lake as 'a fine rich transparent colour, rarely of a true brown; but being in general of an orange broken with green it falls into the class of citrine colours'. It appears from Field's discussion that it was based on quercitron (*q.v.*). Later authors and editors such as Salter (1869) conflate citrine lake with brown pink (*q.v.*).

Quercitron; *Brown pink*
Field (1835) 142; Salter (1869) 312–313

CITRON YELLOW

Yellow
Synonym, variant or common name

Salter (1869) identifies citron yellow as a zinc chromate; this term and meaning was apparently still current for Heaton (1928). However Kühn and Curran (1986), citing Bennett (1963), indicate that this term referred to strontium chromate (*q.v.*).

Zinc chromates group; Strontium chromate; *Zinc yellow*
Bennett (1963); Heaton (1928) 380; Kühn & Curran (1986); Salter (1869) 95

CLARAITE

Blue
Generic compound

Claraite is a blue copper-zinc carbonate mineral with composition $(Cu,Zn)_3(CO_3)(OH)_4.4H_2O$. It was first discovered by Walenta and Dunn (1983), who named it after its type locality at the Clara mine in the Black Forest, Germany. Claraite is a secondary mineral forming in the weathering zone of copper- and zinc-rich ore bodies. It has since been identified in the Tyrol (Austria) and the Languedoc region of France. Claraite forms as fibrous, spherulitic or radiating prismatic crystals and is closely related to the minerals aurichalcite and rosasite (*qq.v.*), the latter of which has been found as a pigment (Dunkerton and Roy, 1996).

Copper group; Zinc group; Aurichalcite; Rosasite
Dunkerton & Roy (1996); Walenta & Dunn (1983)

CLAUDETITE

White
Generic compound

Claudetite is a white monoclinic arsenic oxide mineral with composition As_4O_6 (sometimes given in the older literature as As_2O_3; Dana, 1868). It occurs as platy crystals produced as a by-product of mine fires (such as at San Domingo mine, southern Portugal; Tsumeb mine, Namibia; Samson mine, Harz, Germany; White Caps mine, Nevada, USA). Named after the French chemist F. Claudet, claudetite is a polymorph of the cubic mineral, arsenolite (*q.v.*), which has been found by FitzHugh (1997) in some late eighteenth/early nineteenth century manufactured arsenic sulfide pigments. Although not recorded in the literature as a pigment used in its own right, claudetite may also occur as a relict phase in the manufacture of arsenic sulfide (*q.v.*) pigments.

Arsenic oxides and hydroxides group; Arsenic sulfides group; Arsenic oxide, arsenolite type; Arsenolite
Claudet (1868); Dana (1868) 796; FitzHugh (1997)

CLAY MINERALS GROUP

Variable
Group term

The clay minerals group consists of a suite of hydrous sheet silicate minerals which have a composition based on $Al_4[(Si,Al)_8O_{20}](OH)_4.nH_2O$. The members of the group have similar characteristics: they have the ability to absorb water to become plastic or liquid; they can also lose water easily and become hard when heated (Rutley, 1988). These properties have meant that clays have been used in the manufacture of pottery for thousands of years. Clay minerals commonly occur as microscopic platy crystals, which aggregate to form soft earthy masses. The term clay is also applied to a sediment composed of particles of $<4\ \mu m$. The microscopic crystalline nature of clay minerals means that they are not readily identifiable by optical techniques, but require techniques such as X-ray diffraction for positive identification. All clay minerals are composed of sheet-like layers of $(Si,Al)O_4$ tetrahedra alternating with layers or ribbons of octahedrally coordinated cations (commonly Al, Mg, Fe, Ca, Na or K), with significant amounts of water trapped between the sheets (Brindley and Brown, 1980; Deer *et al.*, 1992). The octahedral layers have sets of three octahedral sites which can be filled (it is most common for either two (di-octahedral) or all three (tri-octahedral) sites to be occupied). Clay minerals typically form as secondary products from the weathering or hydrothermal alteration of rocks, in particular from the degradation of members of the feldspar and mica groups (*qq.v.*) of minerals. Clays may remain *in situ* or may be redeposited away from their site of origin in terrestrial, lacustrine or marine environments, forming the main components of shales, mudstones and soils (Deer *et al.*, 1992; Rutley, 1988).

Although the clay minerals show many similarities, important differences exist between them which necessitate their subdivision into smaller groups. The subdivisions are based upon the distances between the constituent layers (basal spacing) under specific conditions, their water content, its variation with temperature and humidity, the composition of the interlayer and tetrahedral cations, and structural variations. The five main groups of clay minerals are the kaolinite, illite, smectite (or montmorillonite), vermiculite and palygorskite groups (*qq.v.*; Bailey, 1980; Deer *et al.*, 1992). These each contain members further distinguished by small compositional or structural variations. Clay minerals are commonly found mixed together, often in association with small crystals of quartz (*q.v.*), feldspar and mica group minerals. The formation of specific clay minerals depends on the composition of the parent materials and the physical-chemical conditions of the alteration process. Illite and smectite sub-group clays are the most common and are often found as interlayered aggregates (called rectorite) in sedimentary rocks. Minerals related to the clay group include apophyllite and prehnite, with aerinite (*q.v.*) also having been classified incorrectly as a clay mineral in the past; clay mixtures that are well documented also exist, and these include Fuller's earth, bentonite and china clay (*qq.v.*). The clay minerals are structurally related to the members of the mica group, but are distinguished from them by the higher silicon content, the smaller particle size and the secondary paragenesis of the clay minerals.

In a pigment context, clays are both principal and minor components of green earth (*q.v.*) pigments, in which they are found in association with chlorite group minerals (*qq.v.*); clay minerals have also been identified as pigments used in prehistoric art (such as Couraud, 1987; Ford *et al.*, 1994; Watchman *et al.*, 1993, 2001) and their use as paint extenders has also been discussed (Huxtable and Pickering, 1979).

Chlorite group; Clay minerals group: illite sub-group; Clay minerals group: kaolinite sub-group; Clay minerals group: palygorskite sub-group; Clay minerals group: smectite sub-group; Clay minerals group: vermiculite sub-group; Feldspar group; Mica Group; Sheet silicates group; **Silicates group:** Aerinite; Apophyllite; Green earth; Prehnite; Quartz; *Bentonite*; *China clay*; *Fuller's earth*
Bailey (1980); Brindley & Brown (1980); Couraud (1987); Deer *et al.* (1992) 353–381; Ford *et al.* (1994); Huxtable & Pickering (1979); Rutley (1988) 410–416; Watchman *et al.* (1993); Watchman *et al.* (2001)

CLAY MINERALS GROUP: ILLITE SUB-GROUP

Variable
Group term

The illite group, a subdivision of the clay minerals group (*q.v.*), consists of a suite of potassium aluminosilicate minerals with composition $K_{1-1.5}Al_4(Si,Al)_8O_{20}(OH)_4$. In natural illite samples, K may be replaced by Ca and Na, with Mg and Fe replacing Al. The illite group includes illite (*q.v.*), phengite (an Al poor member) and brammallite; hydromuscovite, or hydromica, is a hydrated form of illite containing interlayer water from the replacement of K by H_3O^-. Illites have a crystal structure composed of sheets of $(Si,Al)O_4$ tetrahedra separated by octahedrally coordinated K and Al cations. They are characterised by a basal spacing of 10 Å and it is common for only two out of three octahedral sites to be occupied in the structure (dioctahedral illites), although trioctahedral illites are found. Illites occur as soft earthy masses or as tabular hexagonal or lath-like crystals; they are white when pure but yellow, green, brown, grey or red samples may be found due to the presence of impurities. They form from the alteration of alkali-rich mica and feldspar group minerals (*qq.v.*), and from the low-grade metamorphism of smectite group clays (*q.v.*). Illites are common constituents of sedimentary rocks such as shales and mudrocks, and are often found interlayered with smectite group clays, a sequence which may be known as rectorite (Deer *et al.*, 1992; Rutley, 1988). The chemical and structural similarities between illite and glauconite and celadonite (*qq.v.*) mean that the latter two minerals are sometimes included in the illite sub-group and in the mica group.

Aluminium group; Clay minerals group; Clay minerals group: smectite sub-group; Feldspar group; Mica group; Sheet silicates group; Celadonite; Glauconite; Illite
Deer *et al.* (1992) 363–368; Rutley (1988) 412

CLAY MINERALS GROUP: KAOLINITE SUB-GROUP

White

Group term

The kaolinite (or kandite) group, a subdivision of the clay minerals group (*q.v.*), consists of a suite of aluminosilicate minerals with the general composition $Al_4[Si_4O_{10}](OH)_8.nH_2O$ (Rutley, 1998; Brindley and Brown, 1980). The principal members of this group are kaolinite, nacrite and dickite (*qq.v.*), which are polymorphous (and anhydrous with $n = 0$), and halloysite (*q.v.*), a hydrated form (with $n = 1$). Kaolinites occur as small and flexible pseudohexagonal tabular crystals, usually found as soft and compact earthy masses or granular aggregates. They are white when pure, but may be grey, blue, red, brown or yellow when impurities such as Ca, Fe and Mg, are present. They form from the weathering or low temperature hydrothermal alteration of feldspar and mica group minerals and have similar properties to the illite sub-group (*qq.v.*) clays (Deer *et al.*, 1992; Rutley, 1988). As with other clay minerals, the structure of the kaolinites is based on sheets of SiO_4 tetrahedra interlayered with AlO_6 octahedra; they are di-octahedral clays, with two out of the three possible octahedral sites occupied; kaolinite is triclinic, with the other common members being monoclinic; kaolinite, nacrite and dickite are characterised by a basal spacing of 7 Å, while halloysite has a larger spacing of 10 Å due to interlayer water. Above 650°C, kaolinite transforms to metakaolinite, and dickite transforms to metadickite (Deer *et al.*, 1992; Giese, 1988). Kaolinite and halloysite are the most common members of this group, while nacrite and dickite are comparatively rare; allophane and imogolite are poorly ordered forms of kaolinites found in soils. China clay (*q.v.*), or kaolin, is a material consisting of a mixture of amorphous and crystalline kaolinite group clay minerals, with minor amounts of smectite sub-group and mica group minerals (*q.v.*) also present. Lithomarge is a variety of clay deposit which is white, red or yellow, and consists mostly of kaolinite and halloysite; the latter minerals are also minor components of bauxite (*q.v.*).

Kaolinite is well known for its use in the manufacture of china and porcelain, as well as in the manufacture of paper and paint. Modern uses of kaolinite clays have been discussed by Brooks and Morris (1973) as well as Huxtable and Pickering (1979). Members of the kaolinite sub-group have been identified at rock art sites by Watchman *et al.* (1993, 2001), Sánchez-Moral *et al.* (2002) and Scott and Hyder (1993).

Clay minerals group; Clay minerals group: illite sub-group; Clay minerals group: smectite sub-group; Feldspar group; Mica group; Sheet silicates group; Bauxite; Dickite; Halloysite; Kaolinite; Nacrite; *China clay*

Brindley & Brown (1980); Brooks & Morris (1973); Deer *et al.* (1992) 357–362; Giese (1988); Huxtable & Pickering (1979); Rutley (1988) 410–412; Sánchez-Moral *et al.* (2002); Scott & Hyder (1993); Watchman *et al.* (1993); Watchman *et al.* (2001)

CLAY MINERALS GROUP: PALYGORSKITE SUB-GROUP

Variable

Group term

The palygorskite group is a subsection of the clay minerals group (*q.v.*) and consists of a suite of sheet silicate minerals described by the general chemical formula $(Mg,Fe,Al)_4[Si_6O_{15}](OH)_2.6H_2O$. The members of the palygorskite group include sepiolite and palygorskite (*qq.v.*; Rutley, 1988) which form a continuous series through the exchange of Mg and Al. The structure of the palygorskites differs from that of the other clay group minerals (kaolinite, illite, smectite and vermiculite sub-groups (*qq.v.*)) in that the constituent layers of SiO_4 tetrahedra alternate with ribbons rather than sheets of (Al,Fe,Mg) octahedra. This results in the formation of channels through the structure which can accommodate organic molecules and water (Deer *et al.*, 1992; Christ *et al.*, 1969). Palygorskite is monoclinic like the majority of other clay group minerals (kaolinite is triclinic), while sepiolite is orthorhombic. Palygorskite clays occur in a variety of environments, although rarely in large quantities, and form from the alteration of minerals such as those of the feldspar group (*q.v.*).

Palygorskite is particularly noted as the substrate for so-called Maya blue (*q.v.*).

Aluminium group; Clay minerals group; Clay minerals group: illite sub-group; Clay minerals group: kaolinite sub-group; Clay minerals group: smectite sub-group; Clay minerals group: vermiculite sub-group; Feldspar group; Magnesium group; Sheet silicates group; Limestone; Maya blue; Palygorskite; Sepiolite

Christ *et al.* (1969); Deer *et al.* (1992) 356; Rutley (1988) 414

CLAY MINERALS GROUP: SMECTITE SUB-GROUP

Variable

Group term

The smectite (or montmorillonite) group is a subdivision of the clay minerals group (*q.v.*). It includes as members montmorillonite, nontronite, volkonskoite, beidellite (*qq.v.*), and the less common hectorite, saponite and sauconite. Smectites have the general chemical formula $(\frac{1}{2}Ca,Na)_{0.7}(Al,Mg,Fe,Li,Zn)_6[(Si,Al)_8O_{20}](OH)_4.nH_2O$, although Na and Ca may be replaced, for example, by K, Sr and Cs. Within the group, montmorillonite, beidellite and nontronite form a continuous series through the exchange of Al, Mg and Fe. As with other clay minerals, the smectite structure consists of layers of $(Si,Al)O_4$ tetrahedra alternating with layers of octahedrally coordinated cations. Smectites are monoclinic and have two or all three of the available octahedral sites filled (di- or tri-octahedral clays; Deer *et al.*, 1992; Brindley and Brown, 1980; Güven, 1988; Odom, 1984). The smectite clays, as with the kaolinite, illite, vermiculite and palygorskite sub-group (*qq.v.*) clays, occur as soft earthy masses and fine-grained aggregates of irregular particles, hexagonal plates or laths. They are generally white when pure (nontronite is green) but often vary in colour according to the presence of different impurities (Deer *et al.*, 1992). Smectites differ from the other clay minerals in that they can absorb significant amounts of water (and organic molecules), with an associated increase in volume of up to 700% in some cases (Rutley, 1988). This results in variable spacing between the constituent layers (generally given as 10–15 Å). The amount of water that can be absorbed is related to the alkali cation present with Na-montmorillonite, for example, able to absorb more water than Ca- or K-montmorillonite. Smectites form from the hydrothermal alteration of volcanic rocks and ore veins under alkaline conditions, and in sedimentary deposits during burial diagenesis. During low-grade metamorphism, smectites may transform to illite or chlorite group (*q.v.*) minerals. Smectite and illite sub-group minerals are the common clay components of sedimentary rocks and soils; they are often found interlayered in which case they are collectively known as 'rectorite'. Montmorillonite and beidellite together comprise a significant proportion of bentonite (*q.v.*), a clay mixture formed from the weathering of volcanic ash, and smectites, particularly montmorillonite, are the principal constituents of Fuller's earth (*q.v.*).

Hill has found smectite sub-group clay minerals in pigments from Okapa, Papua New Guinea (Hill, 2001).

Chlorite group; Clay minerals group; Clay minerals group: illite sub-group; Clay minerals group: kaolinite sub-group; Clay minerals group: palygorskite sub-group; Clay minerals group: vermiculite sub-group; Sheet silicates group; Beidellite; Montmorillonite; Nontronite; Volkonskoite; *Bentonite*; *Fuller's earth*
Brindley & Brown (1980); Deer *et al.* (1992) 369–376; Güven (1988); Hill (2001); Odom (1984); Rutley (1988) 412–413

CLAY MINERALS GROUP: VERMICULITE SUB-GROUP

Variable
Group term

The vermiculites are hydrated aluminosilicate minerals which can be considered collectively as the vermiculite group, a subdivision of the clay minerals group (*q.v.*). They are described by the general chemical formula $(Mg,Ca)_{0.6-0.9}(Mg,Fe,Al)_6[(Si,Al)_8O_{20}](OH)_4.nH_2O$, with substitutions by Na or K common; minor amounts of Ti, Li or Cr may also occur. As with all clay minerals, vermiculites are composed of sheets of $(Si,Al)O_4$ tetrahedra which interlayer with sheets of octahedrally coordinated cations. In the vermiculites, the principal octahedral cations are Mg and Fe, and in most cases all octahedral sites are occupied so that they may be termed tri-octahedral (Deer *et al.*, 1992; Calle and Suquet, 1988). Vermiculite was first described by Webb in 1824 from Milbury (Massachussetts, USA). It is named from the Latin *vermiculare*, meaning 'to breed worms', in allusion to the worm-like exfoliations produced upon rapid heating to 200°C. Vermiculites occur most commonly as soft aggregates of thin fibres and lamellae, or as larger pseudohexagonal tabular plates, and vary in colour from brown, red-brown to green or yellow (Deer *et al.*, 1992; Dana, 1892). They form principally from the alteration of biotite and phlogopite (*qq.v.*), particularly during the weathering or hydrothermal alteration of basic and ultrabasic igneous rocks; they are also found in metamorphosed limestones (*q.v.*) and at the contact between acid and basic rocks, where they occur in association with talc, serpentine and chlorite group minerals (*qq.v.*). Vermiculites are generally found only in small amounts although at many localities, such as Amer (India), Kovdor mine (Kola, Russia), Magnet Cove (Arkansas, USA), Minas Gerais (Brazil), Mount St Hilaire (Quebec, Canada) and Moonta (South Australia).

Hill identified vermiculite with goethite and smectite group (*qq.v.*) clay minerals in blue and green earth (*q.v.*) pigments from the Okapa region, Papua New Guinea (Hill, 2001).

Chlorite group; Clay minerals group; Clay minerals group: smectite sub-group; Serpentine group; **Sheet silicates group;** Biotite; Goethite; Green earth; Limestone; Phlogopite; Talc
Calle & Suquet (1988); Dana (1892) 674; Deer *et al.* (1992) 377–381; Hill (2001)

CLINOATACAMITE

Blue-Green
Generic compound

Clinoatacamite is one of the four copper chloride hydroxide polymorphs $Cu_2(OH)Cl_3$, along with atacamite, paratacamite and botallackite (*qq.v.*). It has monoclinic symmetry and is the most stable form of the four types (Grice *et al.*, 1996; Frondel, 1950). It is named after its structural relationship with atacamite and paratacamite and their type locality of the Atacam Desert, Chile. As with its polymorphs, clinoatacamite also forms as a secondary mineral in the weathering zone of copper lode deposits, with its precipitation enhanced by an arid environment. It has only been identified recently as a mineral and Scott (2002) suggests that it should now replace most of the previously reported occurrences of paratacamite in the conservation literature. Paratacamite has a rhombohedral structure and necessarily contains a small percentage of atoms such as zinc substituting for copper to stabilise the structure. Thus the pure copper form, which is monoclinic, should be referred to as clinoatacamite. Jambor *et al.* (1996) have shown that the clinoatacamite and paratacamite forms and atacamite itself can coexist naturally. While other copper chloride hydroxides have been observed in artefacts, the recent assignment of clinoatacamite means that it may be too early for identifications of it to appear in the literature.

Copper group; Copper halides group; Atacamite; Botallackite; Paratacamite
Frondel (1950); Grice *et al.* (1996); Jambor *et al.* (1996); Scott (2002)

CLINOBISVANITE

Yellow
Generic compound

Clinobisvanite is a bismuth vanadate mineral with composition $Bi(VO_4)$. It was first described by Bridge and Pryce in 1974 from Yinnietharra Station (Western Australia) and is only known from a few other locations such as Pala District (California, USA; Foord, 1996) and Hesse (Germany). It occurs as yellow to yellowish red crystals and is trimorphous with pucherite and dreyerite (*q.v.*), with clinobisvanite being the monoclinic form. Collier and Plimer (2002) indicate that clinobisvanite occurs in both high and low temperature geological settings, usually associated with ore deposits, and may form as a weathering product from the inversion of deyerite.

Clinobisvanite is not known to have been used as a pigment itself; however, synthetic bismuth vanadate (*q.v.*) is listed in the *Colour Index* (1971; CI Pigment Yellow 184) as bismuth yellow (*qq.v.*).

Bismuth group; Vanadium group; Bismuth vanadate; Dreyerite; *Bismuth yellow*
Bridge & Pryce (1974); Collier & Plimer (2002); *Colour Index* (1971) Pigment Yellow 184; Foord (1996)

CLINOCHLORE

Green
Generic compound

Clinochlore is the magnesium-rich member of the chlorite group (*q.v.*) of minerals and has composition close to $Mg_4Fe_2Al(Si_3Al)O_{10}(OH)_8$ (Bailey, 1988; Rule and Bailey, 1987). First described by Blake in 1851 at its type locality in West Chester (Pennsylvania, USA), it occurs as thin green prismatic crystals in a wide variety of rock types (Dana, 1932). It typically occurs as a primary mineral in metamorphic greenschist rocks and as secondary mineral in igneous rocks formed from the weathering of magnesium-rich minerals such as enstatite and biotite (*qq.v.*). Clinochlore also occurs with members of the clay minerals group (*q.v.*) in sedimentary rocks, particularly those forming in a marine environment, where it may be found with glauconite (*q.v.*). It may also be found in amygdales in volcanic rocks with celadonite (*q.v.*).

Chlorite minerals have been identified in green earth (*q.v.*) pigments rich in glauconite, together with members of the clay minerals group, in particular illite and montmorillonite ((*qq.v.*) Grissom, 1986).

Chlorite group; Clay minerals group; Magnesium group; Sheet silicates group; Biotite; Celadonite; Enstatite; Glauconite; Green earth; Illite; Montmorillonite
Bailey (1988); Dana (1932) 670; Grissom (1986); Rule & Bailey (1987)

CLINOCHRYSOTILE

White
Generic compound

Clinochrysotile is a monoclinic polymorph of the magnesium-rich silicate mineral chrysotile (*q.v.*) and belongs to the serpentine group (*q.v.*) of minerals (Wicks and O'Hanley, 1988). It has the chemical composition $Mg_3Si_2O_5(OH)_4$, and is also polymorphous with the ortho- and para-chrysotile forms. Clinochrysotile commonly occurs as white or yellowish fibres in hydrothermally altered or metamorphosed carbonate and ultramafic rocks such as those found in Cornwall (England), North Auckland (New Zealand), Transvaal (South Africa) and Cyprus.

Not specifically noted among pigment analyses, the general term asbestos (*q.v.*) may, however, include specific use of this mineral.

Magnesium group; Serpentine group; Silicates group; Chrysotile; *Asbestos*
Wicks & O'Hanley (1988)

COAL

Black-Brown
Generic compound

Coal is a generic term referring to the preserved organic matter that has been altered by the effects of increasing temperature and pressure over the geological timescale. Coals are composed primarily of complex organic compounds rich in carbon, hydrogen and oxygen. The terms coal rank or coal grade refer to the successive transformation of the organic material with increasing temperature and increase in rank is characterised by the decrease in volatile components (water, carbon dioxide, etc.) accompanied by a corresponding increase in the amount of carbon present. Lowest grade coals are the fissile, friable and porous humic earths or lignites (*qq.v.*). All volatiles are driven off and coals become black, compact and non-porous at temperatures of c. 60°C (maintained over geological time), where they become bituminous coals, the rank normally associated with the term 'coal'. The highest rank of coal, anthracite (*q.v.*), forms at temperatures between 120 and 150°C and has greatly reduced hydrogen compared to bituminous coals. All hydrogen is lost and coal is metamorphosed into pure carbon, graphite (*q.v.*), at temperatures exceeding 200°C.

Bituminous coals are analogous to rocks in that they are impure substances made up of various constituents, called macerals. Macerals are the equivalent to minerals in coals and can be divided into three main groupings: vitrinites which are derived from woody plant material and are the commonest group of constituents; liptinite (also called 'exinite') derived from algae and the waxy and lipid-rich fractions of plants; and inertinite which is similar to charcoal in that it is a woody plant material which has been oxidised at an early stage of its formation. Macerals may be identified using reflected light microscopy. Based on the type, distribution and relevant amounts of macerals present, coals can be classified into four main types: vitrain, clarain, durain and fusain, which commonly form banded seams. Non-banded coals are called cannel coals. Vitrain is dominantly composed of vitrinites and is characteristically a brightly reflective black coal, breaking up along cubic fractures. Clarain has a silky lustre and is finely banded, and is also reflective but less so than vitrain. It too is dominantly composed of vitrain with minor amounts of liptinite and inertinite present. The major constituents of durain are inertinites, but minor amounts of vitrinite and liptinite are also present and it forms grey-black bands with a dull greasy lustre. Fusain is soft and friable with a charcoal-like appearance and contains predominantly inertinites. Additionally coals contain trace amounts of inorganic mineral impurities. Sulfates and sulfides, the latter often in the form of pyrite (*q.v.*), are also a common constituent of coals. Clays, carbonates and quartz (*q.v.*) are also frequently present. The geology and petrology of coals is described by Stach *et al.* (1982) and Stopes (1935).

The majority of coal-based pigments are derived from the humic earths or lignites producing brown paints, which are variously called Vandyke Brown or Cassel earth (*qq.v.*; Feller and Johnson-Feller, 1997).

The use of bituminous coal or anthracite as a pigment, 'coal black', appears to have a long history judging from documentary sources although relatively few identifications on artefacts have been reported. Harley (1982) found a number of early seventeenth century English sources describing the use of coal as a pigment. Associated terms employed in these documents are sea coal, smyth coale, sallowe cole blacke, common coal and Scottish coal; John Smith, for example, describes 'Sea Coal' among the black pigments in the first edition of his book (1676), but not in the second (1687; cf. Bristow, 1996b), suggesting that it had fallen from use. Two terms that may be interpreted as coal are recorded in seventeenth century Iberian treatises: *Carbón de piedra molida* is used in the treatise of Garcia Hidalgo; *Preto lapis* is a term found in the Portuguese treatise by Nunes (1615); Veliz (1986) translates the former as coal and considers that the latter probably refers to a pigment based on graphite or coal. Bideford black (*q.v.*) is a coal-based pigment derived from mines in the Bideford area that was used primarily as an industrial pigment, particularly as a ship paint.

Toch (1916) describes 'powdered anthracite and bituminous coal' as being used as pigments, though he ascribes their use to poor specification: 'An engineer will at times prescribe a paint containing a certain percentage of ash, and in order to meet this requirement a paint manufacturer will have to add coal in order to conform.' The *Colour Index* (1971) lists CI 77268/Pigment Black 8 as 'impure carbon of organic and mineral origin', further noting that it is formed from 'various organic and mineral substances rich in carbon, particularly lignite, ethiops mineral, anthracite, bituminous coal, slate, etc.' as well as other carbonised materials, also noting the use of the terms Grade black and Coke black to describe a fine product obtained from the coke produced in the Thuringian lignite industry. Vibert brown (*q.v.*) also appears to have been a form of coal.

Despite its apparently obvious attributes as black pigment, use of coal has not been widely reported. Terry (1893), for example, lists it as one of his 'Unimportant blacks'. He goes on to say 'coal black has been suggested by grinding coal but lacks the requisite qualities of a pigment'. The present authors have identified coal in an early fifteenth century wall painting in Holy Trinity Church, Coventry, UK. Coal has also been found in baroque wall paintings of around 1620 at Bolsover Castle, Derbyshire, UK (Hughes, pers. comm., 2003). A recent survey of sixteenth century Italian paintings in the National Gallery, London, suggests possible widespread use of coal as a pigment (Spring, pers. comm., 2003). Pedersen (1974) has identified coal in an animal fat binder as a black pigment in Argentinian rock paintings. Bakuradze and Chelshoyli (1975) have detected coal (as a filler) in Georgian church wall paintings dating from the tenth to the nineteenth centuries.

Carbon-based blacks group; Anthracite; Graphite; Humic earth; Lignite; Pyrite; Quartz; *Bideford black*; *Cassel earth; Vandyke brown*; *Vibert brown*

Bakuradze & Chelshoyli (1975); Bristow (1996b) 59; *Colour Index* (1971) 77268; Feller & Johnston-Feller (1997); Harley (1982) 157; Nunes (1615) 57; Pedersen (1974); Smith (1676) 14–15; Smith (1687); Stach *et al.* (1982); Stopes (1935); Terry (1893) 25; Toch (1916) 106; Veliz (1986) 136

COAL BLACK

Black
Synonym, variant or common name

See: coal.

COAL COKE

Black
Generic compound

See: coal.

COAL TAR

Brown
Synonym, variant or common name

See: asphalt and bitumen.

COAL TAR COLOURS

Variable
Synonym, variant or common name

Term used in reference to synthetic dyestuffs and pigments formed from them based on reagents derived from coal tar. The *Oxford English Dictionary* (2002) defines coal tar as 'A thick black viscid liquid, which is one of the products of the destructive distillation of bituminous coal. It is a compound of many different substances, chiefly hydrocarbons; and out of its constituents are obtained paraffin, naphtha, benzene, creosote, the aniline or coal-tar colours, etc.' Watts' *Dictionary of Chemistry* (1859–81) adds that 'The more volatile portion of coal-tar, called light-oil or coal-naphtha, consists mainly of benzene and its homologues … Coal-tar has also acquired great value as the source of aniline-colours' (cf. *OED*, 2002). Heaton (1928) writes of the history of the colours that 'The introduction of the synthetic dyes prepared from coal tar was made possible, in the first instance, by the discovery of benzene by Faraday in 1826, followed by the isolation of this compound from coal tar by Hoffmann in 1845. In 1856 William Henry Perkin was working, as a young pupil of Hoffmann, on the synthesis of quinine, and in the course of his researches he produced a mauve coloured substance by the oxidation of aniline, which he called mauveine. This was the first artificial dye, and was the forerunner of a host of similar products.' The term 'coal tar' appears to have been used primarily from the late eighteenth through to the earlier twentieth century, aniline colours being an essentially synonymous term. Both are now wholly superseded by the use of the chemical nomenclature of the azo and polycyclic pigment groups.
See also: azo pigments group and polycyclic pigments group.

Azo pigments group; Polycyclic pigments group
Heaton (1928) 187 ff.; *OED* (2002) 'Coal-tar'; Watts (1859–81) V. 670

COAL TAR PURPLE

Purple
Synonym, variant or common name

See: mauve.

COBALT ACETATE

Pink
Generic compound

Bouvier (1827) mentions 'acetate of cobalt' as a composition of Thénard's blue (*q.v.*) reported to him by a chemist. However, this composition is probably erroneous. Only one cobalt acetate is generally reported in the chemical literature, cobalt(II) acetate ($Co(OAc)_2$); this occurs as light pink crystals.

Cobalt group; *Thénard's blue*
Bouvier (1827) 46

COBALT ALUMINATE

Blue
Synonym, variant or common name

See: cobalt aluminium oxide and cobalt blue.

COBALT ALUMINIUM ARSENATE

Blue-Purple
Generic compound

See: cobalt aluminium phosphate.

COBALT ALUMINIUM OXIDE

Blue
Generic compound

The bright reddish-blue compound cobalt aluminium oxide ('cobalt aluminate'), $CoAl_2O_4$, may be formed by the thermal conversion of intimate mixtures of the two metal oxides at high temperature. Cobalt aluminium oxide forms in the cubic crystal system with the spinel structure, where the aluminium cations occupy octahedral sites and the cobalt atoms occupy tetrahedral sites (a so-called *normal* spinel). It can be synthesised from the solid-state reaction between the dry oxides CoO and Al_2O_3 at high temperature (minimum temperature of 1200°C for 15 hours; Navrotsky and Kleppa, 1968). However, Buxbaum (1998) indicates that as a pigment it usually has a deficiency of cobalt against the ideal formula, with about 0.6–0. 7 mol CoO per mol Al_2O_3.

While modern studies of the synthesis of cobalt aluminium oxides have shown that other compounds can be formed, these have never been reported as pigmentary phases. For example, an investigation of the Al-Co-O system by Dutt and Kröger (1975) showed that the oxygen pressure (pO_2) during synthesis is critical in determining which phases will form. At atmospheric pressure with temperatures in the range of 1620°C, these authors found $CoAl_2O_4$ to be the stable phase, coexisting with aluminium oxide, while at lower temperatures, solid solutions of Co-Al oxides formed. This would appear to be consistent with Buxbaum's remarks. The literature further indicates that cobalt aluminate is a highly stable phase with very little substitution for the Al_2O_4 component occurring, although cobalt ferrite spinels, $CoFe_2O_4$, are known (for example, Kahn and Zhang 2001). However, the cobalt component may be more readily replaced in solid solution, for example by cadmium, although this may change the structure from a normal spinel to a partially inverted spinel (Otero Arean *et al.*, 1979). More importantly from the point of view of modern pigments, the tetrahedral sites can be filled by zinc or magnesium ions, as well as chromium; in the latter case, colours ranging from a neutral blue ($Al:Cr \sim 7:3$) to a greenish-blue ($Al:Cr \sim 3:7$) can be achieved (Buxbaum).

Some note should be made of the historical methods used to create this pigment (for a fuller discussion, see cobalt blue), where the intent of using such starting phases as acetified cobalt phosphate or arsenate was probably to incorporate fluxing agents that reduced the temperature at which the compound effectively formed.

Cobalt aluminium oxide does occur naturally as the rare blue gemstone, cobalt spinel. It is commonly referred to historically as cobalt blue (*q.v.*), with various other common terms related to those who discovered and developed it in the late eighteenth and early nineteenth centuries. Interestingly, however, the compound appears to have been also known in Dynastic Egypt.

Cobalt oxides and hydroxides group; *Cobalt blue*
Buxbaum (1998); Dutt & Kröger (1975); Kahn & Zhang (2001); Navrotsky & Kleppa (1968); Otero Arean *et al.* (1979)

COBALT ALUMINIUM PHOSPHATE

Blue-Purple
Generic compound

Thénard (1803–1804) produced cobalt blue by calcining aluminium hydrate with acetified cobalt arsenate or acetified cobalt phosphate. Church (1901) gives a recipe for this, however, to our knowledge, no arsenate nor phosphate has been found in analyses of cobalt blue in paintings.
See: cobalt blue; cobalt phosphates group; Thénard's blue.

Thénard (1803–1804); Church (1901) 210–212

COBALT AMMONIUM ARSENATE

Purple
Generic compound

Heaton (1928) gives cobalt ammonium arsenate as one possible formulation for cobalt violet (*q.v.*).

Arsenic group; Cobalt group; *Cobalt violet*
Heaton (1928) 163

COBALT AMMONIUM PHOSPHATE

Blue-Purple
Generic compound

Cobalt ammonium phosphate ($CoNH_4PO_4.H_2O$) is listed by the *Colour Index* (1971) as a related form of CI Pigment Violet 14.
See: cobalt phosphates group.

Cobalt phosphates group
Colour Index (1971)

COBALT ARSENATE

Blue-Purple
Generic compound

Cobalt(II) arsenate is synonymous with cobalt arsenic oxide, $Co_3(AsO_4)_2$. A production method given by Riffault *et al.* (1874) involves a 'sulpho-arsenide of cobalt being mixed with sand and twice its weight of potassa and fused'. The product is ground and the process repeated with the addition of more potassa. The pure arsenide formed is then powdered and roasted.

Cobalt arsenates are generally reported to be the components of some pigments referred to as cobalt violet (*q.v.*); however, recent work on these pigments has identified magnesium cobalt arsenate as the more likely constituent (Corbeil *et al.*, 2002). Magnesium arsenate is isostructural with cobalt arsenate, and substitution between the two compounds is likely.

Cobalt arsenate may also be referred to as the anhydrous 'synthetic vivianite arsenate of cobalt' because the compound is related to the naturally occurring mineral vivianite, $Fe_3(PO_4)_2.8H_2O$ (*q.v.*), where cobalt may substitute for iron, and arsenic for phosphorous. The hydrated equivalent of cobalt arsenate is the mineral erythrite (*q.v.*) and synthetic analogues (Martens *et al.*, 2003a).

Arsenic group; Cobalt group; Cobalt arsenic oxide hydrate; Erythrite; Vivianite; *Cobalt violet*
Corbeil *et al.* (2002); Martens *et al.* (2003a); Riffault *et al.* (1874) 455

COBALT ARSENIC OXIDE

Purple
Generic compound

See: cobalt arsenate.

COBALT ARSENIC OXIDE HYDRATE

Purple
Generic compound

Cobalt arsenic oxide hydrate (hydrated cobalt arsenate) is the synthetic equivalent of the mineral erythrite (*q.v.*) and in various states of hydration forms a component of the pigment group known as cobalt violet (*q.v.*), usually with substitution by magnesium (Corbeil *et al.*, 2002).

The synthetic equivalent of erythrite has the formula $Co_3(AsO_4)_2.8H_2O$. Dehydration of both the mineral and its synthetic equivalent occurs at 105°C to form $Co_3(AsO_4)_2.6H_2O$ and at 225°C the dehydrated cobalt arsenate (*q.v.*) is formed. A monohydrate, $Co_3(AsO_4)_2.H_2O$, may also be synthesised (Martens *et al.*, 2003a).

These compounds may be synthesised by slow addition of cobalt sulfate solution to sodium arsenate solution.

Arsenic group; Cobalt group; Cobalt arsenate; Erythrite; *Cobalt violet*
Corbeil *et al.* (2002); Martens *et al.* (2003a)

COBALT ASH

Grey
Synonym, variant or common name

According to Carlyle (2001), cobalt ash was a trade name used by the British artists' colourmen Reeves between 1860 and 1870. It may be synonymous with cobalt grey, a mixture prepared by the firm of Robersons from 'pink madder, ivory black, indigo and cobalt [blue?]' [*qq.v.*].

Indigo; Madder; *Cobalt blue*; *Ivory black*
Carlyle (2001) 497

COBALT BLACK

Black
Synonym, variant or common name

Heaton (1928) records that cobalt oxide 'forms an intense and beautiful black', noting that 'it is used to some extent in fresco painting'. Mayer (1991) describes this as a 'rather coarse black powder'. This colour (as 'black oxide of cobalt') was found in the paintbox belonging to Joseph Southall (1861–1944). Dunkerton (1980) states that this is a potter's colour which was 'made by Sir William Burton in collaboration with … John Batten and available through the society of tempera painters and Lechertier Barbe', thereby being also known as Burton's cobalt.
See: cobalt oxides and hydroxides group.

Cobalt oxides and hydroxides group
Dunkerton (1980); Heaton (1928) 182; Mayer (1991) 39

COBALT BLUE

Blue
Synonym, variant or common name

Numerous compounds and manufacturing processes have been used under the heading cobalt blue and while it is nowadays commonly assumed to refer specifically to cobalt aluminium oxide (*q.v.*; $CoO.Al_2O_3$), a raft of other meanings is to be found in the historical literature. Some other authors also treat (not unreasonably) all cobalt-based blue pigments under this heading, including the cobalt-doped glass known as smalt (*q.v.*) and the cobalt tin oxide generally called cerulean blue (*q.v.*). However, in the current common usage it is cobalt aluminate and close compositional or manufacturing variants that are meant.

The earliest modern history of cobalt aluminate pigments commences with Leithner in Vienna, who appears to have discovered the basic process of calcining cobalt oxide and alumina (aluminium oxide) in 1775. Just before 1777, Gahn independently observed that after moistening aluminium compounds with a cobalt solution they would turn blue when strongly calcined. Almost contemporaneously, C.F. Wenzel discovered the same reaction in Freiberg. Gahn's process involved the precipitation of a mixture of iron-free alumina with a pure cobalt solution, which is itself free of nickel and iron, with an alkali, followed by washing, drying and strong calcination. An alternative method involved pouring cobalt nitrate over a precipitation of alumina, then drying and calcining it. Depending on the amount of cobalt the pigment has a deep to light tone. According to Binder (1857) the blue manufacturing companies of Saxony, Germany, used a similar procedure to the first one mentioned above, which was considered a secret process (cf. Terry, 1893).

In 1803, Thénard showed that by calcining a mixture of aluminium hydrate with acetified cobalt phosphate or acetified cobalt arsenate one could more easily produce the pigment than with mixtures of cobalt carbonate or cobalt nitrate. Cobalt nitrate solutions would be precipitated with the acetified sodium phosphate, the purple cobalt phosphate washed with water and mixed with eight times the weight of alumina hydrate which had been precipitated with ammonia. Afterwards this mixture would be brushed onto boards for drying; when it became solid and brittle it would be ground and calcined in a closed clay container for half an hour.

Other modifications were also introduced. For example, Rose (1916) mentions McEachern, who claims to have found in 1911 that an addition of magnesium salts improves the colour: 'To achieve good results it is necessary to add to 25 parts ammonia alum, 2.5 to 5 parts cobalt sulfate and 0.3 parts magnesium sulfate or to 2.5 parts cobalt sulfate, 0.3 parts zinc sulfate or 0.15 parts zinc sulfate and 0.15 parts magnesium sulfate.' However in 1911, Vanino states that he had already worked on this modification since 1908 with H. Wagner.

Cobalt blue is an extremely stable pigment that strongly promotes curing of drying oils. Optical absorption has been discussed by Bacci and Piccolo (1996).

Numerous identifications have been made of cobalt blue pigments. The earliest discussion of the occurrence of cobalt aluminate in dynastic Egyptian artefacts is from Riederer (1974) and Noll and Hangst (1975a). Helmi and Attia (1992) have detected cobalt blue on a nineteenth century oil painting. It was widely used by Impressionist painters as reviewed, for example, by Bomford *et al.* (1990); they list occurrences on a great number of paintings in the National Gallery, London, including those by Renoir, Monet, Manet and Sisley.

There are many related terms, generally indicating the originator of the production method or some variant. From the principal discoverers terms such as Leithner's blue, Gahn's blue, Wenzel's blue, Thénard's blue and Binder's cobalt blue are derived. There are also a number of terminological variants which appear to be corruptions of one another; hence *Königsblau*, as well as the anglicised King's blue, while Leithner blue is also listed as Leidner blue and thereby (probably) Leyden blue. Other terms include new blue and Dresden blue.

It is listed by the *Colour Index* (1971) as CI 77346. Cobalt blue as a pigment should not be confused with cobalt blues used as glazes and enamels in pottery decoration. The compositions of similar amorphous vitreous materials are discussed under smalt.

Cobalt group; Cobalt aluminium oxide; Cobalt arsenate; Cobalt borate; Smalt; *Binder's cobalt blue*; *Cerulean blue*; *King's blue*; *Königsblau*; *Leithner's blue*; *Leyden blue*; *New blue*; *Thénard's blue*; *Wenzel's blue*
Bacci & Picollo (1996); Binder (1857); Bomford *et al.* (1990) 56; *Colour Index* (1971) 77346; Helmi & Attia (1992); Noll & Hangst (1975a); Riederer (1974); Rose (1916) 285; Terry (1893) 27–28; Thénard (1803–4)

COBALT BROWN
Brown

Synonym, variant or common name

According to the *Colour Index* (1971; CI 77326) cobalt brown is obtained by 'calcining a mixture of ammonium, ferrous and cobalt sulphates'. The extent of its use as a pigment is unclear.

Colour Index (1971) 77326

COBALT CARBONATE
Pink
Generic compound

See: cobalt(II) carbonate.

COBALT CARBONATES GROUP
Variable
Group term

There is a single cobalt carbonate, cobalt(II) carbonate ($CoCO_3$) used as a pigment and listed by the *Colour Index* (1971). Cobalt carbonate is used as a raw material for the manufacture of other cobalt pigments, such as Turkish green (*q.v.*).
See: cobalt(II) carbonate.

Cobalt group; Cobalt(II) carbonate; *Turkish green*
Colour Index (1971) 77353

COBALT CHROMATE
Blue
Generic compound

The German author Jännicke (1893) describes 'blue oxide' as a cobalt chromate. Little is known about this compound as a pigment. It may have been confused with Turkish green (*q.v.*), however a chromium cobalt oxide ($CoCr_2O_4$) is described as a green pigment in the *Merck Index* (1996).

Blue oxide
Jännicke (1893) 70; *Merck Index* (1996) 2499

COBALT GREEN
Blue-Green
Synonym, variant or common name

Cobalt green is said to be similar to cobalt blue (*q.v.*) except that zinc oxide partially or wholly replaces the aluminium hydroxide. Church (1901) describes making it by adding a solution of a cobalt salt to a paste of zinc oxide and water; the mass is then dried and calcined.

Field (1835) noted two kinds – a mixture of cobalt blue and ‘chromic’ yellow, and another prepared directly from cobalt; with the latter he stated that it consists of ‘cobalt with the addition of oxide of iron or zinc’. In the Mallet edition of Field (1870) the reference to iron oxide was omitted; however, early examples of this cannot be ruled out (see cobalt iron oxide). Salter’s edition of Field’s *chromatography* (1869) describes the pigment as being composed of zinc carbonate and cobalt, with only 2–3% cobalt being necessary; other sources describe only the use of the oxides (such as Scott Taylor, 1885 and Standage, 1887; cf. Carlyle, 2001). Terry (1893) describes Rinmann’s green and Zinc green (*q.v.*); citing Wagner, he states that the composition of cobalt green varied considerably with 71.5–88% zinc oxide and 11.5–19% cobalt oxide with fluctuating amounts of phosphoric acid, soda, iron oxide, etc., depending on the manufacturing process followed. The *Colour Index* (1971; CI 77335) describes cobalt green as ‘an isomorphous mixture of cobalt zincate and zinc oxide which cannot be chemically separated’. Various preparation routes are given, some of which form named pigments:

(a) Rinmann’s green, made by precipitating zinc sulfate and cobalt sulfate with potassium or sodium carbonate, then calcining at very high temperature.
(b) Precipitating cobalt chloride and zinc chloride and, again, calcining.
(c) Heating zinc oxide and cobalt oxide or phosphate.
(d) Calcining zinc oxide cobalt nitrate to obtain a particularly bright product, the brightness of hue being increased if phosphoric or arsenic oxide is present in the mix.
(e) Gellert green, formed by igniting cobalt with sodium nitrate and zinc oxide.

Modern texts such as Buxbaum (1998) describe the incorporation of cobalt into magnesium and zinc titanate (*q.v.*) spinels (Mg_2TiO_4 and Zn_2TiO_4) to produce blue to green compounds with a general formula $Mg_aCo_bZn_cTiO_4$, where $a + b + c = 2$. A brilliant cobalt green is also produced by replacing magnesium with nickel (approximately $NiCo_{0.5}Zn_{0.5}TiO_4$), or a turquoise colour with lithium ($Li_2(Co,Ni,Zn)Ti_3O_8$).

Cobalt iron oxide; Cobalt zinc oxide; *Gellert green*; *Rinmann’s green*; *Swedish green*; *Zinc green*
Buxbaum (1998) 101; Carlyle (2001) 491, 492, 496; Church (1901) 196; *Colour Index* (1971) 77335; Field (1835) 129; Mallet (1870); Salter (1869) 285; Scott Taylor (1885) 141; Standage (1887) 23; Terry (1893) 119–120

COBALT GREY

Grey
Synonym, variant or common name

A mixture prepared by the British firm of colourmen Robersons from ‘pink madder, ivory black, indigo & cobalt [blue?]’ (*qq.v.*; cf. Carlyle, 2001).

Indigo; Madder; *Cobalt blue*; *Ivory black*
Carlyle (2001) 497

COBALT GROUP

Variable
Group term

Cobalt is named after the goblin Kobbald who haunted mines. It is an important element used in the manufacture of a wide range of pigments of various colours, but particularly shades of green, blue and purple. The following compounds are either known as pigments or are closely associated with pigment compounds:

Carbonates: cobalt carbonate ($CoCO_3$).
Nitrates: cobalt nitrate ($Co(NO_3)_2.6H_2O$); tripotassium hexanitrocobalt(III) ($K_3Co(NO_2)_6.nH_2O$); dipotassium monosodium hexanitrocobalt(III) ($K_2NaCo(NO_2)_6.nH_2O$).
Oxides and hydroxides: cobalt(II) oxide; cobalt(III) oxide (Co_2O_3).
Oxides with group 2 elements (Mg): cobalt magnesium oxide.
Oxides with group 3–11 elements (Cr, Fe, W): cobalt iron oxide; cobalt tungstate.
Oxides with group 12 elements (Zn): cobalt zinc oxide.
Oxides with group 13–15 elements (B, Al, Sn, As): cobalt aluminium oxide; cobalt boron oxide (cobalt borate); cobalt tin oxide (cobalt stannate); cobalt arsenic oxide (cobalt arsenate); cobalt arsenic oxide hydrate and erythrite ($Co_3(AsO_4)_2.8H_2O$); cobalt ammonium arsenic oxide; smaltite ($(Co,Ni)As_{3-n}$).
Phosphates: cobalt phosphate ($Co_3(PO_4)_2$); cobalt phosphate tetrahydrate $Co_3(PO_4)_3.4H_2O$; cobalt phosphate octahydrate $Co_3(PO_4)_2.8H_2O$; cobalt aluminium phosphate; cobalt ammonium phosphate ($CoNH_4PO_4.H_2O$); cobalt magnesium phosphate; cobalt zinc phosphate.
Organo-cobalt compounds: cobalt acetate.

Other cobalt compounds with chromium have also been used as pigments (see: chromates group). Additionally, smalt, a cobalt-doped glass, has been an important blue pigment.

Cobalt carbonates group; Cobalt nitrates group; Cobalt oxides and hydroxides group; Cobalt phosphates group; Chromium aluminium cobalt oxide; Cobalt acetate; Cobalt aluminium oxide; Cobalt aluminium phosphate; Cobalt ammonium arsenate; Cobalt ammonium phosphate; Cobalt arsenate; Cobalt arsenic oxide hydrate; Cobalt chromate; Cobalt hexacyanoferrate(II); Cobalt iron oxide; Cobalt magnesium oxide; Cobalt magnesium phosphate; Cobalt tin oxide; Cobalt tungstate; Cobalt zinc oxide; Cobalt zinc phosphate; Cobalt(II) carbonate; Cobalt(III) oxide; Erythrite; Potassium hexanitrocobalt(III); Smalt; Smaltite

COBALT HEXACYANOFERRATE(II)

Blue
Generic compound

Salter (1869) discusses a pigment which he calls cobalt Prussian blue, although he reports that it was not in ordinary use. It appears to be essentially Prussian blue (*q.v.*) with the iron(III) replaced by cobalt (Fe^{3+} replaced by Co^{3+}), prepared by mixing ‘yellow prussiate of potash … with a solution of oxalate of sesquioxide of cobalt’. Salter further noted that it was described by Gmelin, but reported ‘the product is … a dingy slate colour’.

Hexacyanoferrate group; *Prussian blue*
Salter (1869) 227

COBALT IRON OXIDE

Green
Generic compound

In a discussion of cobalt green, Field (1835) noted two kinds – a mixture of cobalt blue (*qq.v.*) and ‘chromic’ yellow, and another prepared directly from cobalt. With the latter he stated that it consists of ‘cobalt with the addition of oxide of iron or zinc’; presumably the use of iron oxides would form a cobalt iron oxide. However, the exact composition appears to be currently unknown.

Cobalt blue; *Cobalt green*
Field (1835) 129

COBALT MAGNESIUM OXIDE

Red
Generic compound

According to Riffault *et al.* (1874) cobalt pink was prepared from magnesium carbonate and cobalt nitrate solution, the paste formed being dried and calcined. This apparently forms a cobalt magnesium oxide, although that has not been confirmed analytically. It is also equivalent to cobalt red (*q.v.*) and is described by authors such as Salter (1869) and Church (1901), who additionally confirm the composition as a cobalt magnesium oxide.

Cobalt group; *Cobalt pink*; *Cobalt red*
Church (1901) 188; Riffault *et al.* (1874) 454–455; Salter (1869) 164

COBALT MAGNESIUM PHOSPHATE

Purple
Generic compound

See: cobalt phosphates group and cobalt violet.

Cobalt phosphates group; *Cobalt violet*

COBALT NITRATE

Red
Generic compound

See: cobalt nitrates group.

COBALT NITRATES GROUP

Red-Orange-Yellow
Group term

Salter (1869) states about cobalt nitrate (cobalt(II) nitrate, $Co[NO_3]_2.6H_2O$), that: 'There are obtainable from cobalt by different processes rose and red colours of more or less beauty and intensity, but all vastly inferior to those of madder (*q.v.*), in whose absence alone they could gain a place on the palette. They are generally characterised by a fatal chalkiness, and poorness of hue. More expensive than the madder colours, and without their purity, depth, or transparency cobalt reds have often been offered as pigments, and as often declined.'

The yellow pigment tripotassium hexanitrocobalt(III) ($K_3Co(NO_2)_6.nH_2O$) and dipotassium monosodium hexanitrocobalt(III) ($K_2NaCo(NO_2)_6.nH_2O$) are also classed here as cobalt nitrates. See the entries for cobalt red, cobalt yellow and potassium hexanitrocobalt(III) for further information.

Cobalt group; Madder; Potassium hexanitrocobalt(III); Cobalt red; *Cobalt yellow*
Salter (1869)

COBALT OXIDE

Black
Generic compound

See: cobalt(III) oxide and cobalt oxides and hydroxides group.

COBALT OXIDES AND HYDROXIDES GROUP

Variable
Group term

Several binary oxides appear to have been used as pigments. Among these, cobalt(III) oxide, Co_2O_3, is prepared by precipitating a cobalt salt with sodium hydroxide and heating the resulting cobalt hydroxide to produce a steel grey to black pigment. Another oxide, Co_3O_4, is also recorded in use as a pigment; the cobalt(II) oxide is not stable and is unlikely to be encountered.

There is also a substantial group of tertiary and quaternary compounds often classed separately but with group similarities:

Oxides with group 2 elements (Mg): cobalt magnesium oxide.
Oxides with group 3–11 elements (Cr, Fe, W): cobalt iron oxide; cobalt chromate ($CoCr_2O_4$); cobalt tungstate.
Oxides with group 12 elements (Zn): cobalt zinc oxide.
Oxides with group 13–15 elements (B, Al, Sn, As): cobalt aluminium oxide ($CoAl_2O_4$); cobalt tin oxide ($CoSnO_3$); cobalt arsenic oxide ($Co_3(AsO_4)_2$); cobalt arsenic oxide hydrate ($Co_3(AsO_4)_2.8H_2O$); erythrite ($Co_3[AsO_4]_2.8H_2O$); cobalt magnesium arsenate ($Mg_2Co[AsO_4]_2$).

See individual entries for further discussion.

Cobalt group; Chromium aluminium cobalt oxide; Cobalt aluminium oxide; Cobalt arsenate; Cobalt arsenic oxide hydrate; Cobalt chromate; Cobalt hexacyanoferrate(II); Cobalt iron oxide; Cobalt magnesium oxide; Cobalt tin oxide; Cobalt tungstate; Cobalt zinc oxide; Cobalt(III) oxide; Erythrite; *Cobalt black*; *Cobalt blue*; *Cobalt violet*

COBALT PHOSPHATE

Blue
Generic compound

See: cobalt phosphates group.

COBALT PHOSPHATE, ALUMINOUS

Blue
Generic compound

See: cobalt aluminium phosphate and the discussion of the cobalt phosphates group pigments.

Cobalt group; Cobalt phosphates group; Cobalt aluminium phosphate

COBALT PHOSPHATES GROUP

Blue-Purple
Group term

Various cobalt phosphates are recorded in a pigment context:

Cobalt phosphate, $Co_3(PO_4)_2$ (violet; cf. *Colour Index*, 1971).
Cobalt phosphate tetrahydrate, $Co_3(PO_4)_3.4H_2O$ (deep violet; *Colour Index*).
Cobalt phosphate octahydrate, $Co_3(PO_4)_2.8H_2O$ (pink; *Colour Index*).
Cobalt lithium phosphate, $CoLiPO_4$ (light violet; Corbeil *et al.*, 2002), plus other equivalent Group 1 element (Na, K) cobalt phosphates.
Cobalt ammonium phosphate, $CoNH_4PO_4.H_2O$ (*Colour Index*).
Cobalt aluminium phosphate (Church, 1901).
Cobalt magnesium phosphate (Heaton, 1928).
Cobalt zinc phosphate (Bersch, 1901; Gentele, 1860).

Rozenberg (1997) also reports a blue cobalt phosphate (given as '$CoPO_4$') from Jericho, possibly as an underpaint for red, producing an overall purple effect. Jännicke (1893) lists coelin as a greenish cobalt phosphate colour.

The characterisation of a number of these pigments has been discussed by Corbeil *et al.* (2002). For a fuller discussion of the history and other related compounds, see: cobalt violet.

Cobalt group; Cobalt aluminium phosphate; Cobalt ammonium phosphate; Cobalt magnesium phosphate; Cobalt zinc phosphate; *Cobalt violet*
Bersch (1901) 232; Church (1901) 210–211; *Colour Index* (1971) 77360–2; Corbeil *et al.* (2002); Gentele (1860) 79; Heaton (1928) 163; Jännicke (1893); Rozenberg (1997)

COBALT PINK

Red
Synonym, variant or common name

See: cobalt magnesium oxide.

Cobalt group; Cobalt magnesium oxide; *Cobalt red*

COBALT PRUSSIAN BLUE

Blue
Synonym, variant or common name

See: cobalt hexacyanoferrate(II).

COBALT PURPLE

Purple
Synonym, variant or common name

See: cobalt violet.

COBALT RED

Red
Synonym, variant or common name

Salter (1869) mentions this pigment: 'There are obtainable from cobalt by different processes rose and red colours of more or less beauty and intensity, but all vastly inferior to those of madder [*q.v.*], in whose absence alone they could gain a place on the palette. They are generally characterised by a fatal chalkiness, and poorness of hue. More expensive than the madder colours, and without their purity, depth, or transparency cobalt reds have often been offered as pigments, and as often declined.' According to Church (1901), 'this little used pigment should consist of the oxides of magnesium and cobalt. It is prepared at a high temperature and is quite permanent. One method of making this pigment involves the use of magnesium carbonate or oxide, which is made into a paste with a solution of pure cobalt nitrate. This paste is then slowly dried, and ultimately calcined in a crucible. Different preparations of this pigment differ considerably in hue; a purplish cast is sometimes due to the accidental presence of alumina.'

Cobalt magnesium oxide; Madder; *Cobalt pink*; *Cobalt violet*
Church (1901) 188–189; Salter (1869) 164

COBALT STANNATE

Blue
Generic compound

See: cobalt tin oxide.

COBALT TIN OXIDE

Blue
Generic compound

Cobalt tin oxide, $CoSnO_3$, also known as cobalt stannate or cerulean blue (*q.v.*), has been prepared by a number of routes historically. Church (1901), for example, gives two methods of preparation, the first by combining tin oxide and cobalt nitrate, the second by precipitating potassium stannate with cobalt chloride then mixing with pure silica; in both cases the material is calcined. Linke and Adam (1913) give a recipe for *Cölinblau* composed of 50% tin oxide, 20% cobalt(II) oxide and 30% silica. Cobalt chloride was precipitated with potassium stannate, this being washed and calcined. They remark that the product was stable and useful for all techniques, but that it was 'not very colourful and easily dispensable'. Standage (1887) noted that with 'stannate of cobalt', 'sulphate of lime' (that is, calcium sulfate) was sometimes present. A factitious version is also recorded in the literature, made from ultramarine, Naples yellow and lead white (*qq.v.*).

Cobalt tin oxide has been identified by Roy (1985) in the palette of three Impressionist paintings in the National Gallery, London and by Helmi and Attia (1992) on a nineteenth century Egyptian oil painting.

Cobalt oxides and hydroxides group; Ultramarine; *Cerulean blue*; *Lead white*; *Naples yellow*
Church (1901) 212; Helmi & Attia (1992); Linke & Adam (1913) 60; Roy (1985); Standage (1887)

COBALT TUNGSTATE

Red-Orange
Generic compound

Cobalt tungstate is prepared by precipitating a cobalt salt with sodium tungstate, being used as a reddish orange pigment. Listed by the *Colour Index* (1971) as CI 77376.

Cobalt group; Tungsten group; Tungsten oxides and hydroxides group
Colour Index (1971) 77376

COBALT ULTRAMARINE

Blue
Synonym, variant or common name

This pigment is described by Riffault *et al.* (1874) as a combination of aluminium oxide and cobalt oxide. It is prepared by taking an alum solution and dissolving in it cobalt nitrate, sulfate or chloride. A pink-white precipitate is formed with sodium or potassium carbonate; the product is then washed, dried and calcined in a crucible at high temperature. It would consequently appear to be a manufacturing variant of cobalt aluminium oxide (that is, 'cobalt blue') and is also stated to be synonymous with Gahn's ultramarine (*qq.v.*).

Rose (1916) describes how in 1914, Arvid Hedvall states that his analysis of cobalt compounds led him to the formula Al_2O_3CoO, which is a cobalt aluminate. However, to get a lighter colour, huge amounts of Al_2O_3 have to be added which therefore leads to Hedvall's assumption that cobalt ultramarine in trade is a mixture of cobalt aluminate with a surplus of alumina.

Cobalt aluminum oxide; *Cobalt blue*; *Gahn's ultramarine*
Riffault *et al.* (1874) 340; Rose (1916) 287

COBALT VIOLET

Purple
Synonym, variant or common name

According to the recent review by Corbeil *et al.* (2002), the principal compounds which can fall under the heading of cobalt violet are cobalt magnesium arsenate ($Mg_2Co(AsO_4)_2$) and cobalt phosphate ($Co_3(PO_4)_2$). Also known to exist are cobalt phosphate octahydrate ($Co_3(PO_4)_2.8H_2O$), ammonium cobalt phosphate hydrate ($NH_4CoPO_4.H_2O$) and cobalt lithium phosphate ($LiCoPO_4$); there are in addition several other Group 1 element cobalt phosphates (containing Na, K). However, it should be noted that there are various further phosphates that lie in the blue to violet range and that cobalt ammonium arsenate is also listed in the literature. Of these, that most frequently mentioned in the literature is cobalt arsenate (*q.v.*), although Corbeil *et al.* (2002)

were not able to detect this compound in the pigments which they analysed, noting that it and cobalt magnesium arsenate were not readily detected by some of the techniques available.

The earlier history of the cobalt arsenate- and cobalt phosphate-type violets appears to be distinct. Cobalt phosphate, 'cobalt violet dark', was discovered and first described by Salvétat in 1859 (Gettens and Stout, 1966; Corbeil *et al.*, 2002). However, the history of the cobalt arsenate 'cobalt violet light' is less well known. It is, however, mentioned in Lefort (1855). Salter (1869) describes 'Cobalt Purples' without in any way explaining what they are composed of, merely stating that they are 'from the richest crimson purple to the most delicate violet' and that he had prepared them using both 'wet and dry methods' – presumably from solution and calcination techniques. More confusion is supplied by Vibert (1892) who says that cobalt violet is both a phosphate of cobalt and a silicate of cobalt, while Church (1901) describes it as 'cobalt arseniate', which could be derived from the mineral erythrite (*q.v.*; also known as 'cobalt bloom') or made artificially. Heaton (1928) adds that it may be cobalt ammonium arsenate or cobalt magnesium phosphate. The attempts of Corbeil *et al.* (2002) to find documentation of the synthesis of magnesium cobalt arsenate proved futile, although the compound did occur in the stock of the British colourmen Roberson's and Winsor & Newton.

According to Corbeil *et al.* (2002) cobalt arsenate was produced either by the calcination of cobalt sulpho-arsenate or purified from erythrite. Salvétat's method of producing cobalt phosphate involved precipitating a cobalt salt with sodium phosphate. The colour of this compound could be changed by heating it to various temperatures.

Cobalt violet begins to appear as a term in the 1890s, although the pigment was in use prior to this, apparently manufactured in France. Its occurrence has not been well documented to date. Corbeil *et al.* (2002) review known identifications including those on several late nineteenth century/early twentieth century paintings. Cobalt arsenate violet and cobalt phosphate violet have been identified on paintings by Gontcharova dating from 1930–40 and 1954, respectively (Rioux *et al.*, 1998) and an 1892 painting by van de Velde, *Garten mit Maria Sethe*. Cobalt arsenate violet has been detected by Kühn (1969) in two paintings dating from the mid-nineteenth century. Corbeil *et al.* (2002) additionally cite the appearance of cobalt arsenate on Monet's *Waterlillies*, and on paintings by Bonnard, Cross, Reinhardt and van Rysselberghe in the Staatsgemaldesammlungen, Munich. Cobalt phosphate violet has been detected on Fantin-Latour's *A Basket of Roses*, plus (again in the Staatsgemaldesammlungen) paintings by Hamza and Beckmann. Ammonium cobalt phosphate hydrate has been detected on Beckmann's *The Falling Man* and Pellan's *Les Prairies* mural.

Ammonium cobalt phosphate hydrate and lithium cobalt phosphate are the only compounds remaining available today; arsenate compounds were phased out in the 1960s.

Cobalt arsenate violet was referred to in mid-nineteenth century texts as mineral chalk (*chaux métallique*). Magnesium cobalt arsenate was also known as cobalt magnesia red or cobalt pink. Ammonium cobalt phosphate hydrate has been called *bronze de cobalt*.

Cobalt phosphates group; Cobalt ammonium arsenate; Cobalt arsenate; Cobalt magnesium phosphate; Erythrite
Church (1901) 188; Corbeil *et al.* (2002); Gettens & Stout (1966) 109; Heaton (1928) 163; Kühn (1969); Lefort (1855); Rioux *et al.* (1998); Salter (1869) 305–306; Salvétat (1859); Vibert (1892)

COBALT YELLOW

Yellow
Synonym, variant or common name

Synonymous with the commonly used term aureolin, cobalt yellow is a potassium or sodium substituted potassium cobalt nitrite. Although generally considered to be tripotassium hexanitrocobalt(III), $K_3Co(NO_2)_6.nH_2O$, a related compound, dipotassium monosodium hexanitrocobalt(III), $K_2NaCo(NO_2)_6.nH_2O$, has also been documented, notably in the book by Church (1901). Gates (1995), however, has recently shown that a more reasonable formulation of the composition of this pigment is $K_{3-x}Na_x[Co(NO_2)_6].nH_2O$. Church also describes a modification involving heating the pigment to 100°C; the structural alteration this might induce appears to be unstudied.

The history of this pigment has been well documented by Cornman (1986). It is generally understood that cobalt yellow was first synthesised by N.W. Fischer in 1831 as part of his study of nitrite salts; in fact the compound is still known as 'Fischer's salt' in its role as a test for potassium. However, Fischer's original publication only broadly described the reaction of potassium nitrite with other metal nitrites including that of cobalt and it was not until 1848 that he discussed specific compounds. In parallel, Saint-Evre, working in Paris, independently rediscovered the compound around 1851 and introduced it as a pigment; it is thus Saint-Evre who is sometimes credited with the invention. The pigment was reputedly made popular by the American watercolourist Aaron Penley and the German artist Arthur Mühlberg (Gettens and Stout, 1966; Wehlte, 1975).

According to Cornman, the principal preparation method was by the acidification of solutions of cobalt salts with acetic acid followed by addition of a concentrated potassium nitrite solution. Cobalt yellow would then slowly precipitate as a yellow crystalline mass. The alternative 'Hayes' method involves nitric acid vapours being passed into a solution of cobalt nitrate and potassium hydroxide (or acetate). Finally, a method where solutions of sodium cobaltinitrite and a potassium salt acidified with acetic acid is used was reputedly devised by DeKoninck and published by Adie and Wood (1900; cf. Cornman) as an analytical test but subsequently used to produce pigmentary grades.

As a consequence of the low opacity of the pigment, it was commonly adulterated with chrome and cadmium yellow pigments (*qq.v.*; Church, 1901; Gentele, 1860).

Apart from aureolin and language variants such as *jaune de cobalt*, cobalt yellow is additionally known by its *Colour Index* (1971) designations CI 77357/Pigment Yellow 40. It was also sold under the name *jaune Indien* or Indian yellow (*q.v.*; Mierzinski, 1881; Bersch, 1901; Gentele, 1860; Kittel, 1960), a term otherwise more commonly used for metal euxanthates of naturally derived origin. Coffignier (1924) uses the term *aurocoline*.

Cobalt group; Cobalt nitrates group; Indian yellow; Potassium hexanitrocobalt(III); *Aureolin*; *Aurocoline*; *Cadmium yellow*; *Chrome yellow*
Adie & Wood (1900); Bersch (1901) 352; Church (1901); Coffignier (1924) 436; *Colour Index* (1971) 77357; Cornman (1986); Gates (1995); Gentele (1860) 212; Gettens & Stout (1966) 110; Kittel (1960); Mierzinski (1881); Wehlte (1975)

COBALT ZINC OXIDE

Green
Generic compound

Cobalt zinc oxide forms a green pigment similar to cobalt blue (typically cobalt aluminium oxide, *qq.v.*) except that zinc oxide partially or wholly replaces the aluminium hydroxide. Church (1901) describes making it by adding a solution of a cobalt salt to a paste of zinc oxide and water; the mass is then dried and calcined. Field (1835) noted two kinds of 'cobalt green', one consisting of 'cobalt with the addition of oxide of iron or zinc' (the other a mixture of cobalt blue and 'chromic yellow'). Salter's edition of Field (1869) describes the pigment as being composed of zinc carbonate and cobalt, with only 2–3% cobalt being necessary.

Cobalt aluminium oxide; *Cobalt blue*; *Cobalt green*
Church (1901) 196–197; Field (1835); Salter (1869) 285

COBALT ZINC PHOSPHATE
Blue
Generic compound

Several authors give instructions for producing this blue pigment, notably Gentele (1860) and Bersch (1901). They describe how it is made by, for example, precipitating zinc sulfate with sodium phosphate, adding cobalt sulfate and then precipitating that with more sodium phosphate, then calcining to give a very deep blue pigment. Bersch considers it to be a mixture of zinc and cobalt phosphates (*qq.v.*) rather than a specific compound.

Listed by the *Colour Index* (1971) as CI 77339.

Cobalt group; Cobalt phosphates group; Zinc group; Zinc phosphate
Bersch (1901) 232; *Colour Index* (1971) 77339; Gentele (1860) 79

COBALT(II) CARBONATE
Pink
Generic compound

According to the *Colour Index* (1971; CI 77353), cobalt carbonate, $CoCO_3$, is a pink insoluble powder used as a pigment.

Cobalt carbonates group
Colour Index (1971) 77353

COBALT(II) OXIDE
Black
Generic compound

See: cobalt(III) oxide and cobalt oxides and hydroxides group.

COBALT(III) OXIDE
Black
Generic compound

Cobalt(III) oxide, Co_2O_3, is prepared by precipitating a cobalt salt with sodium hydroxide and heating the resulting cobalt hydroxide to produce a steel grey to black pigment (*Merck Index*, 1996). According to the *Colour Index* (1971), commercial pigments are generally a mixture of the Co(II) and Co(III) oxides; however, since Co(II) oxide is unstable the reference is to another supposed oxide, Co_3O_4.

Heaton (1928) records that cobalt oxide 'forms an intense and beautiful black', noting that 'it is used to some extent in fresco painting'. Mayer (1991) on the other hand describes this as a 'rather coarse black powder'. It is also known as black oxide of cobalt and cobalt black.

Cobalt oxides and hydroxides group; *Black oxide of cobalt*; *Cobalt black*
Colour Index (1971); Heaton (1928) 182; Mayer (1991); *Merck Index* (1996) 2507

COBALT-MAGNESIA RED
Red
Synonym, variant or common name

A complex cobalt oxide/magnesium oxide compound is known under the name cobalt-magnesia red. It is prepared by mixing magnesium carbonate into a thin paste with dilute aqueous cobalt nitrate, heating and stirring until dry and then fusing in a covered crucible. It is apparently used as a pink pigment (*Colour Index*, 1971: CI 77330).

Cobalt group; Magnesium group; Cobalt magnesium oxide
Colour Index (1971) 77330

COCHINEAL
Red
Common generic composite

Cochineal is a red dyestuff principally derived from various species of Coccoidea (scale insects) belonging to *Dactylopiidae* and *Porphyrophora.* These are often termed New World and Old World cochineals respectively. Of the New World species there is one domesticated insect, the *Dactylopius coccus* Costa (formerly *Coccus cacti* L.), and three wild species; D. *Confusus* Cockerell, D. *ceylonicus* Green and D. *opuntiae* Cockrell native to Central and South America; Mexico, Honduras, Peru and Argentina.

Of the Old World species *Porphyrophora polonica* L., found on the roots of *Scheleranthus perennis* L., a plant indigenous to Eastern Europe (Poland, Lithuania, Ukraine and parts of Germany), for which reason it is not surprisingly often referred to as 'Polish' and *P. hamelii* Brandt, being native to Armenia and Azerbaijan and called 'Armenian' or 'Ararat' are the best known. There are, however, numerous other species: from central Asia and eastern Siberia including *P. sophorae* Archangelskaja; from Anatolia, *P. tritici* Bodenheimer; southern Ukrane, *P. minuta* Borchsenius and in Egypt, *P. hirsutissima* Hall. For a fuller list see Cardon (2003). There have been many attempts to class these insects which has led to there being numerous old and obsolete names found in the pigment literature, for example, Bersch (1901) mentions '*Coccus polonicus*', and '*Coccus euvae ursi*'.

The extracted dyestuff of cochineal insects is principally carminic acid, however the *P. polonica* additionally contains small amounts of kermesic and flavokermesic acids as does *P. hamelii* to a lesser degree. As kermesic acid is the principal dyestuff of the kermes insect it is possible that this has led to some misattributions of cochineal lakes as kermes lakes. The smaller amount of kermesic acid in the Armenian cochineal has made this very difficult to distinguish from the New World cochineal (Kirby and White, 1996). Research by Wouters and Verhecken (1991) has shown that there are clear differences in the chemicals produced by the two species and that the relative proportions of the dye precursers will allow us to distinguish between the various *Porphyrophora.*

Schweppe and Roosen-Runge (1997) state that the earliest use of cochineal as a dye was by the Peruvian Paracas culture in 700 BC. In a painting context it was used by the Aztecs and called *nochezli* (the wild product being called *xalnocheztli* or *ixquimiliuhqui*; Cardon). The Old World cochineals were the only source for cochineal lakes in Europe until the introduction of the New World species from America by the Spanish in the 1540s. By the late sixteenth century use of the dye-rich New World cochineals had become widespread and by the nineteenth century it was, along with madder, the principal red source for artist's pigments, kermes and lac being virtually obsolete (Kirby and White).

The early terminology for cochineal is confused and often indistinguishable from that for kermes. The term derives from the Greek *κόκκος* and then the latin *coccinum*, thence *carmesinus* and the modern carmine and crimson (Clarke, 2001). These terms were used synonymously with kermes, however the term *chermisi* does refer to cochineal. Cardon states that the Armenian name for cochineal was *Kirmiz* and that it was wrongly applied to the Kermes insect by Arab writers in the Middle Ages. Furthermore the animal origin of the dye was often not recognised as, in its dried form, it resembled seeds or grains. It was therefore, along with kermes, also wrongly termed *grana.* For a full discussion of this and other historic terms see: Kermes.

Preparation as a lake pigment was by extraction of the dye with alum solution followed by precipitation with soda. Neri (1612) claimed to have invented a simple method, which he boasts he 'tried at Pisa', requiring mixing alum and aqua vitae (ethanol) with powdered cocchineal which is left to stand for four days and then further alum is added to make a '*laccha di chermissi nobilissima*' ('a most noble cochineal lake'). It was also prepared from previously dyed textile cuttings, a method producing *cimatura di grana*. See: *cimatura.* A fuller review of the manufacture of cocchineal lakes is given by Cardon.

As identification of the exact dyestuff in red lake pigments is difficult there has therefore been little confirmed analysis on works of art. Kirby and White have however, examined a broad range of paintings in the National Gallery, London from 1400 to 1900. Cochineal is first found on a painting by Gerard David of 1510. Its use thereafter becomes increasingly more commonplace.

Porphyrophora polonica L. has historically been also known as *German kermes, Polish kermes*, and *root k.*, as well as root cochenical, *cremesino xavo, cremese* and *chremesino tedesco* (Rosetti, 1548). Synonym and variant names associated with cochineal lakes include *carmine, cremisi, cremisino,* crimson lake, *grana*, scarlet lake, purple lake, Chinese lake, Florentine lake, Hamburgh lake, Roman lake and Venetian lake.

Anthraquinones group; Insect-based reds group; Carminic acid; Kermes; Lac; *Carminie*; *Chinese lake*; *Cimatura*; *Crimson lake*; *Florentine lake*; *Grana*; *Hamburgh lake*; *Purple lake*; *Roman lake*; *Scarlet lake*; *Venetian lake*

Bersch (1901) 362; Cardon (1990); Cardon (2003) 470–510; Clarke (2001) 30; Kirby & White (1996); Neri (1612/Mentasti 1980) cxix; Rosetti (1548); Schweppe & Roosen-Runge (1986); Wouters & Verhecken (1991a)

COELIN

Blue

Synonym, variant or common name

Under the general heading of cerulian blue, after mentioning the synonymous caerulium, Salter (1869) also states that 'Under the name Coëlin there has of late years been imported from Germany the cobalt blue with a tin base … This comparatively new pigment … contains or is mixed with gypsum, silica, and sometimes magnesia.' However, Jännicke (1893) gives this as a cobalt phosphate colour which he states is slightly greenish.

The term has merited listing as recently as the 1991 edition of Mayer.

See: caeruleum, cerulean blue and cobalt phosphates group.

Jännicke (1893) 70; Mayer (1991) 43; Salter (1869) 190

COERULEUM

Blue

Synonym, variant or common name

See: cerulean blue.

COFFEE BLACK

Black

Synonym, variant or common name

Osborn (1845) says that coffee black was 'little known and not on sale' and that De Montabert (citing Bouvier) preferred to call this coffee brown. The formulation and composition remain obscure.

Osborn (1845)

COFFEE BROWN

Black-Brown

Synonym, variant or common name

See: coffee black.

COKE BLACK

Black

Synonym, variant or common name

See: carbon-based blacks group: cokes sub-group.

COLCOTHAR

Red

Synonym, variant or common name

The *Oxford English Dictionary* (2002) defines colcothar (or *-chotar*, *-cotar* or *-kethor*) as 'the brownish red peroxide of iron which remains in the retort after the distillation of sulfuric acid from iron sulphate'. Watin (1785) implies that colcothar is equivalent to *caput mortuum* (*q.v.*), linking it also to the term Prussian red. Harley (1982) notes from late eighteenth century English documentary sources that colcothar vitriol is listed as a colour name (Atkinson, 1794) and described as 'a bright, light purple', or as a 'purple brown calx of iron' (*Practical Treatise*, 1795). Terry (1893) lists colcothar as 'a fancy name for a kind of iron oxide pigment', and states that it is synthetic. Riffault *et al.* (1874) state that this is a red iron oxide produced from the calcination of green iron sulfate. He also describes a method of 'wet' production producing a precipitate which, 'when effected in hot liquors … is fine, more velvety, and deeper in colour'. It is also listed by Church (1901) as a term for a synthetic red iron oxide pigment synonymous with Venetian red (*q.v.*). Heaton (1928) indicates that it was by then an obsolete term, or nearly so.

The name appears to have been derived during the earliest seventeenth century by alchemists who used it to describe metallic residues (*OED*, 2002). It is possibly a corruption of the Greek for 'flowers of copper', *chalcanthus*, with a similar etymology as copperas (*q.v.*) referring primarily to the colour of the material rather than its chemistry. Colcothar is jeweller's rouge, used for polishing gold and silver due to the non-abrasive qualities of the very fine iron oxide particles.

Colcothar is listed as a domestic pigment in eighteenth century colonial America by Candee (1967).

Iron oxides and hydroxides group; *Caput mortuum*; *Copperas*; *Indian red*; *Prussian red*; *Venetian red*

Atkinson (1794); Candee (1967); Church (1901); Harley (1982) 122; Heaton (1928) 380; *OED* (2002) 'Colcothar'; *Practical Treatise* (1795); Riffault *et al.* (1874) 424; Terry (1893) 145; Watin (1773/edition of 1785) 22–23

COLLENS EARTH

Brown

Synonym, variant or common name

See: Vandyke brown.

COLLOPHANE

White
Generic variety

Collophane is a general term applied to cryptocrystalline varieties of apatite group minerals (*q.v.*; Rutley, 1988). It is often used when the specific phase of apatite cannot be identified. Deposits of mineral collophane are often associated with fossilised bone (*q.v.*) or coprolites; the term is also sometimes used in the context of bone composition and structure.

Collophane has been identified by Kakoulli *et al.* (2001) as a pigment phase associated with bone in the Hellenistic painted tombs at Vergina (c. 340 BC).

Apatite group; Calcium phosphates group; Bone
Kakoulli *et al.* (2001); Rutley (1988) 338

COLOGNE EARTH

Brown
Synonym, variant or common name

Cologne earth is generally described as a form of humic earth (*q.v.*) and compared or equated to Vandyke brown. Salter states that it was also incorrectly called Cullen's earth (Salter, 1869). It is also known as German umber and Cologne u. (Tingry, 1804).

Humic earth; *Vandyke brown*
Salter (1869) 344–345; Tingry (1804) 367

COLOGNE YELLOW

Yellow
Synonym, variant or common name

Essentially an adulterated form of chrome yellow (*q.v.*), Cologne yellow was apparently 'a cheap inferior chrome yellow, unfit for artistic purposes, and consists of twenty-five parts chromate of lead, fifteen of sulphate of lead, and sixty of sulphate of lime' (Salter, 1869). The term was still apparently current for Heaton (1928) some 60 years later. Other sources also describe Cologne yellow as chrome yellow mixed with additional white materials, such as gypsum (Schützenberger, 1867), lead sulfate (Kühn and Curran, 1986), and lead sulfate, gypsum, baryte and alumina (*qq.v.*; Liebig *et al.*, 1842), the latter stating that adulterants were added as chrome yellow was an expensive pigment when used on its own.

Aluminium oxides and hydroxides group; Lead chromates group; Baryte; Calcium sulfate; Gypsum; *Chrome yellow*
Heaton (1928) 381; Kühn & Curran (1986); Liebig *et al.* (1842) 279; Salter (1869) 94; Schützenberger (1867) 254

COLORADO

Red
Synonym, variant or common name

A term used, for example, in the anonymous Spanish treatise known as the *Tractado del arte de la pintura* of about 1656. It is a general term denoting a red or reddish hue; several formulations are given, based on *almagra* (a red ochre) or carmine (*qq.v.*; Veliz, 1986).

Almagra; *Carmine*; *Red ochre*
Tractado (1656); Veliz (1986) 210, n.10

COMMELINA

Blue
Common generic composite

A blue dye may be derived from the dayflower *Commelina communis* L. (Commelinaceae) that, according to Schweppe (1992), primarily contains the metal chelate complex commelinin as well as flavocommelin, swertisin, awobanin and flavocommelitin. Shimoyama *et al.* (1995) have reported the use of commelina dye in *Ukiyo-e* prints.

Schweppe (1992) 395; Shimoyama *et al.* (1995)

COMPOSITE BLACK

Black
Synonym, variant or common name

Osborn (1845) states that composite black is 'the residuum from the fabrication of Prussian blue' (*q.v.*).

Prussian blue
Osborn (1845) 50

COMPOSITION BLUE

Blue
Synonym, variant or common name

See: indigo carmine.

CONDENSED TANNINS

Variable
Synonym, variant or common name

See: proanthocyanidins group.

CONDY'S WHITE LEAD

White
Synonym, variant or common name

A process of manufacturing basic lead carbonate (lead white) was patented by Condy of Battersea in 1881. Molten metallic lead was poured into cold water to 'feather' it (that is, to form granules). The granules were then put into wooden vats with perforated false bottoms that were filled up with diluted acetic acid (1 part acid to 12.5 parts water) and allowed to stand for 2 hours before drawing the acid off. The lead was oxidised over 3 to 4 hours, then the acid pumped back in. The process was repeated until the solution of basic acetate of lead had a specific gravity of 1.040 at 15.5°C. At this stage, excess bicarbonate of soda was added, white lead being precipitated (Terry, 1893).

Lead white
Terry (1893) 197

CONICHALCITE

Green
Generic compound

Conichalcite ($CaCu[AsO_4][OH]$) belongs to the adelite group of minerals, a series of orthorhombic arsenates and vanadates. A wide variety of substitutions may occur, this giving a general formula for this group of $AB^{2+}(XO_4)(OH)$, where A is calcium or lead, B is cobalt, copper, iron, magnesium, nickel or zinc and X is either arsenic or vanadium. Conichalcite is generally found among surface or near-surface alteration products associated with copper mineralisaton. The Raman spectra of this mineral and others of the adelite group have been recorded by Martens *et al.* (2003b).

Brecoulaki and Perdikatsis (2002) have identified conichalcite on a painted stelae in the mid-fourth century BC tombs of Vergina, Greece.

Arsenic group; Copper group
Brecoulaki & Perdikatsis (2002); Martens *et al.* (2003b)

CONSTANT WHITE

White
Synonym, variant or common name

Constant white may refer to either barium sulfate ('blanc fixe') or zinc oxide ('zinc white'), though according to Kühn (1986) it could also contain lead white (*qq.v.*). Field (1835) and Salter (1869) give the synonyms permanent white (*q.v.*) and barytic white for constant white, and identify it as barium sulfate while further stating that it could refer to both the mineral ('heavy spar' – that is, baryte, *q.v.*) and the synthetic analogue. Salter comments that the natural product could be impure. The synthetic material was prepared by adding sulfuric acid (or a soluble sulfate) to a solution of a 'barytic salt', further noting that barium sulfate was often used to adulterate lead white. Field is very positive about its use as a watercolour pigment; by the time Salter was writing, the form of zinc white known as Chinese white (*q.v.*) had effectively superseded its utility in this context. Heaton (1928) merely lists constant white as 'blanc fixe', which usually meant the synthetic precipitate of barium sulfate.

Barium sulfate; Baryte; Zinc oxide; *Barytic white*; *Blanc fixe*; *Chinese white*; *Heavy spar*; *Lead white*; *Permanent white*; *Zinc white*
Field (1835) 70–71; Heaton (1928) 104; Kühn (1986); Salter (1869) 65–69, 75–76

COPAIFERA

Yellow
Common generic composite

A species of *Copaifera* (*C. himenifolia*) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) names, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, are given as *quauhtepuztli* and *tepozcavil*.

Flavonoids group
Wallert (1995c)

COPPER ACETATE ARSENITE

Green
Generic compound

See: emerald green and copper arsenite group.

COPPER ACETATE GROUP

Blue-Green
Group term

There are eight copper acetate compounds currently recognised; one is a copper(I) acetate while the rest are copper(II) acetates, acetate hydroxides and hydrates. For convenience they have been given here additional the letter designations A–H, following previous schemes (Gauthier, 1958; Rahn-Koltermann *et al.*, 1991): copper(II) acetate hydroxide hydrate (A; $[Cu(CH_3COO)_2]_2.Cu(OH)_2.5H_2O$); Copper(II) acetate hydroxide hydrate (B; $Cu(CH_3COO)_2.Cu(OH)_2.5H_2O$); copper(II) acetate hydroxide (C; $Cu(CH_3COO)_2.[Cu(OH)_2]_2$); copper(II) acetate hydroxide hydrate (D; $Cu(CH_3COO)_2.[Cu(OH)_2]_3.2H_2O$); copper(II) acetate (E; $Cu(CH_3COO)_2$); copper(II) acetate hydrate (F; $Cu(CH_3COO)_2.H_2O$); copper(I) acetate (G; $Cu(CH_3COO)$); copper(II) acetate hydroxide hydrate (H; $Cu(CH_3COO)_2.[Cu(OH)_2]_4.3H_2O$). E to G are neutral acetates; A to D and H are basic acetates. Syntheses are given by Gauthier and Rahn-Koltermann *et al.*; additional preparation has been described by Schweizer and Mühlethaler (1968) and Scott (2002), the latter of whom also discusses the issues surrounding these compounds extensively. Additionally, a recipe in the fifteenth century manuscript 1243 in the Biblioteca Riccardiana was found by Orna (1996) to give a compound which did not match any published data; Scott has since made a tentative identification of potassium copper acetate ($2K(CH_3COO).Cu(CH_3COO)_2$) and/or ammonium copper acetate acetic acid ('$C_{14}H_{50}CuN_4O_{20}$').

Verdigris (*q.v.*) and its variants will essentially be one or, more probably, several of these compounds. Scott has also pointed out that a range of copper formate compounds can be formed and that these may occur in the context of pigments. Useful reviews of copper acetate compounds used as pigments have been given by Kühn (1993a) and Scott.

Copper formate group; Copper group; *Verdigris*
Gauthier (1958); Kühn (1993a); Orna (1996); Rahn-Koltermann *et al.* (1991); Schweizer & Mühlethaler (1968); Scott (2002) 269–270

COPPER(I) ACETATE

Blue-Green
Generic compound

A synthetic, anhydrous, neutral copper acetate with the formula $Cu(CH_3COO)$ (Rahn-Koltermann *et al.*, 1991; Scott, 2002). This compound has probably limited relevance as a pigment, but may be a component of some verdigris-related compounds (*q.v.*). This is compound G in Scott's (2002) classification.

See verdigris for a fuller discussion and known occurrences.

Copper acetate group; *Verdigris*
Rahn-Koltermann *et al.* (1991); Scott (2002) 270–275

COPPER(II) ACETATE

Blue-Green
Generic compound

A synthetic, anhydrous, neutral copper acetate with the formula $Cu(CH_3COO)_2$ (Rahn-Koltermann *et al.*, 1991; Scott, 2002). This compound has probably limited relevance as a pigment, but may be a component of some verdigris-related compounds (*q.v.*). This is compound E in Scott's (2002) classification.

See verdigris for a fuller discussion and known occurrences.

Copper acetate group; *Verdigris*
Rahn-Koltermann *et al.* (1991); Scott (2002) 270–275

COPPER(II) ACETATE HYDRATE

Blue-Green
Generic compound

A synthetic, neutral copper acetate with the formula $Cu(CH_3COO)_2.H_2O$ (Rahn-Koltermann *et al.*, 1991; Scott, 2002). This compound is the most common copper acetate and the most easily prepared using modern chemical techniques. This is compound F in Scott's (2002) classification. It was originally synthesised by dissolving crude verdigris in vinegar, the crystals left to precipitate on wooden sticks.

See verdigris for a fuller discussion and known occurrences.

Copper acetate group; *Verdigris*
Rahn-Koltermann *et al.* (1991); Scott (2002) 270–275

COPPER(II) ACETATE HYDROXIDE

Blue-Green
Generic compound

A synthetic, basic copper acetate with the formula $Cu(CH_3COO)_2.[Cu(OH)_2]_2$. This compound, unlike the other copper(I) and copper(II) acetates, may only occur alone (Scott, 2002). This compound may form certain verdigris pigments.

See verdigris for a fuller discussion and known occurrences.

Copper acetate group; *Verdigris*
Scott (2002) 270–275

COPPER(II) ACETATE HYDROXIDE HYDRATE

Blue-Green
Generic compound

A series of synthetic, basic copper acetates exists which have the formulae $[Cu(CH_3COO)_2]_2.Cu(OH)_2.5H_2O$, $Cu(CH_3COO)_2.Cu(OH)_2.5H_2O$, $Cu(CH_3COO)_2.[Cu(OH)_2]_3.2H_2O$ and $Cu(CH_3COO)_2.[Cu(OH)_2]_4.3H_2O$. These are compounds A, B, D and H respectively in Scott's (2002) classification. All compounds are important components of verdigris pigments. However, Rahn-Koltermann *et al*. (1991) were unable to synthesise compound B and concluded that it therefore did not exist. On the other hand, recent syntheses by Scott (2002) were successful in manufacturing this compound.

See verdigris for a fuller discussion and known occurrences.

Copper acetate group; *Verdigris*
Rahn-Koltermann *et al*. (1991); Scott (2002) 270–275

COPPER ARSENATE

Green
Synonym, variant or common name

A number of historical sources erroneously report the existence of copper arsenate compounds associated with the terms Scheele's green and emerald green (*qq.v.*). These are, however, hydrated copper arsenites.
See: copper arsenite group.

Copper arsenite group; *Emerald Green*; *Scheele's green*

COPPER ARSENITE GROUP

Green
Group term

The term 'copper arsenite' covers a large group of compounds generally associated with the historical pigment known as Scheele's green (*q.v.*); a degree of confusion, borne of these compounds' complexities, surrounds which of these should be identified with it. Currently it is thought that (including hydration states) some ten copper arsenites exist (Gmelin, 1961; Fiedler and Bayard, 1997). Scheele's green is considered to be a mixture of several of these compounds, including the following: copper diarsenite ($2CuO.As_2O_3.2H_2O$); copper metaarsenite ($CuO.As_2O_3$); neutral copper orthoarsenite ($3CuO.As_2O_3.2H_2O$); trippkeite ($CuAs_2O_4$); copper arsenate ($CuAsO_2$); copper arsenate ($Cu(AsO_2)_2$); copper arsenite salt ($Cu_3(AsO_3)_2.3H_2O$); copper arsenite salt ($CuHAsO_3$).

The copper acetate arsenite generally called emerald green or Schweinfurt green (*qq.v.*) is discussed below. A copper-arsenic mineral called tyrolite ($Ca_2Cu_9(AsO_4)^{4-}(OH)_{10}.10H_2O$) also exists.

Historical recipes, and studies on them, show that the shade of the pigment was determined by varying the copper to arsenic ratio of the starting materials as well as by the temperatures involved in the production.

Commercial pigments were therefore a mixture of various phases with one form predominating. For example, synthesis by Schweizer and Mühlethaler (1968) suggested that copper diarsenite ($2CuO.As_2O_3.2H_2O$) might form in the cold, with copper orthoarsenite ($3CuO.As_2O_3.2H_2O$) or copper metaarsenite ($CuO.As_2O_3$) formed respectively in hot solutions or when the arsenic content was increased.

Scott (2002) has additionally pointed out that there is a group of copper arsenite minerals as well as trippkeite ($CuAs_2O_4$) – lammerite ($Cu_3(AsO_4)_2$), mixite ($Cu_3(AsO_4)_2.6H_2O$), lindackerite ($Cu_5As_4O_{15}.9H_2O$), cornubite ($Cu_5(AsO_4)_2(OH)_4$), clinoclase ($Cu_3(AsO_4)(OH)_3$) and olivenite ($Cu_2(AsO_4)(OH)$) – arguing that since many different routes were used historically for preparing the pigment, these, or rather, their synthetic analogues, need to be considered as possible members of this group of pigments. However, there is currently no evidence for their occurrence.

Scheele's original recipe for the pigment involved preparing a solution of sodium carbonate heated to about 90°C, arsenious oxide then being gradually added, whilst stirring, until it completely dissolved. The resulting sodium arsenite solution was then added slowly to a solution of copper sulfate, a precipitate of copper arsenite forming. The product was then washed in hot water and dried at 45°C. It is said that it becomes considerably brighter if then exposed to 60–70°C. Other methods include precipitating a solution of dilute copper sulfate with an alkaline solution of arsenic, and washing the precipitate (Zerr and Rübencamp, 1906).

Various researchers have commented that the compounds produced from historical recipes for Scheele's green are typically amorphous, with only the synthetic analogue of the mineral trippkeite apparently forming a crystalline structure. Some of the arsenites may also be polymeric; for example, the metaarsenites are known to be composed of extended anionic chains formed by oxygen-bridged pyramidal AsO_3 units (King, 1996), which helps to explain some of the difficulties in identification sometimes encountered with this group of pigments (Scott).

Unsurprisingly a number of compositions have also been given historically, with Schweizer and Mühlethaler listing the following: $2CuO.As_2O_3$ (Berzelius, 1845); $CuO.As_2O_3$ (Ure, 1847); $CuO + CuHAsO_3$ (Bloxam, 1862); $CuHAsO_3$ (Miller, 1864); $Cu_3(As_2O_3).H_2O$ (Sharples, 1877 and Bornemann, 1922). It should also be noted that some literature refers to 'copper arsenate'; this is erroneous, such compounds being based on AsO_4^{3-} rather than the arsenite ions $[AsO(OH)_2]^-$, $[AsO_2(OH)]^{2-}$ and $[AsO_3]^{3-}$.

Bis(acetato)hexametaarsenitotetracopper (copper(II) acetate arsenite), $Cu_4(OAc)_2(AsO_2)_6$, otherwise commonly known as emerald green (though that term had variable meaning in the nineteenth century) was discovered in an attempt to improve Scheele's green. Two main methods of production exist. An acetate method involved heating verdigris (*q.v.*; copper acetate) with distilled vinegar to dissolve it. Then arsenic trioxide dissolved in water was added and a precipitate formed which was then boiled again with vinegar. The resultant crystals were washed and drained (Leibig, 1822, cf. Fiedler and Bayard, 1997). Later improvements were made, one being substitution of the verdigris with distilled verdigris (neutral copper acetate), which produced a darker colour. Zerr and Rübencamp writing in 1906 state that this method was then obsolete, supplanted by the second, sulfate method, which involves dissolving copper sulfate in water and slowly adding to this a solution of arsenic trioxide boiled with potassium carbonate until the carbon dioxide is released. A precipitate is formed which is then subjected to a slight excess of acetic acid resulting in emerald green crystals. Both methods are very difficult to carry out as great care is required to ensure that there is precisely the right amount of agitation at the correct moment, and the degree of heat must be carefully regulated as this influences the resultant colour. Salter (1869) describes an olive-coloured calcined form (of 'Schweinfurt green'), adding that 'It may be directly prepared by mixing boiling aqueous solutions of equal parts of crystallised verdigris (*q.v.*) and arsenious acid. An olive-green precipitate is immediately formed.'

Fiedler and Bayard give several further methods of production used in the twentieth century and list numerous adulterants.

Additionally, a copper formate arsenite has been tentatively identified among pigments in the Hafkenscheid collection of early nineteenth century Dutch pigments (Pey, 1987).

Copper group; Trippkeite; Tyrolite; *Crystallised verdigris*; *Emerald green*; *Scheele's green*; *Verdigris*
Berzelius (1845) v.III, 829–830; Bloxam (1862); Bornemann (1922); Fiedler & Bayard (1997); Gmelin (1961); King (1996); Leibig (1822); Miller (1864) 684; Pey (1987); Salter (1869) 332–333; Schweizer & Mühlethaler (1968); Scott (2002) 309; Sharples (1877); Ure (1847) 61, 242, 929, 1100–1101; Zerr & Rübencamp (1906/1908) 227

COPPER BLUE

Blue
Synonym, variant or common name

See: bremen blue.

COPPER BORATE

Green
Generic compound

Copper borate probably refers to copper metaborate and copper metaborate dihydrate. Salter (1869) lists copper borate, providing instructions for its preparation by precipitating copper with borax, washing the residue with cold water, and, after drying, igniting it. This gave a 'pretty yellowish green' apparently, which would turn a dark green on further heating. It is glassy in character and was levigated for use. Bersch (1901) provides a broadly similar recipe for the same pigment (mix solutions of 3 parts borax to 2 parts copper sulfate), noting that it must be dried 'at a very moderate temperature', otherwise it would decompose, but that when fully dry it could be heated to a red heat without decomposition; it could be used in oil.

Though otherwise obscure and probably rarely if ever used by artists, it is none-the-less listed by the *Colour Index* (1971; CI 77415).

Copper group
Bersch (1901) 250; *Colour Index* (1971) 77415; Salter (1869) 285–286

COPPER BROWN

Brown
Synonym, variant or common name

Listed by Salter (1869); it apparently refers to copper hexacyanoferrate(II) (*q.v.*) and other unspecified compounds of copper. The *Colour Index* (1971; CI 77403) gives an alternate formulation where aqueous copper sulfate (2 parts) and magnesium sulfate (1 part) are mixed, then potassium carbonate added so long as a precipitate forms; this is filtered, dried and ignited.

Copper group; Hexacyanoferrate group; Copper hexacyanoferrate(II)
Colour Index (1971) 77403; Salter (1869) 355

COPPER CARBONATE HYDROXIDE

Blue-Green
Generic compound

See: copper carbonates group.

COPPER CARBONATE HYDROXIDE, AZURITE TYPE

Blue
Generic compound

Synthetic equivalents of the naturally occurring mineral azurite include the pigments generally referred to as blue verditer (*qq.v.*; Gettens and FitzHugh, 1993a). These materials are known to have been synthesised since the early Renaissance by various methods employing copper(II) sulfate solution and other complex copper(II) salts mixed with either bicarbonates of sodium or potassium, or with lime and sal ammoniac. Alternatively, copper(I) oxide may be reacted with water and carbon dioxide (Scott, 2002). The synthesis of this (and the green malachite type, *qq.v.*) has been studied by Mactaggart and Mactaggart (1980).

Copper group; Copper carbonates group; Azurite; Malachite; *Blue verditer*; *Copper carbonate hydroxide, malachite type*; *Green verditer*; *Verditer*
Gettens & FitzHugh (1993a); Mactaggart & Mactaggart (1980); Scott (2002) 111

COPPER CARBONATE HYDROXIDE, MALACHITE TYPE

Green
Generic compound

Synthetic equivalents of the naturally occurring mineral malachite include the pigments generally referred to as green verditer (*qq.v.*; Gettens and FitzHugh, 1993b). These materials are known to have been synthesised since the early Renaissance by various methods employing copper(II) sulfate solution and other complex copper(II) salts mixed with bicarbonates of sodium or potassium (Scott, 2002). Typically synthetic forms of the compound form spherulitic particles with a diameter of 10–20 μm. The synthesis of this (and the blue azurite type (*qq.v.*)) has been studied by Mactaggart and Mactaggart (1980).

Copper group; Copper carbonates group; Azurite; Malachite; *Blue verditer*; *Copper carbonate hydroxide, azurite type*; *Green verditer*; *Verditer*
Gettens & FitzHugh (1993b); Mactaggart & Mactaggart (1980); Scott (2002) 111

COPPER CARBONATES GROUP

Blue-Green
Group term

There are a number of copper carbonate hydroxides ('basic copper carbonate') encountered as pigments, most notably azurite, malachite and their synthetic analogues, the latter generally referred to as blue and green verditer. Excellent reviews of these compounds as artists' materials are also provided by Scott (2002) and Gettens and FitzHugh (1993a,b). Those copper carbonate compounds currently recognised in a pigment context are azurite and its synthetic analogue ($Cu_3(CO_3)_2(OH)_2$); malachite and its synthetic analogue ($Cu_2CO_3(OH)_2$); georgeite ($Cu_2CO_3(OH)_2$) (*qq.v.*). There are some secondary substituted carbonates (Na, Zn) as well, though these appear to be of limited occurrence in a pigment context: aurichalcite ($(Cu,Zn)_5(CO_3)_2(OH)_6$); claraite ($(Cu,Zn)_3(CO_3)(OH)_4.4H_2O$); chalconatronite and the synthetic analogue ($Na_2Cu(CO_3)_2.3H_2O$); rosasite and the synthetic analogue ($(Cu,Zn)_2CO_3(OH)_2$) (*qq.v.*).

For a fuller discussion see the individual entries.

Copper group; Aurichalcite; Azurite; Chalconatronite; Claraite; Copper carbonate hydroxide, azurite type; Copper carbonate hydroxide, malachite type; Copper sodium carbonate, chalconatronite type; Copper zinc carbonate, rosasite type; Georgeite; Malachite; Rosasite; *Verdigris*
Gettens & Fitz Hugh (1993a, b); Scott (2002) 106–116

COPPER CHLORIDE HYDROXIDE

Green
Synonym, variant or common name

See: copper halides group.

COPPER CHLORIDE HYDROXIDE, ATACAMITE TYPE

Blue-Green
Generic compound

Synthetic copper chloride hydroxide analogue of the mineral atacamite (*q.v.*; $Cu_2Cl(OH)_3$). It is polymorphous with the other copper chloride hydroxides, botallackite, clinoatacamite and paratacamite (*qq.v.*).

Copper halides group; Atacamite; Botallackite; Clinoatacamite; Paratacamite

COPPER CHLORIDE HYDROXIDE, BOTALLACKITE TYPE

Blue-Green
Generic compound

Synthetic analogue of the copper chloride hydroxide mineral botallackite (*q.v.*; $Cu_2Cl(OH)_3$). It is polymorphous with analogues of other copper chloride hydroxides – atacamite, paratacamite and the recently assigned clinoatacamite (*qq.v.*).

Copper halides group; Atacamite; Botallackite; Clinoatacamite; Paratacamite

COPPER CHLORIDE HYDROXIDE, CLINOATACAMITE TYPE

Green
Generic compound

Clinoatacamite is a recently assigned form of copper chloride hydroxide ($Cu_2Cl(OH)_3$). This is the synthetic analogue, polymorphous with analogues of other copper chloride hydroxides – the atacamite, botallackite and paratacamite (*qq.v.*) types. Not so far identified in a pigment context, possibly because its existence was unknown.

Copper halides group; Atacamite; Botallackite; Clinoatacamite; Copper chloride hydroxide, atacamite type; Copper chloride hydroxide, botallackite type; Copper chloride hydroxide, paratacamite type; Paratacamite

COPPER CHLORIDE HYDROXIDE, PARATACAMITE TYPE

Green
Generic compound

Synthetic analogue of the copper chloride hydroxide mineral paratacamite (*q.v.*; $Cu_2Cl(OH)_3$). It is polymorphous with analogues of other copper chloride hydroxides – the atacamite, botallackite and the recently assigned clinoatacamite (*qq.v.*) types. Dei *et al.* (1998) have found that paratacamite can be formed from azurite (*q.v.*) after certain conservation treatments; this may therefore be the origin of identifications in a painting context.

Copper halides group; Azurite; Atacamite; Botallackite; Clinoatacamite; Copper chloride hydroxide, atacamite type; Copper chloride hydroxide, botallackite type; Copper chloride hydroxide, clinoatacamite type; Paratacamite
Dei *et al.* (1998)

COPPER CHROMATE HYDROXIDE

Brown
Generic compound

The common copper chromate hydroxides given in the literature are $CuCrO_4.Cu(OH)_2$ which is yellow, copper-red, chocolate-brown to lilac, $CuCrO_4.2Cu(OH)_2$ which is light brown, and $2CuCrO_4.3Cu(OH)_2$ which is yellowish brown. According to Riffault *et al.* (1874), a basic copper chromate was calcined to produce a black copper chromate pigment (see: copper chromate, calcined).
See: copper chromates group.

Copper chromates group
Riffault *et al.* (1874) 444

COPPER CHROMATE OXIDE HYDRATE

Brown
Generic compound

The *Colour Index* (1971) lists the composition of ‘chrome brown’ as a copper chromate oxide hydrate with composition $CuCrO_4.2CuO.2H_2O$ (CI 77403). It is synthesised by mixing a potassium chromate solution with a copper salt. A chrome brown pigment is also described by Salter (1869).
See: copper chromates group.

Copper chromates group; *Chrome brown*
Colour Index (1971) 77403; Salter (1869) 116

COPPER CHROMATE(III)

Black-White
Generic compound

This is a grey-black or black copper compound with composition $CuCr_2O_4$ (also termed cupric chromite). It is also a component in a brown-black or black ‘copper-chromium oxide’ pigment mentioned in the pigment literature and said to be a mixture of $CuCr_2O_4$ and CuO.

Riffault *et al.* (1874) describe a black copper chromate pigment as ‘basic copper chromate, calcined in air’. The exact composition of the pigment is unknown, but it may be copper chromate(III) or the mixed copper-chromium oxide.
See: copper chromates group.

Copper chromates group
Riffault *et al.* (1874) 514

COPPER CHROMATE(VI)

Red-Brown
Generic compound

A reddish brown cupric chromate(VI) compound with composition $CuCrO_4$ is known to exist; however, use as a pigment is uncertain.
See: copper chromates group.

COPPER CHROMATE, CALCINED

Black
Synonym, variant or common name

Riffault *et al.* (1874) described the production of a black pigment from a ‘basic copper chromate calcined in air’, also termed ‘black copper of chromate’. The exact composition of the pigment (or starting material) is currently unknown, but it is likely to be copper chromate(III) (*q.v.*). It may also be related to the brown-black or black ‘copper-chromium oxide’ mentioned in the chemical literature and described as a mixture of $CuCr_2O_4$ and CuO.
See: copper chromates group.

Riffault *et al.* (1874) 514

COPPER CHROMATES GROUP

Variable
Group term

According to the literature, copper chromates with several different stoichiometries exist. The most common of these are: copper chromate(VI), $CuCrO_4$ (reddish brown cupric chromate), the basic copper chromates which vary in colour, $CuCrO_4.Cu(OH)_2$, $CuCrO_4.2Cu(OH)_2$ and $2CuCrO_4.3Cu(OH)_2$, and copper chromate(III) (or cupric chromite), $CuCr_2O_4$ (grey-black). Further copper chromate-based pigments, in which the compositions are less clear include a brown-black or black 'copper-chromium oxide', said to be a mixture of $CuCr_2O_4$ and CuO, and a 'copper chromate oxide hydrate'. According to the *Colour Index* (1971), chrome brown (CI 77403) is a copper chromate oxide hydrate of composition $CuCrO_4.2CuO.2H_2O$, produced by mixing aqueous potassium chromate and a copper salt. Salter (1869) also describes chrome browns 'produced by various methods of several hues, tints, and shades, both by wet and dry processes' although he seemed to think them wholly superfluous.

According to Martel (1860), there was 'a chromate of copper (*marron rougeâtre*)' classed as a maroon-red pigment, also known as madderine lake. Carlyle (2001) in her survey of British nineteenth century documentary sources found it only rarely listed, such as in a c. 1855 catalogue of the colourmen Rowney. However, it is also mentioned by Salter, as copper chrome, and by Riffault *et al.* (1874).

Riffault *et al.* also describe a black copper chromate pigment as 'basic copper chromate, calcined in air'. The exact composition of the pigment is unknown, but it may be black copper chromate(III) or the mixed copper-chromium oxide. A further yellow pigment, termed 'copper yellow', was described by Salter (1869) as a 'chromate of copper potassa … of a bright yellow tint, not insoluble in water'.

Chromates group; Copper group; *Black chromate of copper*; *Copper chromate, calcined*; *Madderine lake*
Carlyle (2001) 157, 487–488, 492–493; *Colour Index* (1971) 77403; Martel (1860) 26; Riffault *et al.* (1874) 514; Salter (1869) 116

COPPER CHROME

Red
Synonym, variant or common name

Mentioned by Salter (1869) as a red copper chromate pigment, although the exact composition is unknown. It may be similar to the maroon-red 'chromate of copper (*Marron Rougeatre*)' referred to by Martel (1860), also known as madderine lake.
See: copper chromates group.

Martel (1860); Salter (1869) 116

COPPER CITRATE

Blue-Green
Generic compound

A recipe to be found in the so-called Paduan manuscript (Merrifield, 1849) provides the following description: 'A most beautiful green colour – Take the powdered verdigris, dissolve it with lemon juice, and let it settle for 24 hours; then strain the most fluid portion very carefully, leaving the lees at the bottom of the vase. Put the strained liquid into a glass vase, and add to it a little of the above-mentioned pasta verde, let it dry, and when you use it, add to it some more lemon juice, and the more you add the more beautiful the colour will be, so that it will be like an emerald; take care, however, that you do not permit the brush to touch water.' Following this recipe, Scott (2002) has been able to synthesise a compound which he then identified as copper citrate. No specific identifications of this have been noted on artefacts.

A number of other compounds based on copper and smaller carboxylic acids such as formic, acetic and tartaric acids are also known.

Copper acetate group; Copper formate group; Copper tartrate
Merrifield (1849) 664; Scott (2002) 287–288

COPPER(II) CITRATE

Blue-Green
Generic compound

See: copper citrate.

COPPER CYANIDES GROUP

Red-Brown
Group term

Although a copper(I) cyanide (white to cream powder, dark green orthorhombic crystals or dark red monoclinic crystals; MacIntyre, 1992) exists, references in the pigment literature to 'copper cyanide' are in fact likely to be a copper hexacyanoferrate. Copper may be substituted into the hexacyanoferrate(II) structure ('Prussian blue', *q.v.*) to give (according to the *Colour Index*, 1971) dicopper hexacyanoferrate(II) hydrate (given as $Cu_2Fe(CN)_6.xH_2O$) and/or a copper dipotassium hexacyanoferrate(II) compound (given as $CuK_2Fe(CN)_6$). Terms associated historically with copper hexacyanoferrates include Hatchett's brown, copper brown and Vandyke red.

Copper group; Hexacyanoferrate group; Copper hexacyanoferrate(II); *Prussian blue*
Colour Index (1971); MacIntyre (1992) 2387

COPPER(I) CYANIDE

Variable
Generic compound

See: copper cyanides group.

COPPER DIARSENITE

Green
Generic compound

See: copper arsenite group.

COPPER DIPOTASSIUM HEXACYANOFERRATE(II)

Red-Brown
Generic compound

See: copper hexacyanoferrate(II).

COPPER FERROCYANIDE

Red-Brown
Synonym, variant or common name

See: copper hexacyanoferrate(II).

COPPER FORMATE ARSENITE

Green
Generic compound

An analogue of copper acetate arsenite (emerald green; *q.v.*) can be prepared based on the formate ion ($HCOO^-$) rather than the acetate ion (CH_3COO^-). Such a compound has been tentatively identified among pigments in the Hafkenscheid collection of early nineteenth century Dutch pigments (Pey, 1987).

Copper acetate group; Copper arsenite group; Copper formate group; *Emerald green*
Pey (1987)

COPPER FORMATE GROUP

Blue-Green
Group term

There are seven copper formate compounds generally recognised; one is a copper(I) formate while the rest are copper(II) formates, formate hydroxides and hydrates. For convenience they have been given here additional letter designations A–G in a similar manner to the copper acetate group compounds (*q.v.*; after Scott, 2002):

Copper(I) formate (A; $Cu(HCOO)$).
Copper(II) formate (B; $Cu(HCOO)_2$).
Copper(II) formate hydrate (C; $Cu(HCOO)_2.2H_2O$)
Copper(II) formate hydroxide (D; $Cu(HCOO)OH$)
Copper(II) formate hydroxide hydrate (E; $2Cu(HCOO)_2.Cu(OH)_2.2H_2O$)
Copper(II) formate hydroxide (F; $Cu(HCOO)_2.Cu(OH)_2$)
Copper(II) formate hydroxide (G; $Cu(HCOO)_2.2Cu(OH)_2$)

The copper formates exist predominantly as corrosion products and are not currently recognised as pigments though in principle they may be present but unrecognised due to the similarity to the acetate analogues. Formic acid was not generally recognised until 1749 when Marggraf described a new acid which he had obtained by the distillation of red ants, naming it '*l'acide des fourmis*' (Crosland, 1962); other sources, however, suggest that there was an earlier identification by Fisher in 1670 (*Merck Index*, 1996).

A copper formate arsenite has been tentatively identified among pigments in the Hafkenscheid collection of early nineteenth century Dutch pigments (Pey, 1987).

Copper acetate group; Copper formate arsenite
Crosland (1962) 286; *Merck Index* (1996) 4268; Pey (1987); Scott (2002) 269–270

COPPER(I) FORMATE

Green
Generic compound

See: copper formate group.

COPPER(II) FORMATE

Green
Generic compound

See: copper formate group.

COPPER(II) FORMATE HYDRATE

Green
Generic compound

See: copper formate group.

COPPER(II) FORMATE HYDROXIDE

Green
Generic compound

See: copper formate group.

COPPER(II) FORMATE HYDROXIDE HYDRATE

Green
Generic compound

See: copper formate group.

COPPER FORMO-ARSENITE

Green
Synonym, variant or common name

See: copper formate arsenite.

COPPER FRIT

Blue
Synonym, variant or common name

See: Egyptian blue.

COPPER GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*). There may also be an association with malachite (*q.v.*).

Malachite; *Emerald green*; *Scheele's green*
Fiedler & Bayard (1997)

COPPER GREEN GLAZE

Green
Synonym, variant or common name

A term recently proposed by Eikema Hommes (1998, 2002) to replace the often inaccurate copper resinate, referring to the group of transparent greens based on copper pigments such as verdigris (*q.v.*) mixed with organic media such as resins, oils or proteins which may or may not be deliberately formulated as such. However, since these compounds also occur in contexts other than as glazes, the term may be misleading. For more information, see: organo-copper complexes group.

Organo-copper complexes group; *Copper resinate; Verdigris*
Eikema Hommes (1998); Eikema Hommes (2002) 107

COPPER GROUP

Variable
Group term

Copper-containing pigments form an extremely large group. They have been extensively reviewed by Scott (2002). Here they are divided for convenience into the following groups:

Acetates, formates and tartrates (excluding arsenic compounds): copper(II) acetate hydroxide hydrate (compound A; $[Cu(CH_3COO)_2]_2.Cu(OH)_2.5H_2O$), copper(II) acetate hydroxide hydrate (compound B; $Cu(CH_3COO)_2.Cu(OH)_2.5H_2O$), copper(II) acetate hydroxide (compound C; $Cu(CH_3COO)_2.[Cu(OH)_2]_2$), copper(II) acetate hydroxide hydrate (compound D; $Cu(CH_3COO)_2.[Cu(OH)_2]_3.2H_2O$), copper(II) acetate (compound E; $Cu(CH_3COO)_2$), copper(II) acetate hydrate (compound F; $Cu(CH_3COO)_2.H_2O$), copper(I) acetate (compound G; $Cu(CH_3COO)$), copper(II) acetate hydroxide hydrate (compound H; $Cu(CH_3COO)_2.[Cu(OH)_2]_4.3H_2O$), copper(II) potassium acetate ($2K(CH_3COO).Cu(CH_3COO)_2$), ammonium copper acetate acetic acid (‘$C_{14}H_{50}CuN_4O_{20}$’), copper(I) formate (compound A; $Cu(HCOO)$), copper(II) formate (compound B; $Cu(HCOO)_2$), copper(II) formate hydrate (compound C; $Cu(HCOO)_2.2H_2O$), copper(II) formate hydroxide (compound D; $Cu(HCOO)OH$), copper(II) formate hydroxide hydrate (compound E; $2Cu(HCOO)_2.Cu(OH)_2.2H_2O$), copper(II) formate hydroxide (compound F; $Cu(HCOO)_2.Cu(OH)_2$), copper(II) formate hydroxide (compound G; $Cu(HCOO)_2.2Cu(OH)_2$), copper tartrate.

Arsenic-containing compounds: copper diarsenite ($2CuO.As_2O_3.2H_2O$), copper orthoarsenite ($3CuO.As_2O_3.2H_2O$), copper metaarsenite ($CuO.As_2O_3$), trippkeite ($CuAs_2O_4$), tyrolite ($Ca_2Cu_9(AsO_4)_4(OH)_{10}.10H_2O$), copper formate arsenate, copper acetate arsenate.

Borates: copper borate ($Cu(BO_3)_2$).

Carbonates (including secondary substituted carbonates (Na, Zn)): azurite and synthetic analogue ($Cu_3(CO_3)_2(OH)_2$), malachite and synthetic analogue ($Cu_2CO_3(OH)_2$), georgeite ($Cu_2CO_3(OH)_2$), aurichalcite ($(Cu,Zn)_5(CO_3)_2(OH)_6$), claraite ($(Cu,Zn)_3(CO_3)(OH)_4.4H_2O$), chalconatronite and synthetic analogue ($Na_2Cu(CO_3)_2.3H_2O$), rosasite and synthetic analogue ($((Cu,Zn)_2CO_3(OH)_2$).

Halides: nantokite ($CuCl$), atacamite, botallackite, clinoatacamite and paratacamite and synthetic analogues ($Cu_2Cl(OH)_3$), calumetite ($Cu(OH,Cl)_2.2H_2O$), anthonyite ($Cu(OH,Cl)_2.2H_2O$), a copper potassium chloride (unknown composition); calcium copper chloride (‘Kuhlmann’s green’).

Cyanides (excluding hexacyanoferrate(II) compounds): copper(I) cyanide; copper(II) cyanide.

Nitrates and nitrites: copper nitrite (‘Ebony black’); gerhardite ($Cu_2(NO_3)(OH)_3$).

Organo-copper complexes and related compounds: copper-oil complexes (with oil from *Juglans regia* (‘Walnut’), *Linum usitatissimum* (‘Linseed’) and *Papaver somniferum* (‘Poppy’)); copper oleate; copper-protein complexes; copper-resin complexes.

Oxides and hydroxides: copper(I) oxide and cuprite (Cu_2O), copper(II) oxide and tenorite (CuO), copper hydroxide ($Cu(OH)_2$), spertiniite ($Cu(OH)_2$), copper(II) tin oxide (‘Gentele’s green’).

Phosphates: copper phosphate hydroxide and pseudomalachite ($Cu_5(PO_4)_2(OH)_4$), sampleite ($NaCaCu_5(PO_4)_4Cl.5H_2O$).

Silicates: dioptase ($CuSiO_3.H_2O$), chrysocolla ($(Cu,Al)_2H_2Si_2O_5(OH)_4.xH_2O$), barium copper silicate, ‘blue’ type ($BaCuSi_4O_{10}$), barium copper silicate, ‘purple’ type ($BaCuSi_2O_6$), calcium copper silicate and cuprorivaite ($CaCuSi_4O_{10}$).

Sulfates: antlerite ($Cu_3SO_4(OH)_4$), brochantite ($Cu_4SO_4(OH)_6$), bonattite ($CuSO_4.3H_2O$), chalcanthite ($CuSO_4.5H_2O$), langite ($Cu_4(SO_4)(OH)_6.2H_2O$), posnjakite ($Cu_4SO_4(OH)_6.H_2O$), copper hydroxide sulfate hydrate ($CuSO_4.3Cu(OH)_2.\frac{1}{2}H_2O$).

Sulfides: copper(I) sulfide (Cu_2S), copper(II) sulfide and covellite (CuS) and other intermediate sulfides.

Copper acetate group; Copper arsenite group; Copper carbonates group; Copper chromates group; Copper cyanides group; Copper formate group; Copper halides group; Copper nitrates and nitrites group; Copper oxides and hydroxides group; Copper phosphates group; Copper silicate group; Copper sulfides group; Organo-copper complexes group; Bonattite; Copper phthalocyanine
Scott (2002)

COPPER HALIDES GROUP

Blue-Green
Group term

The following copper chlorides and chloride hydroxides are currently recognised as either being pigments or associated with pigment use:

Nantokite ($CuCl$).
Atacamite and its synthetic copper chloride hydroxide analogue ($Cu_2Cl(OH)_3$).
Botallackite and its synthetic copper chloride hydroxide analogue ($Cu_2Cl(OH)_3$).
Clinoatacamite and its synthetic copper chloride hydroxide analogue ($Cu_2Cl(OH)_3$).
Paratacamite and its synthetic copper chloride hydroxide analogue ($Cu_2Cl(OH)_3$).
Calumetite $Cu(OH,Cl)_2.2H_2O$.
Anthonyite $Cu(OH,Cl)_2.2H_2O$.

The *Colour Index* (1971; CI 77426) lists ‘basic copper chloride’ as a green pigment (without identifying the above range), citing preparation methods according to Bersch (1901), who in turn gives preparation methods of (a) exposing a moist mixture of copper sulfate, copper and sodium chloride to air, or (b) by moistening copper turnings with aqueous ammonium chloride and exposing them to air. Additionally, ‘Kuhlmann’s green’ was apparently made by heating lime with excess copper chloride. Clearly the first and last of these three recipes may form copper sodium or copper calcium chlorides rather than or as well as simple copper chlorides.

Copper group; Anthonyite; Atacamite; Botallackite; Calumetite; Clinoatacamite; Copper chloride hydroxide, atacamite type; Copper chloride hydroxide, botallackite type; Copper chloride hydroxide, clinoatacamite type; Copper chloride hydroxide, paratacamite type; Nantokite; Paratacamite; *Kuhlmann’s green*; *Verdigris*
Bersch (1901) 243; *Colour Index* (1971) 77426

COPPER HEXACYANOFERRATE(II)

Red-Brown
Generic compound

According to the *Colour Index* (1971), two copper hexacyanoferrate(II) compounds are known, copper dipotassium hexacyanoferrate(II) ($CuK_2Fe(CN)_6$) and dicopper hexacyanoferrate(II) hydrate ($Cu_2Fe(CN)_6.xH_2O$).

These may also be called copper ferrocyanide in the literature, while other synonyms included prussiate of copper, Hatchett brown, Florence brown, Vandyke red and, probably, Prussian black (*q.v.*; Salter, 1869; Bersch, 1901).

Hexacyanoferrate group; *Florence brown*; *Hatchett’s brown*; *Prussian black*; *Vandyke red*
Bersch (1901) 280; *Colour Index* (1971); Salter (1869) 323–324

COPPER HYDROXIDE

Blue
Generic compound

See: copper oxides and hydroxides group.

COPPER HYDROXIDE NITRATE

Blue
Generic compound

Copper hydroxide nitrate, $Cu_2(NO_3)(OH)_3$, is the synthetic analogue of the mineral gerhardite (*q.v.*). The mineral has been

identified in a pigment context by Banik (1989) and Van'T Hul-Ehrnreich and Hallebeek (1972) although the reported phase may be the synthetic analogue described here.
See: copper nitrates and nitrites group.

Copper nitrates and nitrites group; Gerhardite
Banik (1989); Van'T Hul-Ehrnreich & Hallebeek (1972)

COPPER HYDROXIDE PHOSPHATE
Green
Generic compound

Copper hydroxide phosphate is the synthetic analogue of the mineral pseudomalachite (*q.v.*; $Cu_5(PO_4)_2(OH)_4$).
See: copper phosphates group.

Copper phosphates group; Pseudomalachite

COPPER HYDROXIDE SULFATE HYDRATE
Blue-Green
Generic compound

This compound has the chemical formula $CuSO_4.3Cu(OH)_2.½H_2O$.
See: copper sulfates group.

COPPER HYDROXYCHLORIDE
Green
Generic compound
See: copper halides group.

COPPER METAARSENITE
Green
Generic compound

Copper metaarsenite has the chemical formula $CuO.As_2O_3$.
See: copper arsenite group.

COPPER NITRATES AND NITRITES GROUP
Variable
Group term

Only one copper nitrate – gerhardite ($Cu_2(NO_3)(OH)_3$), or its synthetic analogue – appears to have been noted as occurring in a pigment context (Van'T Hul-Ehrnreich and Hallebeek, 1972; Banik, 1989). However, 'ebony black' is also recorded in documentary sources as being derived from copper nitrate (Riffault *et al.*, 1874).

Copper group; *Ebony black*
Banik (1989); Riffault *et al.* (1874) 515; Van'T Hul-Ehrnreich & Hallebeek (1972)

COPPER-OIL COMPLEX
Green
Generic compound

This broad classification encompasses a variety of naturally derived polymeric materials (oils) containing different organic species (ligands), which coordinate to the copper (and other metal centres) via oxygen, nitrogen and sulphur ligands, etc. It is commonly known as copper oleate.

Moffatt *et al.* (1997) have identified such compounds on Naskapi artefacts. The term is also applied to the green transparent strata typically found in contact with copper plates on paintings executed on these supports (Horovitz, 1986, 1999). However, numerous identifications in the literature of 'copper resinate' are in all probability copper-oil compounds.

For a fuller discussion, see: organo-copper complexes group.

Copper oleate
Horovitz (1986); Horovitz (1999); Moffatt *et al.* (1997)

COPPER OLEATE
Green
Generic compound

Unstandardised term used to refer to potentially complex organometallic compounds formed between copper and fatty-acid containing materials such as oils and waxes (Scott, 2002).
See: copper-oil complex.

Scott (2002)

COPPER ORTHOARSENITE
Blue-Green
Generic compound

Copper orthoarsenite has the chemical formula $3CuO.As_2O_3.2H_2O$.
See: copper arsenite group.

COPPER OXIDES AND HYDROXIDES GROUP
Variable
Group term

The following oxides and hydroxides have been noted in a pigment context: cuprite and copper(I) oxide (Cu_2O); tenorite and copper(II) oxide (CuO); spertiniite and copper hydroxide ($Cu(OH)_2$). However, the only member of this group generally encountered as a pigment is the synthetic analogue of Spertiniite (*q.v.*); Scott (2002) for example states that it is this form of copper hydroxide that mostly occurs in modern synthesis of historical recipes for light blue pigments. Terms such as *Bremen blue* and *Copper blue* are sometimes associated.

Copper group; Copper(I) oxide; Copper(II) oxide; Cuprite; Spertiniite; Tenorite
Scott (2002) 81

COPPER(I) OXIDE
Red
Generic compound

Synthetic analogue of the mineral cuprite (*q.v.*).

Church (1901) describes the use of 'copper oxide' as a base for lake pigments.

Copper oxides and hydroxides group; Copper(II) oxide; Cuprite
Church (1901) 173

COPPER(II) OXIDE
Black
Generic compound

Synthetic analogue of the mineral tenorite (*q.v.*). Church (1901) describes the use of 'copper oxide' as a base for lake pigments. The *Colour Index* (1971; CI 77403) provides methods to prepare this as a pigment by heating copper(II) nitrate or carbonate to dull redness.

Copper oxides and hydroxides group; Copper(I) oxide; Tenorite
Church (1901) 173; *Colour Index* (1971) 77403

COPPER PHOSPHATE HYDROXIDE
Green
Generic compound

See: copper hydroxide phosphate and pseudomalachite ($Cu_5(PO_4)_2(OH)_4$).

COPPER PHOSPHATES GROUP
Blue-Green
Group term

The following copper phosphate compounds have been identified in a pigment context: copper hydroxide phosphate and pseudomalachite ($Cu_5(PO_4)_2(OH)_4$) and sampleite ($NaCaCu_5(PO_4)_4Cl.5H_2O$).

Copper group; Copper hydroxide phosphate; Pseudomalachite; Sampleite

COPPER PHTHALOCYANINE
Blue-Green
Generic compound

See: phthalocyanine group.

COPPER POTASSIUM CHLORIDE
Green
Generic compound

See: copper halides group.

COPPER(II) POTASSIUM ACETATE
Green
Generic compound

See: copper acetate group.

COPPER-PROTEIN COMPLEX
Green
Generic compound

Copper salt-based pigments and particularly verdigris (*q.v.*) are known to react with proteinaceous material including egg yolk, animal glues, gelatine derived from vellum or even wine lees. The derived pigment is similar to those described as copper resinates. Scott (2002) reviews some occurrences of such pigments in illuminated manuscripts.

For a fuller discussion, see: organo-copper complexes group.

Verdigris
Scott (2002) 298–299

COPPER PROTEINATE
Green
Generic compound

See: organo-copper complexes group.

COPPER RED
Red
Synonym, variant or common name

Salter (1869) lists two copper reds, copper oxide (cuprite) and an organo-copper compound supposedly derived from a species of bird called *Turacine*. For further information see: copper oxides and hydroxides group, cuprite and turacine.

Copper oxides and hydroxides group; Cuprite; *Turacine*
Salter (1869) 164–165

COPPER-RESIN COMPLEX
Green
Generic compound

This broad classification encompasses a variety of naturally derived polymeric materials (resins) containing different organic species (ligands), which coordinate to the copper (and other metal centres) via oxygen, nitrogen and sulfur ligands, etc. Commonly known as copper resinate.

For a fuller discussion, see: organo-copper complexes group.

COPPER RESINATE
Green
Synonym, variant or common name

See: organo-copper complexes group.

COPPER SILICATES GROUP
Variable
Group term

Several naturally occurring copper silicate minerals are known to have been used as pigments, notably the green minerals dioptase ($CuSiO_3.H_2O$) and chrysocolla ($(Cu,Al)_2H_2Si_2O_5(OH)_4.xH_2O$).

Additionally, a number of essentially synthetic copper silicate compounds are encountered: the so-called 'Han' pigments – blue ($BaCuSi_4O_{10}$) and purple ($BaCuSi_2O_6$) barium copper silicates and 'Egyptian blue', a calcium copper silicate with the structure of cuprorivaite ($CaCuSi_4O_{10}$).

Barium copper silicate, blue type; Barium copper silicate, purple type; Calcium copper silicate; Chrysocolla; Cuprorivaite; Dioptase

COPPER SODIUM CARBONATE, CHALCONATRONITE TYPE
Green
Generic compound

The synthetic analogue of chalconatronite (*q.v.*). Scott (2002) found that this compound was formed by a Chinese recipe quoted by Needham (1974): 'to get a fine green pigment from copper one must calcine the rust [to make a copper oxide] and then boil it with white alum in a sufficient amount of water. After it has cooled it will be green, and one must add some natron solution [a naturally occurring mixture of sodium carbonate, sulphate and chloride] which will precipitate the green colour called *hsiao lu se*. This is used in painting for the colour of plant and bamboo leaves.' Further, Scott also found it formed during the replication of a recipe of Pliny's.

Chalconatronite has been observed by Banik (1989) on a sixteenth century illuminated manuscript and Magaloni (1996) identified it as used as a wall-painting pigment in two Mayan sites.

Copper group; Chalconatronite
Banik (1989); Magaloni (1996); Needham (1974); Scott (2002) 119

COPPER STANNATE
Green
Synonym, variant or common name

See: copper tin oxide.

COPPER SULFATE HYDROXIDE, ANTLERITE TYPE
Green
Generic compound

See: antlerite.

COPPER SULFATE HYDROXIDE, BROCHANTITE TYPE
Green
Generic compound

See: brochantite.

COPPER SULFATE HYDROXIDE HYDRATE, LANGITE TYPE

Blue-Green
Generic compound

See: langite.

COPPER SULFATE HYDROXIDE HYDRATE, POSNJAKITE TYPE

Green
Generic compound

See: posnjakite.

COPPER SULFATE, BASIC

Blue
Synonym, variant or common name

See: copper sulfates group.

COPPER SULFATES GROUP

Blue-Green
Group term

A series of copper sulfate and hydroxide sulfates are known to exist of which some at least appear to have been used in a pigment context. These include antlerite ($Cu_3(SO_4)(OH)_4$), brochantite ($Cu_4SO_4(OH)_6$), chalcanthite ($CuSO_4.5H_2O$), langite ($Cu_4(SO_4)(OH)_6.2H_2O$) and posnjakite ($Cu_4SO_4(OH)_6.H_2O$). A copper hydroxide sulfate hydrate ($CuSO_4.3Cu(OH)_2.½H_2O$; CI 77445) is also listed by the *Colour Index* (1971).

Antlerite; Brochantite; Chalcanthite; Langite; Posnjakite
Colour Index (1971) 77445

COPPER SULFIDES GROUP

Variable
Group term

The copper-sulfur system is, as Scott (2002) has rightly pointed out, complex, calling it 'a diverse and difficult group of compounds with dubious stoichiometry and crystallinity'. A provisional analysis has been published by Chakrabarti and Laughlin (1983).

The main copper sulfide compounds are the following ore minerals and their synthetic equivalents: anililite (Cu_7S_4); chalcocite (copper(I) sulfide, Cu_2S); covellite (copper(II) sulfide, CuS). Chalcocite can also exist in forms stable at different temperatures and pressures, all adopting different crystal systems. Additionally, several non-stoichiometric compounds occur with between 1.2 and 1.96 mole of copper to one mole of sulfur (that is, yarrowite, spionkopite, geerite, roxbyite, djurleite and digenite). Chalcopyrite $CuFeS_2$, is the most important copper ore. Other common sulfides include bornite ('peacock ore'), Cu_5FeS_4 and enargite, Cu_3AsS_4.

Copper sulfides have limited importance as pigments. However, they are common as corrosion products, especially on objects which have been buried in marine sediments and on bronze objects exposed to pollution. Niello, a decorative black compound used in metalwork, is composed of mixed sulfides. Scott has identified the copper sulfides anilite, chalcocite, djurleite ($Cu_{1.96}S$), digenite ($Cu_{1.76}S$), the copper silver sulfide stromeyerite, $Ag_{0.93}Cu_{1.07}S$, and the silver sulfide acanthite, Ag_2S, in examples of niello.

Bersch (1901) has described a pigment known to him as oil blue as being copper sulfide; Zerr and Rübencamp (1906) describing it as 'copper mono-sulphide, CuS, of a very pretty bright blue shade'.

Orna *et al.* (1980) proposed that the original blue pigment observed to be degraded to dark brown/black by Lucas on trefoil marks on the cow couch from the tomb of Tutankhamun was covellite. However, no analysis of the material was given and Scott has suggested this supposition by Orna *et al.* is doubtful, as there is no evidence for the use of covellite on Egyptian wall paintings; he has instead suggested that the discoloration product may be tenorite (*q.v.*; CuO). Duang *et al.* (1987) identified a black copper sulfide in pigments from wall paintings of the Qutan temple in the Qinghai Province, Northwest China.

Copper group; Covellite; Tenorite; *Oil blue*
Bersch (1901) 228; Chakrabarti & Laughlin (1983); Duang *et al.* (1987); Orna *et al.* (1980); Scott (2002) 224–239; Zerr & Rübencamp (1906) 164

COPPER(I) SULFIDE

Black
Generic compound

See: copper sulfides group.

COPPER(II) SULFIDE

Blue
Generic compound

Synthetic analogue of covellite (*q.v.*).
See: copper sulfides group.
Covellite

COPPER TARTRATE

Blue-Green
Generic compound

Turner (1998) has noted that numerous recipes from Johannes Alcherius (c. 1380–1420, transcr. Jean le Begue, Clarke MS 2790; cf. Merrifield (1849)) give directions for preparing green pigments from copper corrosion products, including copper tartrate pigments. The structure of copper(II) D-tartrate has been given by Prout *et al.* (1971). A number of other compounds based on copper and smaller carboxylic acids such as formic, acetic and citric acids are, of course, also known.

Copper acetate group; Copper formate group; Copper citrate
Merrifield (1849) 46–48, 66, 84, 86; Prout *et al.* (1971); Turner (1998)

COPPER TIN OXIDE

Green
Generic compound

According to Salter (1869), 'Copper Stannate, or Tin-Copper Green, equals in colour any of the copper greens free from arsenic. The cheapest way of making it is to heat 59 parts of tin … with 100 parts nitrate of soda, and dissolve the mass when cold in a caustic alkali. To the clear solution, diluted with water, a cold solution of sulphate of copper is added: a reddish-yellow precipitate falls, which on being washed and dried, becomes a beautiful green.' Riffault *et al.* (1874) give another recipe for green stannate of copper, in which copper sulfate is added to tin dissolved in nitric acid; precipitation then follows with sodium hydroxide. Gentele's green was reportedly prepared by precipitating a solution of tin chloride and copper sulfate with sodium hydroxide and then calcining the product (*Colour Index*, 1971).

Given as copper(II) tin oxide and copper tin oxide hydrate, $CuSnO_3.nH_2O$, the chemical literature also suggests that there is a copper tin hydroxide, $Cu[Sn(OH)_6]$, with synthesis given as from aqueous $K_2[Sn(OH)_6]$ and $CuCl_2$ to form light blue tetragonal crystals.

Colour Index designation CI 77441.

Copper group; Tin group
Colour Index (1971) 77441; Riffault *et al.* (1874) 552–553; Salter (1869) 286

COPPER(II) TIN OXIDE

Green
Generic compound

See: copper tin oxide.

COPPER VANADATE

Yellow
Generic compound

Nord and Tronner (1998) have identified a yellow copper vanadate in various green samples from Swedish mediaeval paintings.

Copper group; Vanadium group
Nord & Tronner (1998)

COPPER YELLOW

Yellow
Synonym, variant or common name

According to Salter (1869), this was a 'chromate of copper potassa … of a bright yellow tint, not insoluble in water'.
See: copper chromates group.

Copper chromates group
Salter (1869) 116

COPPER ZINC CARBONATE, ROSASITE TYPE

Green
Generic compound

See: rosasite.

COPPERAS

Red
Synonym, variant or common name

Copperas is a name given from early times to the protosulfates of copper, iron and zinc. However in English use, when undistinguished by attribute or context, it has always been most commonly, and is now exclusively, applied to green copperas or 'green-vitriol', the protosulfate of iron or ferrous sulfate ($FeSO_4$), used in dyeing, tanning, and making ink.

Copperas occurs naturally as the mineral melanterite ($FeSO_4.7H_2O$) which occurs as an alteration product of iron pyrite (*q.v.*; FeS_2). It is found in small quantities as prismatic crystals, or more commonly in massive or botryoidal forms. It is a greenish white colour and according to Rutley's *Elements of Mineralogy* (1988), sometimes resembles 'a furnace slag'. Copperas is produced in greater quantities as a waste product of sulfuric acid manufacture and various galvanising processes.

Terry (1893) gives methods for producing the red iron oxide pigment, copperas red, from either source: '[natural copperas] is an acid sulphate of iron, which is leached out and neutralised by addition of iron in the form of scrap. The neutral sulphate is crystallised out of the liquor, and calcined in a muffle furnace, the shade of the ultimate product being governed by the degree of duration of the roasting.' Alternatively, 'waste-product copperas' was neutralised by the addition of scrap iron and lime was added 'to throw down the iron as oxide'; the material was then calcined.

According to Buxbaum (1998), high quality pigments called copperas red were obtained by the thermal decomposition of iron sulfate hydrate ($FeSO_4.7H_2O$). Fuller (1973) indicates that it was a two-stage process involving successive degrees of dehydration and (in the second step) oxidation and loss of sulfur trioxide. The resultant colour depends on the particle size formed. The product was also used to produce Venetian red (*q.v.*) by subsequent calcination with hydrated lime.

Copperas was also used as a raw material for the manufacture of other pigments and dyes. Weber (1923) writes that copperas was used in dyeing and making writing ink. He states that: 'Tannic acid, extracted from nut galls, forms with copperas a soluble, almost colourless salt, ferrous tannate, which when exposed to air is oxidised to the ferric condition. The ferric compound is a fine black insoluble precipitate. A blue or black dye is added to give the ink a temporary colour'. Bettey (1982) discusses the use of copperas as a dye and also as a mordant.

The name has the same root as colcothar (*q.v.*) being ultimately derived from the Greek *chalcanthus*, 'flowers of copper'. Variations are *cupri rosa*, *cuperosa*, *cuprosa*, *coporosa*, *coupperose*, *chalcantum*, *vitriolum*, *vulgo cuperosa* and *coppa rosa* (*OED*, 2002). White copperas is hydrated zinc sulfate and was mentioned as a dryer by Merrifield (1849). Blue copperas is hydrated copper sulfate; naturally occurring forms are chalcanthite (*q.v.*; $CuSO_4.5H_2O$) or pistantite ($[Fe,Cu]SO_4.7H_2O$), the latter is frequently found with melanterite.

Iron oxides and hydroxides group; Chalcanthite; Hematite; Iron(III) oxide, hematite type; Pyrite; *Colcothar*; *Venetian red*
Bettey (1982); Buxbaum (1998) 85; Fuller (1973); Merrifield (1849) ccxlii–ccxliii; *OED* (2002); Rutley (1988) 326; Terry (1893) 152; Weber (1923) 184

CORAL

Red
Generic variety

Stony corals (of order Scleractinia) are in general reef builders and colonial, although they can also be solitary. They are formed of individual polyps which form a skeleton. Each polyp sits in an aragonite (calcium carbonate; *q.v.*) cup, or *theca*, secreted by the animal. Reef building corals require certain minimal conditions: warm shallow waters, where the temperature must not fall below 18°C; they must not be exposed for long periods to sun and rain and require very low silt content. Consequently most coral reefs are confined to areas such as the Caribbean and related waters, Indo-Pacific and Pacific east of Australia. At greater depths corals normally occur as solitary cups. The skeleton of either a solitary or a colonial coral is called the corallum, while skeletal parts deposited by a single polyp are called the corallite. As a colonial coral grows it leaves beneath it horizontal layers of skeletal material (Wood, 1983). The warm pink tones associated with corals used for pigments are derived from the slow growing, red precious corals, *Corallium japonicum* and *C. secundum* which occur in the western Pacific Ocean.

According to Gettens *et al.* (1993a) ground coral is sold by Japanese art supply dealers, who call it *sango matsu* ('coral powder'); it is used to create decorative effects and was considered valuable; a sample of a coarse pink powder labelled 'sango' analysed by them gave an X-ray diffraction pattern for calcite (*q.v.*) rather than the aragonite expected (Gettens *et al.*, 1993a).

The use of coral (*Acropa* species) as a source of material for conversion into slaked lime for painting in Papua New Guinea has been recorded (Hill, 2001). Edwards *et al.* (1997) document a powdered coral known as dragon's blood (*q.v.*; normally in a pigment context a tree resin) in Yemen as a medicine.

Although references have not been found in European literature sources to the use of coral as a pigment, white coral was cheap and widely available in the past.

Calcium carbonates group; Aragonite; Calcite
Edwards *et al*. (1997); Gettens *et al*. (1993a); Hill (2001); Wood (1983)

CORK

Variable
Synonym, variant or common name

The term cork occurs in three specific contexts. First, the bark from the cork oak *Quercus suber* L. (Fagaceae) was used to produce so-called cork black (*q.v.*); it is indigenous to southern Europe and north Africa, and the thick bark – the cork of commerce – is stripped off trees older than 20 years every 8–10 years and used for a wide variety of applications. Second, the Amur cork tree, *Phellodendron amurense* Rupr. (Rutaceae), which contains high levels of berberine (*q.v.*) has been noted by several authors as a source of dye extracts (see: *Phellodendron*). Third, *cork* (also *korke*) is a red-purple lichen dye; for example, Ray (1673) records 'This kind of moss, called in Wales *kenkerig*, and in England *cork* or *arcel*' (cf. Harley, 1982). Cork and linguistic variants are in fact associated with the lichen species *Ochrolechia tartarea* (L.) Massal (Diadick Casselman, 2002). For further information see: lichens group, orchil and cudbear.

Lichens group; Berberine; Phellodendron; *Cork black*; *Cudbear*; *Orchil*
Diadick Casselman (2002); Harley (1982) 63; Ray (1673) 296

CORK BLACK

Black
Synonym, variant or common name

Produced by charring cork, the bark from *Quercus suber* L. (Fagaceae). Bouvier (1827) says that his friends call it *outremer des gueux*, 'beggar's ultramarine' (Carlyle, 2001), and that it is the most blue of blacks. While it lacks intensity in mixtures, it is admirable for white draperies, skies and distances. It was also known as Spanish black, a term current to Heaton in the 1920s (Heaton, 1928).
See also: carbon-based blacks group: chars sub-group.

Carbon-based blacks group; Chars sub-group; *Spanish black*
Bouvier (1827) 78–79; Carlyle (2001) 186–187, 469; Heaton (1928) 381

CORNFLOWER BLUE

Blue
Synonym, variant or common name

Robert Boyle, writing in the seventeenth century, recommended a blue dye prepared from petals of the cornflower (*Centaurea cyanus* L., Compositae). According to Harley (1982), such was his reputation as a scientist that the colour was recommended for watercolour painting in some eighteenth century books, either as cornflower blue, Boyle's blue or cyan blue. The colour was strongly criticised by Hoofnail (1738); there is also no evidence that it was ever supplied commercially (Harley, 1982). Schweppe (1992) lists apigenin, isoswertisin, naringin, cyanidin, pelargonidin and succinylcyanin as extractable dye components of *Centaurea cyanus* L.

Boyle's blue; *Cyan blue*
Boyle (1664); Harley (1982) 65–66; Hoofnail (1738); Schweppe (1992) 397

CORUNDUM

Variable
Generic compound

Corundum is a trigonal aluminium oxide mineral of variable colour with formal chemical composition, α-Al_2O_3 (Deer *et al*., 1992; Pauling and Hendricks, 1925). Synthesis experiments have shown that hexagonal (β-Al_2O_3) and cubic (γ-Al_2O_3) forms exist although these revert to the trigonal form on heating (Deer et al., 1992). Named from the Tamil word *kurundum*, this mineral readily incorporates impurities. This results in a wide variation in colour from white to green (ferrous iron), blue (iron and titanium), red (chromium) or yellow (ferric iron). The coloured forms are better known as ruby or sapphire. Corundum forms as hexagonal elongated or squat barrel-shaped crystals, and commonly occurs in silica poor igneous (e.g. Haliburton, Ontario, Canada; Fiskenaesset, Greenland; Litchfield, Maine, USA) or metamorphic rocks (e.g. Naxos and Samos, Greece). The gemstone varieties occur as isolated crystals in limestones or as rounded grains in alluvial deposits (such as Bo Ploi, Thailand; Mias, Ural Mountains, Russia). Corundum may also be found in xenoliths (such as Haddo House and Mull, Scotland; Deer *et al*., 1992). Corundum is an extremely stable and inert mineral and is therefore often found in sedimentary deposits. It may be manufactured from aluminium hydroxide minerals such as gibbsite (*q.v.*) at high temperatures (around 1200°C), or in greater quantities from bauxite (*q.v.*). Emery is a granular form of corundum usually mixed with hematite, magnetite and silica (*qq.v.*) and used as an abrasive. The durability of corundum means that it may occur in materials derived from natural sources.

For a fuller discussion of related compounds in a pigment context, see the entry for aluminium oxides and hydroxides group.

Aluminium group; Aluminium oxides and hydroxides group; Bauxite; Gibbsite; Hematite; Magnetite; Silica; *Emery*
Deer *et al*. (1992) 536–539; Pauling & Hendricks (1925)

CORY'S YELLOW MADDER

Yellow-Brown
Synonym, variant or common name

Mentioned in a discussion of yellow madder (*q.v.*) by Salter (1869), who says Cory's (Yellow) Madder was in fact 'an orange-brown of the burnt Sienna [*q.v.*] hue.' It was none-the-less apparently prepared from madder and was also known as Cory's brown madder.

Madder; *Burnt sienna*; *Madder yellow*; *Yellow madder*
Salter (1869) 353

COSMOS

Yellow-Orange
Common generic composite

A species of cosmos (*C. sulphureus* Cav., Compositae) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *xochipalli*. According to Wallert, the colouring principal in these plants is primarily based on flavonoid constituents, chalcone and aurone glycosides being present; additionally there is an unidentified (possibly carotenoid) component, while the petals contain an anthocyanin and luteolin (*q.v.*; Chmiel *et al*., 1983; Karrer, 1958; cf. Wallert, 1995c).

Flavonoids group; Luteolin
Chmiel *et al*. (1983); Karrer (1958) 593; Wallert (1995c)

COTTON SEED BLUE

Blue

Synonym, variant or common name

Described by Salter in his 1869 edition of Field's *Chromatography*, cotton seed blue was the residue remaining from bleaching cotton-seed oil with sodium carbonate or calcium hydroxide, which was then treated with sulfuric acid and distilled at a high temperature until a very intense pure blue colour was produced. As that author adds: 'This blue has not been introduced as a pigment; and of its permanence, and other attributes, we know nothing.'

In an entry for *Oleum Gossypii Seminis* (Cotton-Seed Oil), Felter and Lloyd in *King's American Dispensatory* (1866/1898) state that 'Cotton-seed blue ($C_{17}H_{24}O_4$), an amorphous body, has been obtained by Kuhlmann in 1861 as an oxidation product of a chromogene contained in the oil. Exposure to light and air bleaches the blue substance, while oxidizers wholly destroy it.' Cotton-seed oil was 'A fixed oil expressed from the seed of *Gossypium herbaceum*, Linné, and of other species of *Gossypium* (Nat. Ord.-Malvaceae), and subsequently purified.'

Felter & Lloyd (1898); Salter (1869) 230–231

COTUNNITE

White

Generic compound

Cotunnite is a lead chloride mineral with composition $PbCl_2$ (Sahl and Zemann, 1961). It occurs as soft acicular crystals or as finely crystalline crusts and masses which have a pearly or silky lustre. It is usually white or colourless, although yellow and green varieties are known. Cotunnite was first described by Monticelli and Covelli in 1825 (Dana, 1944) from Mount Vesuvius (Italy) and is also known from areas such as Karnataka (India), Alsace (France), Attica (Greece), Sierra Gorda (Chile), Leadhills (Australia) and Cornwall (England). It is soluble in water and forms as a secondary mineral associated with ore vein formation or volcanic fumerole activity. Cotunnite is also closely related to the lead chloride hydroxide minerals laurionite, paralaurionite and blixite (*qq.v.*).

Cotunnite has been identified as a pigment with other lead halide minerals (laurionite, blixite) by Naruse (1996) in Japanese *Shoso-in* objects.

Lead group; Lead halides group; Blixite; Laurionite; Paralaurionite
Dana (1932) 464; Naruse (1996); Sahl & Zemann (1961)

COULEUR

Blue

Synonym, variant or common name

Mühlethaler and Thissen (1993), citing Winckler, explain that the terms *couleur* and *eschel* (also *sumpfeschel*) were part of the Saxonian quality designations for the pigment smalt (*q.v.*), though Riederer (1968) implies that it was a more general German grading system.

Smalt
Mühlethaler & Thissen (1993); Riederer (1968)

COVELLITE

Blue

Generic compound

Covellite (or covelline) is a dark blue iridescent copper(II) sulfide mineral with composition CuS. It occurs as a secondary mineral replacing copper and iron sulfide minerals in the weathering zone around copper lode deposits or in volcanic terrains where it occurs as crusts or platy crystals. It was first described by Beudant in 1832 at Vesuvius (Italy) and was named after the Italian mineralogist N. Covelli (1790–1829; Dana, 1944). Covellite is commonly found in association with galena, pyrite and marcasite (*qq.v.*) (e.g. at Burra mine, South Australia, and Queenstown, New Zealand).

Orna *et al.* (1980) proposed that the original blue pigment observed to be degraded to dark brown/black by Lucas on trefoil marks on the cow couch from the tomb of Tutankhamun was covellite. However, no analysis of the material was given and Scott (2002) has suggested that this supposition by Orna *et al.* is doubtful as there is no evidence for the use of covellite on Egyptian wall paintings; Scott has instead suggested that the discoloration product may be tenorite (*q.v.*).

Copper group; Copper sulfides group; Copper(II) sulfide; Galena; Marcasite; Pyrite; Tenorite
Dana (1944) 248; Orna *et al.* (1980); Scott (2002) 96

CREMISI

Red

Synonym, variant or common name

Merrifield (1849) found two principal meanings for *cremisi* or *cremisino*, either cochineal or dragon's blood (*qq.v.*) with the addition of a substantial amount of soap (alkali) added. However, she also writes that 'it … appears that the term cremesino was applied in Italy during the time of Matthioli [Matthioli, Pietro Andrea *De medica materia*, of which there were various editions in the sixteenth century] to the colour procured from certain berries or grains attached to the roots of the pimpinella, as well as to cochineal'. In a footnote Merrifield further states that pimpinella was '*Poterium sanguisorba*. The Burnet, probably the Bruneta of the Sloane MS No. 1754'; botanically this now appears as *Sanguisorba officinalis* L. (Rosaceae), which has a Eurasian distribution.

Cochineal; Dragon's blood
Merrifield (1849) clxxvi–clxxviii

CREMNITZ WHITE

White

Synonym, variant or common name

Generally used synonymously with Kremnitz and Crems (or Krems) white as well as Vienna white (*q.v.*), it is said to be a high grade form of lead white (*q.v.*). Sources such as Field (1835) state that the name was derived either from Kremnitz in Hungary or Crems/Krems in Austria, adding that it had less hiding power ('body') because it had a finer particle size. Tingry (1804) on the other hand found in experiments on Cremnitz white from various colourmen that it was composed of bismuth oxide or lead oxide; however, he also applied the term to a formulation of his own based on tin dissolved in nitric acid, zinc oxide and white clay.

Lead carbonates group; *Crems white*; *Kremnitz white*; *Krems white*; *Lead white*; *Vienna white*
Field (1835) 69; Tingry (1804) 285–286

CREMS WHITE

White

Synonym, variant or common name

See: cremnitz white.

CRETA

White
Synonym, variant or common name

Latin (and Italian) name for chalk (*q.v.*).
See: Crete white.

Chalk; *Crete white*

CRETA SELINUSIAM

White
Synonym, variant or common name

See: earth of selinus.

CRETA VIRIDIS

Green
Synonym, variant or common name

See: green chalk.

CRETE WHITE

White
Synonym, variant or common name

Synonym/historical term for a form of chalk (*q.v.*) derived from deposits on the island of Crete. These were traditionally of high quality.

Chalk; *Creta*

CRIMSON ANTIMONY

Red
Synonym, variant or common name

Heaton (1928) records crimson antimony as a then-current term for antimony vermilion (*q.v.*).

Antimony sulfides group; *Antimony vermilion*
Heaton (1928) 381

CRIMSON LAKE

Red
Synonym, variant or common name

Crimson was a term applicable to all the scale insect colours. Initially this would not have included the new world cochineal which was only imported into Europe by the Spanish in the 1540s; however, as this dyesource produced a far stronger colour the other scale insects eventually were no longer used. By the nineteenth century therefore it had become a synonym for a cochineal (*q.v.*) lake. Salter (1869) states that it was 'a cochineal pigment containing more aluminous base than carmine, and is consequently weaker in colour and less stable'.

Cochineal
Salter (1869) 135

CRISTOBALITE

White
Generic compound

Cristobalite is one of the high temperature crystalline polymorphs of SiO_2. The lower temperature form is orthorhombic tridymite, and the room temperature stable form is trigonal quartz (*qq.v.*). α-quartz, the most stable form, converts to high quartz (β-quartz) at around 573°C, and then to tridymite at 867°C; tridymite subsequently inverts to α-cristobalite at 1470°C (Buerger, 1935; Fenner, 1913). Cristobalite is the tetragonal form and occurs as small vitreous white or colourless crystals with octahedral or cubic shape; it may also occur as rounded aggregates. It is found in thermally metamorphosed sandstones that were previously composed of quartz, and in cavities in volcanic rocks (often in association with tridymite), or frozen in glassy volcanic rocks (obsidian). It is named after its type locality of Cerro san Cristobal in Mexico. It exists metastably and there is also an additional cubic form (β-cristobalite) that exists at higher temperatures (Barth, 1932; Nieuwenkamp, 1935; Wyckoff, 1925). Cristobalite may be found as a component in Egyptian blue (*q.v.*).

Silicates group; Quartz; Tridymite; *Egyptian blue*
Barth (1932); Buerger (1935); Fenner (1913); Nieuwenkamp (1935); Wyckoff (1925)

CROCETIN

Red-Brown
Generic compound

Crocetin, 8,8′-diapo-ψ,ψ-carotenedioic acid (carotenoid-dicarboxylic acid) is the main dyestuff produced by stamens of the saffron plant, *Crocus sativus* L. and by the seeds of *Gardenia jasminoides* Ellis (Schweppe, 1992; *Merck Index*, 1996). It has the *Colour Index* (1971) designation CI 75100.
See: gardenia seed and saffron.

Carotenoid group; Saffron; *Gardenia seed*
Colour Index (1971) 75100; *Merck Index* (1996) 2657; Schweppe (1992) 172–174

CROCIDOLITE

White
Generic variety

See: riebeckite and asbestos.

CROCOITE

Red-Orange-Yellow
Generic compound

Crocoite is a lead chromate mineral with composition $PbCrO_4$. Its red-orange translucent prismatic crystals or aggregates of crystals form where lead ore deposits cross-cut chromium-bearing rocks (such as at Beresovsk in Russia, in Hungary, Tasmania and the Philippines; Rutley, 1988).

Crocoite is a comparatively rare mineral, discovered in the gold mine at Beresovsk in 1770. Harley (1982) states that it was used occasionally in painting, presumably being supplied from the mine in Beresovsk, although this mine was not being worked continuously.

A closely related lead chromate(VI) oxide mineral, phoenicochroite (*q.v.*) with composition PbCrO4.PbO, has also been described by Williams *et al.* (1970) and is often found with crocoite. The synthetic analogue of crocoite, lead chromate(VI) (*q.v.*), CI Pigment Yellow 34, has of course been extensively used as a pigment (Kühn and Curran, 1986). In their study of yellow chromium-based pigments, Burnstock *et al.* (2003) identified crocoite as a single phase or in solid solution with barium sulfate (*q.v.*), in which the lead or chrome atoms were partially replaced by barium or sulfur, respectively. The solid solution was reportedly produced by the addition of barium sulfate or lead sulfate (*qq.v.*) during manufacture of the pigment.

Chromates group; Lead chromates group; Lead sulfates group; Barium sulfate; Lead chromate(VI); Phoenicochroite
Beudant (1932); Burnstock *et al.* (2003); *Colour Index* (1971); Harley (1982) 100; Kühn & Curran (1986); Rutley (1988) 332; Williams *et al.* (1970)

CROCUS
Red
Synonym, variant or common name

See: crocus martis and saffron.

CROCUS MARTIS
Red
Synonym, variant or common name

Essentially a synthetic iron oxide pigment generally prepared by the calcination of iron sulfate.

De Mayerne (writing in England in the seventeenth century) recorded several methods for producing this: ‘As for red substances, they are straightforward; crocus martis is made quite simply with steel filings or iron chips, well washed and cleansed of all impurity, and calcined in a glass-blowers’ furnace in a good earthenware dish only two inches deep, the metal spread out to a thickness of two knife handles so that the flames can penetrate it easily. Alternatively, the same saffron is made by dissolving the filings in aqua regia, completely evaporating the liquid, and calcining the residue for several hours until it becomes a perfect red. But the finest red of all is martial vitriol calcined to the utmost limit, ground, and washed to remove the salt’ (BL MS Sloane 1990, f. 29v., cf. Harley, 1982).

Harley (1982) 121; MS Sloane 2052 (nd) f. 29v.; Mayerne (1620)

CRONSTEDTITE
Black
Generic compound

Cronstedtite is a black iron-rich sheet silicate mineral which occurs with platy or massive form. Its composition may vary in terms of the metal cations present, but it has the empirical chemical formula $Fe_2^{2+}Fe_2^{3+}SiO_5(OH)_4$; it most often contains magnesium, a variety known as magnesiocronstedtite. A range of polytypes have been described but the most common consists of alternating single layers of serpentine and brucite (*q.v.*), and as such is closely related in chemistry to the chlorite group (*q.v.*) of minerals (Frondel, 1962; Steadman and Nuttall, 1963, 1964). Cronstedtite forms in low-grade regional metamorphic rocks, in hydrothermal ore veins or as a secondary replacement mineral in the weathering of intermediate or acid igneous rocks. The type locality was designated as Pribam and Kuttenberg, Bohemia and it has also been found in areas such as Chihuahua, Mexico.

According to Grissom (1986), green earth (*q.v.*) from Cornwall, England, has been both noted as a source of pigment (Lemoine and du Manoir, 1893) and shown by analysis to probably consist of cronstedtite. Cronstedtite has been identified on a portrait of William Crowe by Bardwell (Mosk, 1975; Talley and Groen, 1975; cf. Grissom).

Chlorite group; Iron group; Serpentine group; Sheet silicates group; Brucite; Green earth
Frondel (1962); Grissom (1986); Lemoine & du Manoir (1893) 317–319; Mosk (1975); Steadman & Nuttall (1963); Steadman & Nuttall (1964); Tally & Groen (1975)

CROSSITE
Blue
Generic compound

Crossite is a sodium-rich member of the amphibole group (*q.v.*) of minerals. It is not currently known as a pigment, but it is commonly found in geological association with the minerals glaucophane and riebeckite, which have been encountered in grey-blue paints (Cameron *et al.*, 1977; Filippakis *et al.*, 1976; Profi *et al.*, 1976; Rutley, 1988).

Amphibole group; Silicates group; Glaucophane; Riebeckite
Cameron *et al.* (1977); Filippakis *et al.* (1976); Profi *et al.* (1976); Rutley (1988) 392

CRYSTALLISED VERDIGRIS
Green
Synonym, variant or common name

The Paduan manuscript (16th–17th century, cf. Merrifield, 1849) gives a recipe for refining verdigris (*q.v.*) by dissolving it in distilled vinegar, then evaporating the liquid until crystallisation takes place. Tingry (1804) states that this process removes impurities and that the material ‘acquires saline properties’, adding that this form of manufacture was carried out by the Dutch.

Mérimée (1830) details the same recipe. The term is synonymous with so-called neutral verdigris, copper(II) acetate hydrate (*q.v.*), $Cu[CH_3COO]_2.H_2O$ (see Scott, 2002) and is also termed distilled verdigris.

Copper acetate group; *Distilled verdigris*; *Verdigris*
Mérimée (1830/trans. Taylor 1839) 175; Merrifield (1849) 664; Scott (2002) 270–294; Tingry (1804) 373–374

CUDBEAR
Red-Blue
Synonym, variant or common name

Cudbear is the common name for the lichen species *Ochrolechia tartarea* (L.) used for the production of red or purple dyes. Cudbear is found in upland areas growing on siliceous rocks and tree trunks, particularly in Scotland and Wales (Purvis, 2000; Phillips, 1994). *O. tartarea* was formerly known as *Lecanora tartarea*. However, the lichen obtained its common name from the dye it produced, which was known as cudbear. The process for dye extraction was patented in 1766 by Dr Cuthbert Gordon; ‘cudbear’ is a corruption of Cuthbert (Ponting, 1981).

The dye is extracted by the ammonia method (see Diadick Casselman, 2001) and produces a range of colours from red, through pinks, magentas and purples. Thurstan (1975) writes that after the lichen had been scraped off the rocks using iron hoops, it was steeped in stale urine. At the end of the fermentation, powdered lime or chalk (*qq.v.*) was added and the resulting paste could be rolled into little balls and then stored. In this state the dye could also have been used as a pigment.

According to a survey by Diadick Casselman (2002), *O. tartarea* was also known as korkje, cork, corcur and korkir. Ponting (1981) points out that initially Dr Gordon’s dyes were not solely extracted from *O. tartarea*; *Urceolaria calcarea* and *Cladonia pyxidata* were also used. Diadick Casselman (2001) writes that later, the overharvesting of cudbear brought about a reliance on imported Norwegian lichens of the *Lassalia* and *Umbilicaria* species.

The related species, ‘*parelle*’, *O. parella* (L.) Massel, is the dye producing lichen known variously as crottle or crotal (Grierson, 1986; Diadick Casselman, 2002). The dye was extracted from this species by the Boiling-water method and produced yellow, rust and brown shades.

Thurstan (1975) writes that the terminology is further confused in that archil (or orchil), cudbear and litmus were the English, Scottish and Dutch names respectively for the same substance. The names may well have been used interchangeably

but are now far more clearly defined (see Diadick Casselman, 2001).
See: lichens group.

Lichens group; Chalk; Lime; *Litmus*; *Orchil*
Diadick Casselman (2001); Diadick Casselman (2002); Grierson (1986); *OED* (2002) 'Crottle'; Phillips (1994) 166; Ponting (1981); Purvis (2000) 94; Thurstan (1975)

CUMENGITE

Blue
Generic compound

The dark ink-blue mineral cumengite ($Pb_{21}Cu_{20}Cl_{42}(OH)_{40}$; also given as: $Pb_4Cu_4Cl_8(OH)_8$) has been mentioned by Prasartset (1990) in the context of pigments of mural paintings at Maitepnit Temple, Thailand. The type locality for the mineral is Boleo, Baja, California, Mexico; deposits are also known at Laurion, Attica, Greece. Cumengite is also related to the similarly coloured mineral Boleite, $KAg_9Cu_{24}Pb_{26}Cl_{62}(OH)_{48}$, on which it forms overgrowths.

Copper group; Copper halides group; Lead group; Lead halides group
Prasartset (1990)

CUPRITE

Red
Generic compound

Cuprite is a cubic red copper(I) oxide mineral, with chemical formula Cu_2O. It is a common mineral which forms in the oxidised zones of copper ore deposits (e.g. in Cornwall, England; Clifton, Arizona, USA; Baha, Mexico; Burra-Burra mine, South Australia; Chessy, France; Linares, Spain; Salzburg and Tyrol, Austria; Harz, Germany; Attica, Greece). Cuprite often occurs with massive form or as well-formed cubes which may be interpenetrant. It may also form as long hair-like threads, in which case it is termed chalcotrichite. It is often found in association with limonite, chrysocolla and malachite (*qq.v.*) and is sometimes known as 'red oxide of copper' (Rutley, 1988).

Cuprite has been important in antiquity as a glass colourant (Freestone, 1987; Oppenheim *et al*., 1970) but is not known to be used specifically as a pigment on mural or easel painting. Scott (1997) suggests that the colour of ground cuprite could be achieved using the more readily available and cheaper natural ochres and siennas (*qq.v.*). Cuprite may also be found as an alteration product of copper carbonate pigments such as azurite (*q.v.*) and malachite; it may also be found as a component in Egyptian blue (*q.v.*).

Copper group; Copper oxides and hydroxides group; Azurite; Chrysocolla; Limonite; Malachite; Ochre; Sienna; *Egyptian blue*
Freestone (1987); Oppenheim *et al.* (1970); Rutley (1988) 258–259; Scott (1997)

CUPRORIVAITE

Blue
Generic compound

Cuprorivaite is a calcium copper silicate mineral whose composition is now given as $CaCuSi_4O_{10}$. The mineral was originally described in 1938 from Monte Somma (Vesuvius, Italy) by Minguzzi who determined the formula to be $CuO.2SiO_2.(CaO, Na_2O).2SiO_2$; however, subsequent studies by Pabst (1959) and Mazzi and Pabst (1962) have reported it to be free of sodium. Cuprorivaite occurs as vitreous tabular blue crystals, often in association with quartz (*q.v.*), and its formation is associated with centres of volcanic activity. It is a rare mineral and is related to the equally rare barium copper silicate mineral, effenbergerite (*q.v.*). Cuprorivaite is known from only a few localities worldwide, such as Sattelberg and Udersdorf (Germany), Messina (South Africa) and Klamath County (Oregon, USA).

The scarcity of natural cuprorivaite suggests that it could not have been collected in sufficient quantity for use as a pigment. However, the synthetic form of cuprorivaite, Egyptian blue (*q.v.*), has been used extensively as a pigment in Egypt, Greece and Mesopotamia from approximately 3100 BC to Roman times, and in Italy and central Europe until the Middle Ages (Jaksch *et al*., 1983; Riederer, 1997). Synthetic samples of cuprorivaite are also reported to contain SiO_2 polymorphs (quartz, tridymite and cristobalite), wollastonite, cuprite or tenorite (*qq.v.*), which form from excesses of the initial starting materials (for example, crushed limestone, malachite (*qq.v.*) and quartz) during heating to up to 1000°C.

It is not uncommon in the literature to use the term cuprorivaite when Egyptian blue has in fact been present. For example, using Raman spectroscopy, Smith and Barbet (1999) identified 'cuprorivaite' in pigment samples taken from a wall painting in a first century tomb at Kertch (Crimea, Ukraine). However, the association of cuprorivaite with calcite and quartz in the sample led the authors to suggest that this is a typical synthetic Egyptian blue assemblage.

Calcium group; Copper group; Sheet silicates group; Calcite; Calcium copper silicate; Cristobalite; Cuprite; Effenbergerite; Limestone; Malachite; Quartz; Tenorite; Tridymite; Wollastonite; *Egyptian blue*
Jaksch *et al.* (1983); Mazzi & Pabst (1962); Minguzzi (1938); Pabst (1959); Riederer (1997); Smith & Barbet (1999)

CUPRO-WOLLASTONITE

Green
Generic compound

Cupro-wollastonite is a term adopted to describe the chemistry of the early synthetic pigment known generally as Egyptian green (*q.v.*). Pseudowollastonite (β-wollastonite, $CaSiO_3$) containing a few per cent copper is the main crystalline phase formed during manufacture of Egyptian green, although a green amorphous phase is also formed (see Pagès-Camagna *et al*., 1999).

Cupro-wollastonite has, for example, been identified by Bouherour *et al.* (2001) mixed with libethenite (*q.v.*) in an Egyptian sample from the period spanning the VIth dynasty to Roman times.

Calcium group; Copper group; Copper silicate group; Silicates group; Libethenite; Wollastonite; *Egyptian green*
Bouherour *et al.* (2001); Pagès-Camagna *et al.* (1999)

CURCUMA

Yellow
Synonym, variant or common name

See: turmeric.

CURCUMIN

Yellow-Orange
Generic compound

(E,E)-1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione, a diaryl compound (*Merck Index*, 1996; Schweppe, 1992). It is the principal colouring matter found in turmeric

(*q.v.*), a dye and pigment derived from the dried and ground rhizome of *Curcuma longa* L., a member of the Zingiberaceae family. Dimethoxycurcumin and bisdimethoxycurcumin are also present. It is listed by the *Colour Index* (1971) as CI 75300/Natural Yellow 3.
See: turmeric.

Diaryl group; Turmeric
Colour Index (1971) 75300; *Merck Index* (1996) 2744; Schweppe (1992) 180–181

CUSCUTA

Yellow
Common generic composite

Three species of *Cuscuta* (*C. tinctoria* Mart., *C. americana* Lin. and *C. odontolepis* Engelmann) are listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *zacatlaxcalli*. Wallert also states that the colourants are due to the presence of high levels of carotenoids (β- and γ-carotenes) in the stems of the plants.

Carotene, β-
Wallert (1995c)

CUTCH

Black-Brown
Synonym, variant or common name

Cutch is a tannin and dye obtained from the heartwood of *Acacia catechu* (L.f.) Willd., a leguminous tree native to India, Myanmar and other regions in southern Asia. Its active contents are catechutannic acid (25–35%), catechin (2–10%), quercetin (*q.v.*), and catechu red or brown (Schweppe, 1992; Roberts and Etherington, 2003). While primarily used to produce a fast dye with shades varying between brown, olive and khaki, a pigment based on this extract called Catechu brown (*q.v.*) is described by Salter (1869).

White cutch ('gambier') is an extract of *Uncaria gambir*, a plant belonging to the madder (*q.v.*) family.

Tannins group; Madder; Quercetin; *Catechu brown*
Roberts & Etherington (2003); Salter (1869) 354–355; Schweppe (1992) 503–506

CUTTLEFISH BONE

White
Common generic composite

Calcareous substance found under the skin of various species of cephalopoda, principally the cuttlefish (*Sepia officinalis* L.) produce a rigid structure, the cuttlefish bone. Merrifield (1849) mentions that she found cuttlefish bone described as a pigment in historical sources, noting that it was among various substances 'frequently mixed with transparent vegetable colours to give them body'.

The cuttlefish also provides the brown ink known as sepia (*q.v.*).

Calcium carbonates group; Bone; Sepia
Merrifield (1849) clii

CYAN BLUE

Blue
Synonym, variant or common name

See: cornflower blue.

CYANIDE OF IRON

Blue
Synonym, variant or common name

Synonym for Prussian blue (*q.v.*; blue hexacyanoferrate(II) pigments).

Hexacyanoferrate group; *Prussian blue*

CYANINE BLUE

Blue
Synonym, variant or common name

According to Salter (1869), cyanine was a mixture of cobalt and Prussian blues (*qq.v.*). He adds that 'Within the last few years, a compound similar to cyanine has appeared, under the name of Leitch's blue [*q.v.*].'

Cobalt blue; *Leitch's blue*; *Prussian blue*
Salter (1869) 198–199

CYANON

Blue
Synonym, variant or common name

Latin word derived from the Greek *κυανος* ('*kyanos*'; *q.v.*) used by classical authors (for example, Pliny 77 AD) to describe various blue pigments.

Kyanos
Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii.161–163

CYANUS BLUE

Blue
Synonym, variant or common name

The *Compendium* of 1808 lists this as an organic blue; the composition is, however, unknown.

Compendium (1808)

CYNOPLE

Red
Synonym, variant or common name

Thompson (1935) introduced the distinction between sinoper (a red earth pigment; *q.v.*) and what he calls cynople on the basis of various recipes in fourteenth and fifteenth century manuscripts for red colours. These are recipes which describe a pigment spelled variously but all characterised by 'referring to a pigment which owes its color fundamentally to gum lac, often with the addition of *grana*, *brazil*, and occassionally of *madder*' (*qq.v.*). For example, the *Book of Master Peter of St. Audemar on Making Colours* (Clarke MS 2790; cf. Merrifield, 1849) essentially gives a recipe for cynople under what it calls '*sinopis de mellana*': 'take lac (gum of ivy), with which parcium is dyed, and grind it very fine, and temper it with vinegar or urine. Then adding wheat flour well cleansed from the bran, make it into little cakes, and bake in an unglazed jar; and while it is being baked, put a little of it upon a stick with a twig, until you see that it is of a very good colour. If you wish to have it very red, bake it but little, if less red bake it more.' This is clearly a lake colour. However, by the sixteenth and seventeenth centuries there appears to have been some confusion between these terms, sinoper sometimes referring to the lac-based colours. Harley (1982), for example, documents various misunderstandings in the seventeenth century British literature. For a fuller discussion of this point, see the entry for sinoper.

Other related terms include sinoper lake (Harley).

Brazilwood; Lac; Madder; *Grana*; *sinoper*
Harley (1982) 132; Merrifield (1849) 144; Thompson (1935) 418, n.11

CYPRIAN BLUE

Blue
Synonym, variant or common name

The naturally occurring mineral blue azurite (*q.v.*) is referred to by the classical authors Theophrastus (c. 315 BC) and Pliny (77 AD) as Cyprian blue, which came from the copper mines of Cyprus; Theophrastus tells us this is rare.

Azurite
Pliny (1st cent AD/Rackham, 1952); Theophrastus (c. 315 BC/Caley & Richards, 1956) 55

CYPRUS UMBER

Brown
Synonym, variant or common name

Cyprus umber is a variety of umber (*q.v.*) derived from the quarries on the northern margin of the Troodos Mountains, Cyprus and especially from the region surrounding the village of Margi (see Prichard and Maliotis, 1998). Cyprus umber was known for its olive greenish cast.

Cyprus was the main historical source of umber and acknowledged as being the best (for example, Church, 1901; Terry, 1893). Due to confusion as to the locality of the island and the trade routes of the pigment, Cyprus umber is often referred to as Turkey umber or Turkish umber.
See: umber.

Umber; Turkey umber; Turkish umber
Church (1901) 227–229; Prichard & Maliotis (1998); Terry (1893) 105

D

DAFFODIL YELLOW

Yellow
Synonym, variant or common name

Daffodil yellow was used as a term for a cadmium yellow-type pigment (Fiedler and Bayard, 1986). Church (1915) describes daffodil as ‘a variety of cadmium sulphide prepared at a red heat and containing a small quantity of magnesia’.

Cadmium yellow
Church (1915) 166; Fiedler & Bayard (1986)

DAHLLITE

White
Generic compound

Dahllite ($Ca_5[PO_4,CO_3]_3OH$) is the carbonate- and hydroxyl-bearing member of the apatite group (*q.v.*) of minerals and is also known as carbonate-hydroxylapatite (LeGeros *et al.*, 1960). Dahllite is a relatively rare member of the apatite group mineralogically speaking; however, it is now considered to be the main ‘inorganic’ mineral comprising ivory (LeGeros, 1994).

Dahllite in the form of ivory has widespread use as a pigment as ivory black (*q.v.*).

Apatite group; Calcium group; Calcium phosphates group; Bone; Fluorapatite; Hydroxylapatite; *Ivory black*
LeGeros (1994); LeGeros *et al.* (1960)

DAMONICO

Orange
Synonym, variant or common name

Field (1835) describes *Damonico* (or *Monicon*) as a compound of ‘Terra di Sienna and burnt Roman ochre’ (*qq.v.*).

Roman ochre; *Sienna*
Field (1835) 119

DAMP BLUE

Blue
Synonym, variant or common name

Davidson (1880) says of Brunswick, celestial and damp blues: ‘Brunswick or Celestial Blue is made by precipitating the alumine from a solution of alum by carbonate of soda, washing the precipitate, and adding sulphate of baryta, sulphate of iron, yellow prussiate of potash, and some bichromate of potash. When dried, this mixture is known as Brunswick or celestial blue; but when the sulphate of baryta is left out, and the material is not dried, it is called damp blue.’

Brunswick blue; *Celestial blue*
Davidson (1880) 83

DAVY’S GREY

Grey
Synonym, variant or common name

Listed by Winsor & Newton in 1896, this was: ‘A new colour prepared from a special variety of slate and suggested by Mr. Henry Davy’ (cf. Carlyle, 2001). Heaton (1928) records it as a term then current, noting it merely as a ‘variety of slate powder’.

Slate
Carlyle (2001) 498; Heaton (1928) 381

DAVY’S WHITE

White
Synonym, variant or common name

The British artist George Frederick Watts (1817–1904) lists among the pigments he used Davy’s foundation white (Watts, 1912). It was by all accounts a lead white (*q.v.*) mixture.

Lead white
Watts (1912) III, 58

DAYLIGHT BLUE

Blue
Synonym, variant or common name

According to Heaton (1928), daylight blue was similar to Brunswick blue in being Prussian blue (blue hexacyanoferrate compounds) struck onto a base such as baryte or barium sulfate (*qq.v.*), though as a pale tint of 5–10%. Seemingly synonymous with celestial blue and related to damp blue (Davidson, 1880).

Hexacyanoferrate group; Barium sulfate; Baryte; *Brunswick blue*; *Prussian blue*
Davidson (1880) 83; Heaton (1928) 160

DE ESPEJUELO

White
Synonym, variant or common name

A term which occurs in a discussion of preparing gesso (‘*yeso*’) grounds given in Pacheco’s *Arte de la Pintura* (1638); Veliz (1986) states that it signifies ‘recrystallised calcium sulphate derived from alabaster’.

Calcium sulfates group; Alabaster
Pacheco (1638) Bk 3, VII, 120; Veliz (1986) 209, n.106

DECK GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

DELPHINIDIN

Brown
Generic compound

Delphinidin, 3,3′,4′,5,5′,7-hexahydroxyflavylium chloride (or delphinidol) is an anthocyanidin flavonoid (*Merck Index*, 1996). As a glycosidic anthocyanine it is the principal colouring matter in *Vaccinium myrtillis* L., along with Cyanidin-, Petunidin- and Malvidin-glycosides (Schweppe, 1992).
See: vaccinium and turnsol blue.

Flavonoids group; Vaccinium; *Turnsol blue*
Merck Index (1996) 2931; Schweppe (1992) 395, 400–401

DERBY RED

Red
Synonym, variant or common name

Listed as a then-current synonym for a chrome red pigment by Heaton (1928). Schiek (1973) states that it was an older name for a chrome orange pigment (lead chromate oxide). In their review of chrome orange and chrome red pigments, Kühn and Curran (1986) refer to Derby red as an older term for basic lead chromate (*qq.v.*).

Lead chromate(VI); *Chrome orange*; *Chrome red*
Heaton (1928) 381; Kühn & Curran (1986); Schiek (1973)

DEVONSHIRE BROWN

Brown
Synonym, variant or common name

Fishwick (1795–1816) describes this as a combination of ‘Burnt umber, frankfort black, rose pink, [and] colcothar’ (*qq.v.*).

Burnt umber; *Colcothar*; *Frankfort black*; *Rose pink*
Fishwick (1795–1816) 72

DEVONSHIRE CLAY

White
Synonym, variant or common name

According to Heaton (1928) Devonshire clay was a then-current alternate term for china clay (kaolin, *q.v.*). Most kaolin production in the UK comes from Cornwall, where there are extensive deposits in the western half of the St Austell granite. However, commercially exploitable deposits also occur in nearby granites such as those on Dartmoor in Devon as well as other granite masses of south-west England.

Clay minerals group; Kaolinite; *China clay*; *Kaolin*
Heaton (1928) 381

DEWINT’S GREEN

Green
Synonym, variant or common name

See: olive green.

DI PALITO

Yellow
Synonym, variant or common name

Of this pigment, Salter (1869) says it is ‘a light yellow ochre, with no special distinguishing quality, except that its tints are rather purer in colour than most ochres’ (*qq.v.*).

Ochre; *Yellow ochre*
Salter (1869) 109

DIARYL GROUP

Yellow
Group term

See: curcumin.

DIARYLIDE PIGMENTS

Yellow
Group term

A group of around 30 synthetic ‘diazo’ (diarylide) pigments first patented as early as 1911 but largely developed around 1938 and related, in terms of their chemical structures, to the monoazo pigments. Structures typically contain a central (perhaps dichlorinated) biphenylene unit bonded directly at either end to two arylide moities via a discrete azo (–N=N–) group. The increased conjugation in the molecule compared with the monoazo analogues increases the intensity of hue, but reduces the lightfastness (Herbst and Hunger, 1997).
See: azo pigments group: disazo sub-group.

Azo pigments group: Disazo sub-group
Herbst & Hunger (1997) 239–261

DIATOMACEOUS EARTH

White
Synonym, variant or common name

Diatomaceous earth is the unconsolidated equivalent of diatomite (*q.v.*), composed of the remains of siliceous marine or freshwater algae, diatoms.

Diatomite

DIATOMACEOUS SILICA

White
Synonym, variant or common name

See: diatomite.

DIATOMITE

White
Generic variety

Diatomite is a rock composed predominantly of the siliceous microfossils or non-fossilised remains of diatoms, unicellular algae. Living species have (X-ray) amorphous opaline tests (shells) that revert, during fossilisation, to cryptocrystalline (chalcedonic) silica. Diatoms may become concentrated in lakes and deposits representative of the lacustrine environment frequently include diatomites. Marine diatoms also exist and may be similarly concentrated.

Diatomites are white, very lightweight, porous deposits that have been used as a base for organic pigments. Augusti (1967) identified diatomite in samples from Pompeii; the present authors have also found freshwater diatoms in certain pigments from Pompeii. Béarat (1997) has detected diatomite as a white pigment in Roman paintings from Avenches.

Diatomite is also known as *kieselguhr* (a German name compounded from the words for flint and for an earthy sediment in water). In some government trade and tariff documents, ‘tripolite’ is the short term for a longer description of ‘siliceous fossil meals’. Other related terms include celite, while an impure (up to 30% clay) Danish variety is called *moler*. There is also confusion between diatomaceous earth and infusorial earth, the latter more logically appropriate for the skeletal remains of infusoria (ciliata) or radiolaria. The consolidated equivalent of this is radiolarite, though radiolarites are relatively uncommon deposits. Diatomite (that is, tripolite) is further often also confused with tripoli (*q.v.*), a lightweight, light-coloured, very friable and porous sedimentary rock that is a weakly consolidated aggregate of individual microcrystals of quartz.

Diatomite is known in French as *farine fossile*. Béarat (1997) equates diatomite with Pliny's *creta argentaria*, used as a base for purple lake pigments.

For occurrences, see: silica

Silica; *Tripoli*
Augusti (1967); Béarat (1997)

Dibromoindigo
Purple
Generic compound

See: indigoid group and tyrian purple.

Dicopper hexacyanoferrate(II) hydrate
Red-Brown
Generic compound

See: copper hexacyanoferrate(II).

Dimorphite
Yellow-Orange
Generic compound

Dimorphite (or 'dimorphine') is a soft, yellow-orange orthorhombic arsenic sulfide mineral. It has chemical composition As_4S_3 and forms by deposition from volcanic hot gas vents (Hey, 1993). Whitfield (1970) has reported the synthesis of two crystalline forms (Type I and Type II). Dimorphite is found in volcanic areas such as Attica, Greece and Vesuvius, Italy, where it can occur in association with the arsenic sulfide minerals, orpiment and realgar; it is also closely related to other arsenic sulfide minerals duransite and alacranite (*qq.v.*).

Although apparently only rarely encountered on artefacts, dimorphite has been identified with orpiment in third millennium BC Egyptian paintings from Giza (Noll, 1981). It is also discussed in the review of orpiment and realgar by FitzHugh (1997).

Arsenic group; Arsenic sulfides group; Alacranite; Duranusite; Orpiment; Realgar
FitzHugh (1997); Hey (1993); Noll (1981); Whitfield (1970)

Dingler's green
Green
Synonym, variant or common name

See: Arnaudon's chrome green.

Dinitroaniline orange
Orange
Synonym, variant or common name

Dinitroaniline orange (also: dinitraniline orange) is one of the most commercially significant organic pigments, with a relatively early date of introduction of 1907. It is classed as a β-naphthol-type azo compound.

According to Herbst and Hunger (1997) this pigment is used for artists' colours, notably in drawing inks, coloured pencils, wax and marking crayons, as well as watercolour paints.

Azo pigments group: β-Naphthol sub-group
Herbst & Hunger (1997)

Diopside
Variable
Generic compound

Diopside is a calcium-magnesium silicate mineral with chemical composition $CaMgSi_2O_6$. It forms a solid-solution series with hedenbergite ($CaFe^{2+}Si_2O_6$) and thus is often found to contain appreciable iron (Deer *et al.*, 1992); other common cation substitutions are by Cr, Mn, Zn, Al, Ti, Na, K, V and Al_2O_3. It is similar in structure and composition to augite (*q.v.*). Diopside is typically green, but may be colourless, white, blue or green-brown according to composition. It commonly forms as short prismatic transparent crystals with a vitreous lustre, although granular examples may also be found. Diopside occurs in a wide range of metamorphic rocks worldwide, most commonly in thermally metamorphosed calcareous sedimentary rocks such as dolomite-bearing limestones; it is also found in certain basic volcanic rocks (Deer *et al.*, 1992; Rutley, 1988).

From X-ray diffraction analysis of lazurite and ultramarine, Plesters (1993) has shown that some samples may contain diopside as well as quartz, calcite and forsterite (*qq.v.*).

Calcium group; Magnesium group; Silicates group; Augite; Calcite; Dolomite; Forsterite; Lazurite; Quartz; Talc; Ultramarine
Deer *et al.* (1992) 170–176; Plesters (1993) 49; Rutley (1988) 378–379

Dioxazine pigments
Variable
Generic compound

See: polycyclic pigments group: dioxazine sub-group.

Dipotassium monosodium hexanitrocobalt(III)
Yellow
Generic compound

See: potassium hexanitrocobalt(III).

Disazo group
Red-Orange-Yellow
Group term

According to Herbst and Hunger (1997), the disazo group falls into two parts, based on the synthesis route. The first of these sub-groups involves the coupling of di- and tetra-substituted diaminodiphenyls as diazonium salts with acetoacetic arylides ('diarylide yellows') or pyrazolones (disazo pyrazolones) as coupling components. The second sub-group, bisacetoacetic arylide pigments, is obtained by diazotization of aromatic amines followed by coupling onto bisacetoacetic arylides. The colours produced range from very greenish yellow to reddish yellow, orange and red.

Azo pigments group
Herbst & Hunger (1997) 5

Distilled verdigris
Green
Synonym, variant or common name

See: crystallised verdigris and verdigris.

Dolomite
White
Generic compound

Dolomite is a white to yellowish calcium magnesium carbonate mineral ($[Ca,Mg][CO_3]_2$), similar to calcite, aragonite ($CaCO_3$)

and magnesite ($MgCO_3$) (*qq.v.*). The pale pink variety ferroan dolomite ($Ca[Mg,Fe^{2+}][CO_3]_2$) shows some degree of substitution of Fe^{2+} for magnesium, following a solid solution series between dolomite and ankerite (*q.v.*). Dolomite forms rarely as a primary mineral in sedimentary rocks, and when it does, it appears to be as an evaporite. There are thick primary dolomite layers in the Great Salt Lake area of Utah, USA. The main occurrence of dolomite is as a diagenetic product of calcite or aragonite. Diagenesis occurs after the deposition and lithification of limestone as a result of the incursion of magnesium-rich fluids. It may transform the entire rock to a dolomite, but this may also be an extremely selective process, transforming discrete areas or even discrete components. Additionally, a variation in mineral chemistry through the calcite, dolomite and magnesite series is to be expected in such rocks. The mineral is notoriously difficult to distinguish from calcite both in hand specimen or using the petrological microscope. However, calcite will stain pink with Alizarin red whereas dolomite will not. This phenomenon also has implications for lake pigments containing dolomite.

Hall (1973), when discussing naturally occurring sources of calcium carbonate pigments, defines dolomite as containing 40–44% magnesium carbonate and 54–58% calcium carbonate, but that 'ground dolomite can refer to any carbonate rock containing 20% or more of $MgCO_3$'. As a common component of limestones and some marbles, dolomite may easily be incorporated into lake pigments containing crushed limestones. In frescos it may occur in the *intonaco* coat of the plaster.

Direct observations of dolomite as a pigment have been made by Varone and Béarat (1997) and Béarat (1997) in Roman wall paintings and by Ford *et al.* (1994) in aboriginal rock paintings in Western Australia. Ferroan dolomite has been reported as occurring in Hellenistic wall paintings of the third to second century BC in Acre, Israel, by Segal and Porat (1997).

The name dolomite is derived from the region in the Italian Alps and is also applied to rocks composed of $>$90% of the mineral dolomite. The mineral was traditionally known as pearl spar. Miemite is a yellow fibrous variety of dolomite known from Tuscany, Italy.

Ankerite; Aragonite; Calcite; Huntite; Magnesite
Béarat (1997); Ford *et al.* (1994); Hall (1973) 109; Segal & Porat (1997); Varone & Béarat (1997)

DOUGLAS GREEN

Green
Synonym, variant or common name

Douglas green is described by Terry (1893), who states that the pigment was prepared through mixing solutions of barium chloride and potassium chromate, forming barium chromate. Addition of sulfuric acid would then cause partial decomposition to give a mixture of barium chromate, barium sulfate and chromic acid, this being finally calcined. This, as Terry says, causes 'the chromic acid [to be] converted into green oxide of chromium oxide, and, being scattered throughout the mass imbues it with a green colour'. Since Terry also describes the pigment as 'being named after the chemist who proposes its use', we may assume that the process was rarely used.

Chromium oxides and hydroxides group; Barium chromate(VI); Chromium oxide
Terry (1893) 120–121

DOYLEITE

White
Generic compound

Doyleite is a triclinic aluminium hydroxide mineral with composition $Al(OH)_3$. It occurs as masses of soft white tabular crystals with pearly lustre which form from the weathering of aluminium-rich rocks in tropical climates. Hence, doyleite is often found in bauxites (*q.v.*). Doyleite is closely related to another triclinic form of $Al(OH)_3$, nordstrandite, and the monoclinic polymorphs, gibbsite and bayerite (*qq.v.*), with which it may be found (Chao *et al.*, 1985); it is also related to the orthorhombic dehydrated forms of AlO(OH), boehmite and diaspore (*qq.v.*). Synthetic aluminium hydroxide $Al(OH)_3$ is commonly encountered as a substrate for lake pigments.

Aluminium oxides and hydroxides group; Bauxite; Bayerite; Boehmite; Diaspore; Gibbsite; Nordstrandite
Chao *et al.* (1985)

DRACORHODIN

Red
Generic compound

The xanthone, dracorhodin, anhydro-7-hydroxy-5-methoxy-6-methyl-2-phenyl-benzopyranol is a principal colouring component, along with dracorubin, of *Daemonorops draco* (Willd.) B. and it is also found in *Croton draco* Schlechtend (Euphorbiaceae; Schweppe, 1992). It is listed in the *Colour Index* (1971) as CI 75210.
See: dragon's blood.

Dracorubin; Dragon's blood
Colour Index (1971) 75210; Schweppe (1992) 433

DRACORUBIN

Red
Generic compound

The xanthone dracorubin (3,4-dihydro-5-methoxy-8-methyl-2,12-diphenyl-2H-dipyrano [2,3-a:2′,3′,4′-K1] xanthen-9-on), along with dracorhodin, is the principal colouring component of *Daemonorops draco* (Willd., B. and it is also found in *Croton draco* Schlechtend (Euphorbiaceae; Schweppe, 1992). It is listed in the *Colour Index* (1971) as CI 75200.
See: dragon's blood.

Dracorhodin; Dragon's blood
Colour Index (1971) 75200; Schweppe (1992) 433

DRAGON'S BLOOD

Red
Common generic composite

A red resinous material which forms as an exudate from a variety of plant species belonging primarily to the *Daemonorops* and *Dracaena* genuses, though other plant resins and materials have also been used and traded under the name dragon's blood.

The genus *Dracaena* (Dracaenaceae, though recently given as Convallariaceae; cf. Pearson and Prendergast, 2001) comprises approximately 60 species (Mabberley, 1998), which are mainly found in tropical and sub-tropical Africa (Bos *et al.*, 1992). The genus also reaches Macaronesia, Arabia, Socotra, Madagascar, south-eastern Asia, northern Australia, and one species (*D. americana* Donn. Sm.) is found in the neotropics. The arborescent taxa of *Dracaena* which form the dragon tree group, comprise five species found in Macaronesia, Morocco (*D. draco* (L.) L.), East Africa (*D. ombet* Kotschy & Peyr., *D. schizantha* Baker), Arabia (*D. serrulata* Baker) and the island of Socotra. (*D. cinnabari* Balf. f.); of these it is *D. cinnabari* which appears to have been the principle source historically, the resin occurring as an exudate from the stem of the tree. Principle colorants identified in the resin are dracoresinotannol and dracoresene, along with terpenes and other flavonoid compounds (Edwards *et al*., 1997); more detailed recent studies have been made by González *et al*. (2000), who have identified some 21 compounds including a phenylpropanoid, four chalcones, six flavonoids, nine homoisoflavonoids and 3,4,5-trimethoxycinnamyl alcohol.

Dragon's blood from *Daemonorops* (Palmae; a type of rattan) occurs as resin drops on the fruit, material being collected by shaking these out. The species reported in the literature as sources of dragon's blood are *Daemonorops draco* (historically known as *Calamus draco*) and *D. propinquus*. The principle colourants identified in resin from *D. draco* are dracorubins and dracorhodins, though again, numerous other flavonoid and xanthone compounds are present including dracoflavans A-D, dracooxepine, plus various methoxyflavans (Arnone *et al*., 1997; Edwards *et al*., 1997).

In addition, several species of *Croton* (Euphorbiaceae) yield a red resin traded as dragon's blood: Edwards *et al.* mention *C. draco* from Mexico; Pearson and Prendergast (2001) list *C. aromaticus* and *C. gossypiifolius*, the former from Sri Lanka and the latter from Trinidad, as well as an unidentified sample of Croton-derived *sangre de drago* from Venezuela. Compositional studies of Croton dragon's blood has been published by Pieters *et al*. (1992). Schweppe (1992) states the nordin is a principle colouring constituent of *C. draco*.

Edwards *et al.* also discuss the Australian *Eucalyptus resinifera* Sm. and *E. terminalis* F. Muell., which also yields a red-coloured ant gall residue apparently also traded under the same general term; the composition seems to be unknown. Finally, these authors also document a powdered coral known as 'dragons blood' in Yemen.

The classical author Pliny (77 AD) is referring to dragon's blood when he describes *cinnabaris* among his 'florid' colours – pigments that the client would have to pay for separately. He is though the source of the fanciful name; supposedly there was a struggle between a dragon-like basilisk and an elephant that, at its climax, led to the mixing of the blood of the two creatures.

The MS. *de clarea* (circa 1090, Clarke MS 140; cf. Straub, 1964) records 'de ista clarea temperatur vermiculus, minium, safrannum et sanguis draconis et azorium et a quibusdam etiam ille color, qui dicitur folium' ('from this clarea is mixed wermiculus, red lead, saffron, and the blood of a dragon, and azoriumand by certain ones that colour which is called folium'). Thompson (1935) lists a number of fourteenth and fifteenth century MSS. that mention dragon's blood.

According to Harley (1982) there is little reference to dragon's blood in seventeenth century British sources, usually appearing under the name *sanguis draconis* when it does (such as MSS. Sloane 6284, Stowe 680 and 86.EE.69). The miniaturist Norgate suggests that it may be used for glazing silver or other metals: 'Dissolue Sanguis Draconis in aquavitie on the ffyer, which done with a pencell lay it on and lett it drye' (MS. Harley 6000, cf. Harley). MS. Sloane 3292, which probably dates from the early seventeenth century although it contains a list of pigments dated 1564, records using dragon's blood ground with red wine vinegar for shading flesh tones. In the so-called *Paduan MS.* (Merrifield, 1849; datable to the second half of the seventeenth century) it states that: 'To make a colour of dragon's blood. – Dragon's blood is ground up with sal ammoniac and pounded gum …'. Boltz (1549) describes the colour *Trachen blut* as being red as human blood. There is also a German source dated 1707 (other editions to late eighteenth century) that says that it is slightly water soluble and can be dissolved in sal ammoniac solution and used in gum arabic (cf. Brachert, 2001).

During the nineteenth and twentieth centuries there seem to be two basic statements in the (English) literature on dragon's blood. The first group are those that derive from Field (1835), stating that it is unsatisfactory for painting (Salter, 1869; Scott Taylor, 1885; Terry, 1893), and those that simply report that it was used for furniture and varnishes. Nineteenth century economic botany literature consistently report the use as a varnish, but not as a pigment. Seward (1889), however, mentions that it was used to prepare a colour known as *Chinese orange*. The latest documentary sources describing dragon's blood seem to be from the earlier twentieth century, such as Zerr and Rübencamp (1906) and Heaton (1928), though this latter author only describes it among various resins and as being used for varnish, listing it later on as little used. Numerous other eighteenth to twentieth century sources fail to discuss it at all.

More problematic is to disentangle the botanical sources at different periods, though it seems likely that the earlier (classical) incidences are from *Dracaena* spp., the later (nineteenth and twentieth century) from *Daemonorops* spp. Identifications of dragon's blood on artefacts are also extremely few, probably as much due to the problems of identification and characterisation as to the lack of use. However, the nineteenth century Dutch Hafkenscheid Collection of pigments contains a sample labelled *Drakenbloed* (ref. IX.1).

Dracorhodin; Dracorubin; Nordin; *Chinese orange*; *Cinnabaris*

Arnone *et al*. (1997); Boltz von Ruffach (1549/Benziger 1913) 68; Bos *et al*. (1992); Brachert (2001) 72–73; Edwards *et al*. (1997); Field (1835) 97; González *et al*. (2000); Harley (1982) 146; Heaton (1928) 278; Lojander (1887); Lyons (1974); Mabberley (1998) 241; Merrifield (1849) 707; MS 86.EE.69 (nd); MS Sloane 3292 (nd) f. 4; MS Sloane 6284 (nd) f. 109v; MS Stowe 680 (nd); Norgate/Thornton & McCain (early 17th C./1981); Pearson & Prendergast (2001); Pieters *et al*. (1992); Pliny (1st cent AD/Rackham 1952) XXXV.xii.30; Salter (1869) 137–138; Schweppe (1992) 539; Seward (1889); Straub (1964); Thompson (1935); Zerr & Rübencamp (1906/1908) 443

DREYERITE

Yellow-Orange

Generic compound

Dreyerite is a bismuth vanadate mineral with composition $Bi(VO_4)$. It is polymorphous with pucherite and clinobisvanite (*q.v.*) and is the tetragonal form. It occurs as relatively soft orange-yellow to yellow-brown microscopic or lamellar crystals and its occurrence was first reported by Dreyer and Tillmanns in 1981 from Hirschorn (Germany). Collier and Plimer (2002) have shown that at Lively's Mine (Australia) dreyerite may be replaced by clinobisvanite during weathering.

Although the mineral dreyerite is not known to have been used as a pigment, bismuth vanadate (*q.v.*) is listed as a pigment in the *Colour Index* (1971; CI Pigment Yellow 184) as bismuth yellow.

Bismuth group; Vanadium group; Bismuth vanadate; Clinobisvanite; *Bismuth yellow*

Collier & Plimer (2002); *Colour Index* (1971) Pigment Yellow 184; Dreyer & Tillmanns (1981)

DROP BLACK

Black
Synonym, variant or common name

Originally the term drop black denoted a fine quality of bone black, but which subsequently became broadly synonymous with any bone black pigment. Heaton (1928) gives drop black as a 'generally accepted trade name for a pigment in general use', listing it as a variety of bone black.

Carbon-based blacks group: Cokes sub-group; Bone
Heaton (1928) 381

DROP LAKE

Red
Synonym, variant or common name

An unidentified red pigment called 'drop lake' is listed by Winsor & Newton, 1865–1876 (Carlyle, 2001). It is, however, likely to be one of the lake pigments, such as Florentine lake, (*q.v.*) frequently supplied at that time in the form of small drops; examples exist with this form in historical collections such as the Hafkenscheid Collection (Pey, 1987).

Florentine lake
Carlyle (2001) 150, 534; Pey (1987)

DRY PROCESS VERMILION

Red
Generic compound

See: mercury(II) sulfide, cinnabar type and vermilion.

DUMONT'S BLUE

Blue
Synonym, variant or common name

According to Field (1835), this is a finer sort of the blue cobalt-doped glass pigment known as smalt (*q.v.*).

Smalt
Field (1835) 111

DURANUSITE

Red-Orange
Generic compound

Duranusite is an orange-red orthorhombic arsenic sulfide mineral with composition As_4S which occurs in association with realgar and orpiment (*qq.v.*). It is named after its type locality of Duranus, France, where it was discovered by Johan *et al.* (1973). It is a soft mineral and usually only occurs as very fine grains or aggregates. Duranusite has been more extensively studied at Mina Capillitas in the Catamarca Province of Argentina where it is observed to occur as thin lamellae and filaments intergrown with sphalerite (Marquez-Zavalia *et al.*, 1999; *q.v.*). It is present as an alteration product of realgar formed by the action of deuteric solutions.

Duranusite has been identified as a pigment in association with orpiment in third millennium BC Egyptian paintings from Giza (FitzHugh, 1997; Noll, 1981).

Arsenic group; Arsenic sulfides group; Orpiment; Realgar; Sphalerite
FitzHugh (1997); Johan *et al.* (1973); Marquez-Zavalia *et al.* (1999); Noll (1981)

DUST GREEN

Green
Synonym, variant or common name

Listed by Mierzinski (1881) and Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997); Mierzinski (1881) 281

DUTCH BLUE

Blue
Synonym, variant or common name

Fishwick (1795–1816) gives several formulations for Dutch blue that involve mixing lead white, Paris white (a high-grade chalk) and Prussian blue (*qq.v.*).

Lead white; *Prussian blue*
Fishwick (1795–1816) 33, 65

DUTCH EARTH

Yellow
Synonym, variant or common name

See: ancorca.

DUTCH PINK

Yellow
Synonym, variant or common name

Lake pigment formed from the combination of a dye derived from plants of *Rhamnus* species ('buckthorn' *Rhamnus catharticus* or '*Persian* or *Avignon berries*' *Rhamnus infectorius*) or from quercitron bark (*Querca tinctoria*) and mordanted on chalk or alum. The *Oxford English Dictionary* (2002) distinguishes various pinks: 'brown pink and French pink derived from Persian or Avignon berries (Rhamnus infectoria); Dutch English, and Italian pink from quercitron bark (Quercus tinctoria)'. Tingry (1804), however, gives a description of various grades of Dutch pink made with yellow berries becoming darker 'according as the earthy substance employed (as substrate) is less mixed with carbonate of lime (calcium carbonate)'; that made with alum, with the addition of clay or marl, being the least strong, and Dutch brown pink made with pure clay, being superior, and that with Spanish white or ceruse being superior even to these. Tingry also describes Dutch pink made with woad (*q.v.*), on clay, marl or chalk. Carlyle (2001) notes that yellow-coloured lake pigments in the nineteenth century varied in intensity from yellow carmine (darkest), through Dutch pink and English pink to yellow lake as the lightest.

There is no explanation of the derivation of the word pink referring to a yellow colour; however, there is speculation that owing to the greenish yellow tone, it is derived from the German *pinkeln* translated in a dictionary of 1798 as 'to piss, to make water' (Adelung and Schwann, 1798).
See also: Rhamnus.

Quercitron; Rhamnus; *Brown pink*; *Buckthorn*; *English pink*; *French berries*; *French pink*; *Italian pink*; *Stil de Grain*; *Woad*; *Yellow berries*; *Yellow lake*
Adelung and Schwann (1798) 'Pinkeln'; Carlyle (2001) 520; *OED* (2002) 'Pink'; Tingry (1804) 363–367

DUTCH ULTRAMARINE

Blue

Synonym, variant or common name

Term used in association with smalt (*q.v.*; Mühlethaler and Thissen, 1993).

Smalt

Mühlethaler & Thissen (1993)

DUTCH WHITE

White

Synonym, variant or common name

Salter (1869; also repeated in later sources such as Church, 1901) states that Dutch white was a mixture of lead white and baryte (*qq.v.*) in a ratio of 1:3. However, according to Mayer (1991), this term can either refer to china clay (*q.v.*) or a lead white produced by the ‘Dutch’ or ‘stack’ method.

Baryte; *China clay*; *Lead white*

Church (1901) 130; Mayer (1991) 44; Salter (1869) 74

E

EARTH BLACK

Black

Synonym, variant or common name

Alternate term for a naturally occurring pigment perhaps derived from coal, black chalk or some other natural black material mentioned in several nineteenth century sources such as Osborn (1845) and Salter (1869) as well as Borghini (1584, as *nero di terra*).
See: black ochre.

Black ochre
Borghini (1584/edition of 1787); Osborn (1845) 39; Salter (1869) 404–405

EARTH OF SELINUS

White

Synonym, variant or common name

The classical author Pliny (77 AD) writes of a white earth that he calls *Creta Selinusiam vel anulariam* ('Earth of Selinus' or 'ring-earth'). It is not clear if it is the same as the *anulare* mentioned elsewhere in the same book; this latter pigment ('ring white') is made from a white earth mixed with the pulverised glass from the stones set in the rings worn by the 'volgi' (lower classes). It was used specifically to give brilliance to renderings of women's complexions in paintings.

Pliny (1st cent AD/Rackham, 1952) XXXV.xxvii, XXXV.xxx

EARTH PIGMENTS GROUP

Variable

Group term

The earth pigments are a large and important group of pigments based on a wide range of minerals. As naturally occurring deposits, they are typically rich in the clay minerals, iron oxides and manganese oxides, but containing a wide variety of other mineral and even organic components. The most important earth pigments can be broadly classified in the following manner:

Ochres are predominantly iron oxide- and hydroxide-rich earths varying in colour from browns and reds through yellows, the colour is imparted by iron oxides and hydroxides in various states of oxidation.

Siennas (Sienas) are iron hydroxide-rich earths, to which they owe their yellow-brown colour, but are distinct from the ochres in that they contain minor amounts (<5%) of manganese oxides.

Umbers contain between 5 and 20% manganese oxides and between 45 and 70% iron oxides. They are a rich, warm brown colour.

Wads are dark brown to black-coloured earths containing c. 50% manganese oxides.

It should be noted that as naturally occurring sediments, there is a wide variation in iron and manganese oxide composition and transitional assemblages are certain to occur. In addition:

Green earths or *Terres vertes* are green-coloured due to concentrations of the clay minerals celadonite or glauconite.

Humic earths are based on low-grade coal deposits or lignites and are a rich brown colour, superficially very similar to umbers and include the pigments Vandyke brown and Cassel earth.

Many of the earth pigments may be modified by roasting to deepen or redden the colour, hence burnt ochre, burnt umber and burnt sienna and so forth. The earth pigments are described at length under separate entries. Occurring in abundant and readily available deposits, they have been widely used in art from the Palaeolithic to the present day by all cultures worldwide.

Clay minerals group; Iron oxides and hydroxides group; Manganese oxides and hydroxides group; Mica group; Celadonite; Coal; Glauconite; Green earth; Humic earth; Lignite; Ochre; Sienna; Umber; Wad; *Cassel earth*; *Vandyke brown*

EBONY

Black-Brown

Synonym, variant or common name

Field (1835) stated that olive lake (*q.v.*) was prepared from ebony. However, Riffault *et al.* (1874) describe how ebony black was obtained from burning copper nitrate with peat.

Copper nitrates and nitrites group; *Olive lake*
Field (1835); Riffault *et al.* (1874) 515

EBONY BLACK

Black

Synonym, variant or common name

According to Riffault *et al.* (1874) ebony black was obtained from burning copper nitrate with peat; the resulting composition is unknown.

Copper nitrates and nitrites group
Riffault *et al.* (1874) 515

EFFENBERGERITE

Blue

Generic compound

Effenbergerite is a sheet silicate mineral with chemical composition $BaCuSi_4O_{10}$. It is found as blue lenses in a matrix consisting primarily of braunite (*q.v.*), purple sugilite and hausmannite (*q.v.*), cut by small pectolite mineral veins. Named after Dr H.S. Effenberger, mineralogist at the University of Vienna, effenbergerite is the Ba-analogue to cuprorivaite (*q.v.*). It was discovered only recently in the Wessels mine, NW Cape Province, South Africa and is a rare mineral in nature (Giestern and Rieck, 1994). A blue barium copper silicate pigment ('Han blue', *qq.v.*) with the same composition as effenbergerite has been identified on Chinese objects by FitzHugh and Zycherman (1983). This pigment was reportedly man-made and although the natural form of effenbergerite has not been identified in a pigment context, it is included here to indicate that a natural form does exist.

Barium group; Copper group; Sheet silicates group; Barium copper silicate, blue type; Braunite; Hausmannite; *Han blue*
FitzHugh & Zycherman (1983); Giestern & Rieck (1994)

EGGSHELL

White
Synonym, variant or common name

A white calcium carbonate pigment may be prepared from ground eggshell (probably generally domesticated fowl, *Gallus domesticus*).

In his survey of fourteenth and fifteenth century technical treatises Thompson (1935) found frequent mention of eggshell to produce a variety of colours, either through the deposition of dyestuffs thereon or in conjunction with copper compounds. So, for example, he lists recipes for blues from the berries of '*solatrum maius*' and indigo, red from Brazil(wood) and yellow with *gualda* (for which, see the discussion under *arzica*), as well as 'blues composed of eggshells tinctured with copper salts'. Eggshell appears listed among pigments in Munich pharmacy *taxae* (price lists) of the fifteenth to sixteenth centuries as '*calx de tistis ovorum*' (Burmester and Krekel, 1998). The Italian author Lomazzo (cf. Merrifield, 1849) recommends mixing pure eggshell with all colours used for fresco painting in his *Trattato* of 1584. The mid-seventeenth century English writer in Rome, Richard Symonds, also documents the use of eggshell by certain artists (Beal 1984), though it otherwise appears rare in that period (Harley, 1982). However, a more complete description is given in the *Secreti di Don Alessio Piemontese*, a well-known 'book of secrets' that was first published in 1557 and which had been through about 25 Italian editions by the mid-seventeenth century. This states: 'To make ink that is so white, that when you write upon paper, and it is most excellent. Take fresh well washed eggshells, which are the pureset white, and grind them with the cleanest water on a porphyry or marble slab which is very clean until they are perfectly ground. Then put these crushed eggshells and water into a clean bowl, and let the powder settle to the bottom and then drain away the water carefully and allow the powder to dry naturally and you will have an incomparable white which cannot be surpassed by lead white [*biacca*] or any other white in the world if it is made carefully and well. Sieve it and when you want to use it, take gum arabic and wash it, removing all the yellowish skin in which it is enclosed and put it to soften in distilled vinegar for one night. By the morning, the gum will have dissolved and the vinegar will have turned whiter than milk' (cf. Beal). While Beal supposes this to mean that the eggshell was then added after the treatment to the gum, it is also conceivable that the eggshell was incorporated earlier and allowed to react with the acetic acid; consequently calcium acetate could be being formed here.
See also Shell white and Calcium carbonates group.

Calcium carbonates group; *Arzica*; *Shell white*
Beal (1984) 126–128; Burmester & Krekel (1998); Harley (1982) 164; Lomazzo (1584) 191; Merrifield (1849) clii; Thompson (1935) 415, n.8; 419 + n.2

EGYPTIAN BLUE

Blue
Synonym, variant or common name

Egyptian blue is the earliest synthetic pigment. It is the common name for a pigment primarily consisting of the synthetic calcium copper tetrasilicate compound $CaCuSi_4O_{10}$, an analogue to the rare natural mineral cuprorivaite (*q.v.*). Hughes *et al.* (1997) have also shown that the analogues $SrCuSi_4O_{10}$ and $BaCuSi_4O_{10}$ may also be synthesised, though their colours lack the intensity of the calcium copper silicate. Barium copper silicate blue was known to be manufactured in China during the Han dynasty and is known as Chinese blue, or more accurately Han blue (*qq.v.*; Wiedemann *et al.*, 1998; FitzHugh and Zycherman, 1983, 1992). Egyptian blue was synthesised and used extensively from 4th dynasty Egypt until the end of the Roman period in Europe, as well as in certain other rare exceptions. Typically the compound was prepared by heating together a calcium compound like powdered limestone with a copper alloy (or copper filings, or even an ore such as malachite, *q.v.*), silica (quartz) and a flux of soda (or plant-derived potash) to temperatures in the region of 850–1000°C (temperatures below this are likely to produce unfused materials or glass and slags). The best blue pigments produced were ground and refired to further purify them. Descriptions of the synthesis may be found in Vitruvius (first century BC). The first modern synthesis of the compound was made by Pabst (1959). Further accounts of the formation, composition and occurrences can be found under the entry for calcium copper silicate. Additionally, attempts to reproduce the pigment are reviewed by Canti and Heathcote (2002), who also manufactured Egyptian blue from copper oxide, calcium carbonate, silica in the form of diatomite and a sodium carbonate flux. Three refirings were required before a block of 'a deep blue mass of crystals' was formed. Excavations at Tell El-Amarna uncovered ancient manufactories for the pigment with stocks of the raw ingredients and round pots for firing them. Green and purple pigments were also found with the debris as well as blues (Spurrell, 1895). Egyptian green was intentionally manufactured and is discussed under the relevant entry. However, the lilac or purple pigments are less well known and identifications in Mediterranean art are so far unknown. However, as mentioned above, similar pigments are known from China and these are discussed under the entry for Han blue. These manufactured copper silicate pigments also contain variable amounts of other phases deriving from the raw materials and techniques used in production (that is: quartz, wollastonite, cuprite and tenorite; *qq.v.*) These phases are generally derived from excess of raw materials used in the manufacturing process. Scott (2002) notes the occurrence of pyrite in several 5th dynasty (2465–2323 BC) tomb paintings despite the fact that pyrite decomposes at temperatures exceeding 743°C. This suggests this phase was either an intentional admixture (perhaps to enhance the resemblance of the pigment to lapis lazuli?) or simply an impurity.

Reviews of the pigment have been recently published by Riederer (1997) and Scott (2002) and it has been widely recorded in painted archaeological materials. Earliest known uses of Egyptian blue are from the 4th dynasty (c. 2613–2494) where it was moulded into amulets as well as being ground and used as a pigment on painted sculptures and sarcophagi. It was in routine use as the standard blue pigment of Egyptian art up until the Ptolemaic period (fourth century BC; see Riederer, 1997a and references therein; Uda *et al.*, 2000b; Wiedemann *et al.*, 2002; Scott, 2002). Egyptian blue appears in Minoan art at

Thira and on Crete (Filippakis *et al.*, 1976). Here, Egyptian blue was known to be occasionally mixed with the blue sodic amphiboles belonging to the glaucophane-riebekite solid solution series (see: glaucophane). Riederer (1997a) reports identifications of Egyptian blue at Mesopotamian sites including Persepolis, Pasargadae and Nineveh. The pigment was widely adopted by the Greeks (see Riederer, 1977a, 1985; Segal and Porat, 1997) and particularly the Romans who set up local production centres. Identifications in Roman art have been made, among others by Béarat (1997) at Pompeii and sites in Switzerland, Bugini and Folli (1997) at Rome, Kakoulli (1997) at Paphos, Cyprus and Meggiolaro *et al.* (1997) at Corinth. Canti and Heathcote (2002) have identified Egyptian blue in Romano-British and Saxon layers in west-central England, including evidence that it was manufactured locally. The most northerly identification comes from Rosenqvist (1959) who reported Egyptian blue on a third century AD painted shield from Norway. The pigment declined in use through the late Roman period and into the Middle Ages. Again Riederer (1997) summarises late appearances of the pigment in Christian wall painting (ninth century AD).

In Pharaonic texts Egyptian blue is designated by the combination of the name for lapis lazuli, referring to its colour, and another term indicating its artificial origin: *hsbd iryt*. Theophrastus (c.315 BC) mentions Egyptian blue and the fact that it is synthetic. He also mentions Scythian blue (Phoenician Blue) as another synthetic compound. It is as likely that the pigment was traded by the Phoenicians as well as manufactured in the Levant. It is from its trading port that the pigment also obtained the name Alexandrian blue. Both Pliny (77 AD) and Vitruvius discuss the terminology of (Egyptian) blue pigments. Vitruvius uses the general term *caeruleum* (*q.v.*; but the pigment described is indubitably Egyptian blue; the same applies to the Greek term *kyanos* and corruptions of this as applied by Theophrastus). Pliny writes that of all the blues *Aegyptium* was the best. He also notes that the material was manufactured at Pozzuoli (*Puteoli*) and called *Puteolanum* (Pozzuoli blue). Both Roman authors also state that one Vestorius set up a factory in Pozzouli, and hence the name *Vestorianum*, or Vestorian blue. Blue frit and copper frit are also encountered, though these terms may be better applied to amorphous, glassy varieties rather than crystalline compounds.

Egyptian blue is identified as cuprorivaite in many places, although it is certainly the synthetic form, rather than the naturally occurring mineral, that is being referred to (natural cuprorivaite occurs in concentrations too small to be viable as pigment sources). Although Egyptian blue as described above is so far unknown from the Far East, related synthetic copper silicate pigments used there are Han blue and Han purple (*q.v.*).

Calcium group; Copper group; Barium copper silicate, blue type; Calcium copper silicate; Cuprite; Cuprorivaite; Diatomite; Effenbergerite; Glaucophane; Malachite; Pyrite; Quartz; Tenorite; Wollastonite; *Caeruleum*; *Egyptian green*; *Han blue*; *Han purple*; *Lapis lazuli*; *Pozzuoli blue*

Béarat (1997); Bugini & Folli (1977); Canti & Heathcote (2002); FitzHugh & Zycherman (1983); FitzHugh & Zycherman (1992); Hughes *et al.* (1997); Kakoulli (1997); Meggiolaro *et al.* (1977); Pabst (1959); Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii.161–163; Riederer (1977a); Riederer (1985); Riederer (1997); Rosenqvist (1959); Scott (2002) 257–262; Segal & Porat (1997); Spurrell (1895); Theophrastus (c. 315 BC/Caley & Richards, 1956) VIII.50–60; Uda *et al.* (2000b); Vitruvius (1st cent BC/Grainger, 1934) VII.xi.1; Wiedemann *et al.* (1998); Wiedemann *et al.* (2002)

EGYPTIAN BROWN

Brown

Synonym, variant or common name

White (1986) states that this was another name for mummy (*q.v.*), and mixed with ultramarine or lake pigments for application as a glaze.

Mummy

White (1986)

EGYPTIAN GREEN

Green

Synonym, variant or common name

By varying the starting components and formation conditions used in the production of Egyptian blue (calcium copper silicate, *qq.v.*), a so-called Egyptian green can be produced. The colour can vary from an olive-green to a blue-green depending on the manufacturing technique, while two distinct varieties have been found: a glass-rich pigment with cuprowollastonite (*q.v.*) as a minor phase and a cuprowollastonite-rich pigment with glass and silica as minor phases.

Analyses of samples also show that Egyptian green has a much higher silica content than the blue compound (Stulik *et al.*, 1993) and, according to Wiedemann and Bayer (1982), Egyptian green will form in preference to blue if the iron content of the silica used as a starting material is in excess of 0.5%. According to Ullrich (1987) Egyptian blue can be made by using quartz (in the form of sand), lime (either as limestone or lime-containing sand), copper compounds (copper ores or bronze waste) and natural soda ('natron') from Wadi Natrun in Lower Egypt as a flux. The ingredients would be ground to a fine powder and mixed in the ratio 5 quartz:2 lime:2 copper:1 soda. After heating the mixture at a temperature of 900–950°C for 24 to 48 hours, a glassy blue mass is produced with a high proportion of the blue compound; if this mass is ground and fired again, the proportion of blue increases further, but if the temperature exceeds 1000°C (or if there is a reducing atmosphere) then a green frit occurs. The green frit is also apparently produced if the ratio of CuO to CaO is not 1:1. Cassiterite (*q.v.*) has also been found in the glass matrix of the wollastonite-bearing pigment (although not as frequently as in Egyptian blue samples), suggesting the use of bronze filings or bronze scrap as a starting material for the pigment.

Ulrich states that Egyptian green was invented during the VIth dynasty (2323–2150 BC), the earliest occurrence being in the tombs of Unas and Khenti in Thebes; Schilling (1988) has also identified Egyptian green in wall paintings of the Tomb of Queen Nefertari, XIXth dynasty (c. 1200 BC). Egyptian green is said to have been first identified by Noll and Hangst in 1975. The pigment has been briefly reviewed by Scott (2002).

Calcium group; Copper group; Silicates group; Calcium copper silicate; Cassiterite; Cuprowollastonite; Wollastonite; *Egyptian blue*

Noll & Hangst (1975a); Noll & Hangst (1975b); Schilling (1998); Scott (2002) 263–264; Stulik *et al.* (1993); Ulrich (1987); Wiedemann & Bayer (1982)

EGYPTIAN RED GOLD

Red

Synonym, variant or common name

See: gold silver sulfide.

EISENACH GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997)

EISLEBEN GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

ELSNER GREEN

Green
Synonym, variant or common name

Various nineteenth to early twentieth century authors list Elsner or Elsner's green (for example, Zerr and Rübencamp, 1906) which seems in essence to be a copper-based blue combined with an organic yellow dyestuff (usually fustic, *q.v.*). According to Zerr and Rübencamp 'Elsner green consists of a mixture of Bremen blue and a fustic-tin lake, and can be obtained by direct precipitation or by simply mixing the above-mentioned finished products.' Salter (1869) gives a more complex process involving 'adding to a solution of sulfate of copper a decoction of fustic, previously clarified by a solution of gelatine. To this mixture are added ten or eleven percent of protochloride of tin, and lastly an excess of caustic potash or soda. The precipitate is then washed and dried, whereupon it takes a green colour tinged with blue.'

Bremen blue; *fustic*
Salter (1869) 286–287; Zerr & Rübencamp (1906/1908) 226–227

ÉMAIL

Blue
Synonym, variant or common name

Also called *bleu d'émail*, the French for enamel blue (*q.v.*).

Enamel blue

EMERALD GREEN

Green
Synonym, variant or common name

In the common application of the term, emerald green refers to copper acetate arsenite produced in a variety of ways. It should be noted, however, that the name appears to have been actually used in four distinct contexts:

(a) for the copper acetate arsenite compound;
(b) for a pigment made from coffee berries also known as Venetian green (Field, 1835; Osborn, 1845);
(c) for a pigment made of copper carbonate with lime or alumina;
(d) for a hydrated chromium oxide pigment (c & d: Martel, 1860).

The identification with copper acetate arsenite stabilises late in the nineteenth century and is to be considered the primary meaning. For a discussion of the chemistry, see the entry for the copper arsenite group. The related Scheele's green is discussed under that term.

Discovery of emerald green is credited to two distinct sources. First, according to Bechstein (cf. Fiedler and Bayard, 1997), the paint manufacturer Wilhelm Sattler, in association with a pharmacist called Friedrich Russ, experimented reacting verdigris with arsenic compounds after seeing a reference in Crell's *Chemische Annalen*. The pigment they produced, under the name Schweinfurt green, was sold commercially from 1814. Second, according to Tschelnitz (1857), Ignaz von Mitis (1771–1842) in Vienna also produced the pigment in 1814, subsequently manufacturing it at his factory in Kirchberg, Austria; this provides a source for a number of the other terms associated with emerald green including Mitis green, Vienna g., Kirchberg g., Saalfeldergrün and Casslergrün (Gentele, 1860). The pre-eminence of either origin is uncertain. However, analysis of samples separately and ensuing publications by Liebig and Braconnot in 1822 led to widespread production by many firms in Europe and, ultimately, the US. Liebig's process was to dissolve verdigris in warm vinegar, to which was added an aqueous solution of arsenic which caused a dirty green precipitate to form. This was then redissolved in vinegar and boiled to produce a bright green precipitate (Mérimée, 1830). Emerald green, as copper acetate arsenite, was produced by various further methods which are discussed in the copper arsenite group entry.

Associated terms listed by Zerr and Rübencamp (1906) include Emperor green, basel g., beautiful g., new g., mineral g., original g., patent g. and Paris g. These authors (and others) suggest that the proliferation of terms for emerald green were because of the toxicity, 'with the intention of leading a suspicious public to believe that non-poisonous products were in question'. However, they also state that 'these names often apply to distinct mixtures of true emerald green with barytes, gypsum, chromes, or lead sulfate, added to lower the somewhat high cost of production, and also for toning the colour to a certain extent' (see the individual entries). Various authors have further collated a huge range of other associated terms: Schaaff and Riederer (1992), for example, list some 86 names connected with emerald and Scheele's greens, many associated with their place of manufacture.

Emerald green was used as a pigment from about 1830 particularly by the Impressionist and post-Impressionist painters. It has also been found on Tibetan *Thang-ka* paintings (Mehra, 1970), and Indian paintings of circa 1900 (FitzHugh, 1988) and a Japanese painting by Hirosage (1797–1858; FitzHugh, 1979).

Fiedler and Bayard have pointed out the confusion between emerald green and viridian: 'There is some confusion between the terms emerald green and the French *vert émeraude*, especially when the latter is translated into English. *Vert émeraude* is a transparent chromium oxide [chromium oxide hydrate] known in English as viridian (*q.v.*) and has often been incorrectly translated as emerald green' (Fiedler and Bayard, 1997). This is also true of the German *Smaragdgrün*.

Arsenic group; Copper arsenite group; Copper group; Baryte; Copper acetate arsenite; Gypsum; *Braunschweig green*; *Brixen green*; *Deck green*; *Eisleben green*; *Fine green*; *French green*; *Hamburg green*; *Imperial green*; *Jasniger green*; *Kassel green*; *Kirchberg green*; *Mitis green*; *Paris green*; *Schweinfurt green*; *Verdigris*; *Veronese green*; *Viridian*; *Würzburg green*
Braconnot (1822); Fiedler & Bayard (1997); Field (1835) 131; FitzHugh (1979); FitzHugh (1988); Gentele (1860) 253; Liebeg (1822); Martel (1860) 27–28; Mehra (1970); Mérimée (1830/trans. Taylor, 1839) 179–180; Osborn (1845) 58; Schaaff & Riederer (1992); Tschelnitz (1857); Zerr & Rübencamp (1906/1908) 212

EMERALD OXIDE OF CHROMIUM

Green
Synonym, variant or common name

See: viridian.

EMERY

Variable
Synonym, variant or common name

Emery is a granular form of corundum (*q.v.*; α-Al_2O_3) associated with iron oxide and silica.

Iron oxides and hydroxides group; Corundum; Silica

EMODIN

Orange
Generic compound

Emodin, 1,3,8-trihydroxy-6-methylanthraquinone, is an anthraquinone dye which occurs mostly as a rhamnoside (see: *Frangulin*) in various *Rhamnus*, *Rheum* and *Cassia* species. It is a major dye component extracted from the bark of *Cassia fistula* L. Also known as *frangula emodin* and *rheum emodin* (*Merck Index*, 1996; Schweppe, 1992).
See: rhamnus, rhubarb and cassia fistula.

Frangulin; Rhamnus; Rhubarb; *Cassia fistula*
Merck Index (1996) 3602; Schweppe (1992) 213

ENAMEL BLUE

Blue
Synonym, variant or common name

Tingry (1804) and Osborn (1845) clearly state that enamel blue is a synonym for smalt (*q.v.*). De Massoul (1797) discusses the term with smalt, citing violet blue, enamel blue and cobalt blue as deriving from cobalt ore. Watin (1785) also states that there is a colour synonymous with *bleu d'émail* (enamel blue) called verre de cobalt, which translates as 'cobalt glass'.

Smalt; *Cobalt blue*
Massoul (1797); Osborn (1845) 51; Tingry (1804) 300; Vitruvius (1st cent BC/Grainger' 1934) VII.xi.1; Watin (1773/edition of 1785) 32

ENAMEL WHITE

White
Synonym, variant or common name

Synonym for barium sulfate (*q.v.*; Feller, 1986).

Barium sulfate
Feller (1986)

ENGLISH GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*); Heaton (1928) also states that it was a then-current term for emerald green. However, Mierzinski (1881) uses English green as a synonym for green cinnabar (*q.v.*), a pigment typically (but not exclusively) composed of a Prussian blue-type pigment co-deposited with a yellow pigment such as lead chromate. He also lists it among the synonyms for Scheele's green. Goeree (1670), however, describes this as a mixture of *bergrun* (malachite, *q.v.*) after mixing with white*, 'mit Safft-grün vertiefet, und Masticot erhöhet'* ('deepened with *sap green* and brightened with *massicot*').

Malachite; *Emerald green*; *Green cinnabar*; *Scheele's green*
Fiedler & Bayard (1997); Goeree (1670) 287; Heaton (1928) 381; Mierzinski (1881) 185

ENGLISH OCHRE

Yellow
Synonym, variant or common name

A variety of yellow ochre (*q.v.*). Harley (1982) found various seventeenth century authors referring to 'English ochre', one of the earliest being Norgate (early seventeenth century.). However, John Smith (1676) remarks that most comes from Shotover Hills near Oxford, England; this is also the origin of 'Oxford ochre', a term which was only introduced in the nineteenth century.

Iron oxides and hydroxides group; Ochre; *Oxford ochre*; *Yellow ochre*
Harley (1982) 89–90; Norgate/Thornton & Cain (early 17th C./1981); Smith (1676)

ENGLISH PINK

Yellow
Synonym, variant or common name

Generally synonymous with Dutch pink (*q.v.*), though seemingly paler. For example, Carlyle (2001) lists from her study of nineteenth century British documentary sources yellow carmine, Dutch pink, English pink and yellow lake in descending order of intensity. Further, Fishwick (1795–1816) gives a recipe for English pink '4th Dutch pink, 10th Paris white, grind in water and dry in Sheeps bladders'; the addition of white would obviously desaturate the colour of the Dutch pink.
See: rhamnus.

Flavonoids group; Quercitron; Rhamnus; *Dutch pink*
Carlyle (2001) 520; Fishwick (1795–1816) 2

ENGLISH RED

Red
Synonym, variant or common name

According to Harley's study of seventeenth to nineteenth century British documentary sources (1982), there was a concurrency in the use of terms such as light red, brown red and English red as terms associated with ochreous pigments but of potentially uncertain composition. She adds that 'According to de Massoul, the yellow ochre from Berry in France was imported to Holland, where it was calcined and then sold as English red. On the other hand Watin states that English brown red is made at Deptford, seven miles from London' (Harley, 1982). It is clear from Watin (1785) though that the latter was a synthetic iron oxide from calcination of iron sulfate produced as a by-product of the preparation of sulfuric acid. Tingry (1804) also refers to this as 'resulting from the decomposition of sulfates of iron'. Merrifield (1846) suggests that the Italian terms *rosso d'Inghilterra*, *bruno d'Inghilterra* and the French *rouge violet* appear to be synonymous and Pozzo (1642–1709, cf. Merrifield) refers to *rossetto d'Inghilterra* as being 'of the nature of vitriol'. This would also indicate that they are artificially manufactured. Merrifield, however, also equates these terms with pabonazzo and sinoper which indicates a natural iron oxide. Despite the evident confusion, the term was still listed as current in the early twentieth century by Heaton (1928).

Iron oxides and hydroxides group; *Light red*; *Red ochre*
Harley (1982) 120; Heaton (1928) 381; Massoul (1797); Merrifield (1846) xxvii, xxxi, 58; Tingry (1804) 354; Watin (1773/edition of 1785) 22

ENGLISH SKY BLUE

Blue
Synonym, variant or common name

According to Riffault *et al.* (1874), English sky blue was indigo (*q.v.*) reduced with sulfuric acid, potash and lime.

Indigo
Riffault *et al.* (1874) 357

ENGLISH STIL DE GRAIN

Yellow-Brown
Synonym, variant or common name

Osborn (1845) states that 'Brown (or English) *Stil de grain* is prepared with a calcareous or marly earth, alum, and a decoction of Avignon berries.'
See: stil de grain.

Osborn (1845) 52

ENGLISH VERMILION

Red
Synonym, variant or common name

According to Watin (1785) this was produced in England and, he believes, was a mixture of cinnabar and minium (meaning the red synthetic lead(II,IV) oxide, *qq.v.*). Watin adds that it is less beautiful and more pale than cinnabar and that it was used in distemper and watercolour 'as it was more stable than pure vermilion' (*q.v.*).

Mercury sulfides group; cinnabar; Lead(II,IV) oxide; *Vermilion*
Watin (1773/edition of 1785) 23

ENGLISH WHITE

White
Synonym, variant or common name

See: chalk.

ENGLISH YELLOW

Yellow
Synonym, variant or common name

English yellow was apparently synonymous with the lead chloride oxide (*q.v.*) pigment known as Turner's or Patent yellow (Bersch, 1901).

Lead chloride oxide
Bersch (1901) 113–114

ENSTATITE

Black
Generic compound

Enstatite is a black magnesium silicate mineral with ideal chemical composition $MgSiO_3$. In natural samples, magnesium may be partially replaced by iron to form bronzite (>15% FeO) and hypersthene (>34% FeO), with complete replacement producing the rare ferrosilite ($FeSiO_3$); samples may also contain small proportions of Ca, Al, Mn, Ni and Cr. The Cr-rich variety, chrome-enstatite, is of an emerald green colour and used as a gemstone. Enstatite is a type of pyroxene and is thus similar in chemistry and structure to diopside and augite (*qq.v.*), with which it may coexist. Enstatite itself has three polymorphs: the low temperature orthorhombic form (orthoenstatite), a high temperature (>985°C) orthorhombic form (protoenstatite) and a metastable (clinoenstatite) monoclinic form (Cameron and Papike, 1981). The low temperature form is the most common and occurs as vitreous black or green-black tabular to prismatic crystals or aggregates. It is found in basic and ultrabasic volcanic rocks and in high temperature metamorphic rocks (granulites) from the dehydration of anthophyllite (*q.v.*). Enstatite alters to fibrous serpentine group minerals or to cummingtonite by the addition of water (Deer *et al.*, 1992; Rutley, 1988). It was first discovered by Kengott in 1855 in Berge Zdjar (Moravia, Czech Republic) and is also known from Boulder (Colorado, USA), Fiskenaesset (Greenland), Medelpad (Norway), Monte Somma (Italy), India, South Africa and Burma (Dana, 1932).

In an art context, Sánchez-Moral *et al.* (2002) have established that the black pigments used in the ancient cave paintings of Galdar are composed of silicate minerals derived from the local volcanic rocks which are rich in pyroxene. Identified ancient beads from the Samad Culture (Oman) were shown by Rosch *et al.* (1997) to be composed of synthetic enstatite, formed from the firing of steatite, a variety of talc, or magnesium-rich members of the clay minerals group (*qq.v.*).

Magnesium silicate has several polymorphs (enstatite, majorite, perovskite) of which the enstatite type is the most common and most stable form. It is therefore likely that it is this form of magnesium silicate which has been described for use as a paint extender.

Clay minerals group; Magnesium group; Serpentine group; Anthophyllite; Augite; Diopside; Magnesium silicate; Talc; *Steatite*
Cameron & Papike (1981); Dana (1932) 553; Deer *et al.* (1992) 155–165; Rosch *et al.* (1997); Rutley (1988) 376–377; Sánchez-Moral *et al.* (2002)

EOSIN

Red
Generic compound

There are a number of varieties of Eosin (sometimes 'eosine'), but the most common are Eosin B (CI 45400/Acid Red 91) and Eosin Y (CI 45380/Acid Red 87); the former is the sodium or ammonium salt of the dibromo derivative of dinitrofluorescein, while the latter is the disodium salt of tetrabromofluorescein. Eosin Y was discovered by Caro in 1871, Eosin B by Caro in 1875 and Baeyer in 1876 (*Colour Index*, 1971).

Eosin was used extensively to produce lake pigments such as that known as Geranium lake, where the dyestuff was commonly deposited onto an aluminium hydroxide base (Weber, 1923), or a pigment known as vermilionette and royal red, for which Heaton (1928) gives recipes involving eosin being struck onto lead(II,IV) oxide (*qq.v.*). Heaton also gives the term imperial red as a then-current synonym for eosin and related lakes. In this context it is interesting to note that Eosin Y also has additional *Colour Index* structure and composition designations – CI 45380:1/Pigment Red 90 for the lead salt and CI 45380:3/ Pigment Red 90:1 for the aluminium salt.

Rioux (1999) found that this was one of the pigments responsible for the severe fading in the paintings of Vincent Van Gogh.

Lead(II,IV) oxide; *Geranium lake*
Colour Index (1971) 45380, 45400; Heaton (1928) 196; Rioux (1999); Weber (1923) 58

EPIDOTE

Green
Generic compound

Epidote is a calcium aluminosilicate mineral with chemical composition $Ca_2(Al,Fe)_3(SiO_4)_3OH$ (Ito, 1947; Ito *et al.*, 1954).

It commonly occurs as hard green or yellow-green vitreous prismatic crystals with striated surfaces, although aggregates, fibrous and granular forms are also found. Iron-free epidote is known as zoisite, while the manganese-bearing variety is known as piemontite; pistacite is a pistachio green variety. Epidote principally occurs in metamorphic rocks derived from impure calcareous rocks, or from basic igneous rocks rich in calcic plagioclase feldspar (*q.v.*); it may also form as a secondary mineral during hydrothermal alteration of basic igneous rocks by the breakdown of plagioclase feldspar and amphibole (*q.v.*) minerals (Deer *et al.*, 1992; Rutley, 1988). It is found in many places worldwide, such as in Cornwall (England), Lazio (Italy), Salzberg (Austria), Zagros Mountains (Iran), Durango (Mexico), Bahia (Brazil), Ontario (Canada), Tasmania, Poland, Pakistan, Russia, Sweden, South Africa and Sri Lanka.

Aluminium group; Amphibole group; Calcium group; Feldspar group; Iron group; Silicates group
Deer *et al.* (1992) 89–95; Ito (1947); Ito *et al.* (1954); Rutley (1988) 363–364

EPSOMITE

White
Generic compound

Epsomite is a magnesian sulfate hydrate mineral with composition $MgSO_4.7H_2O$. The natural form is also known as heptahydrate or seelandite, with synthetic forms termed Epsom salts or bitter salt. Epsomite was first described by Delmaetherie in 1806 and is named after deposits found at Epsom (Surrey, England). It occurs as relatively soft white botryoidal or fibrous masses and crusts, or more rarely as acicular crystals; the presence of impurities produces pale pink or green varieties. It forms as water-soluble deposits from saline lakes and hot springs, and as effluorescent crusts on the walls of limestone caves and other magnesium-rich rocks (Dana, 1932). In dry conditions, epsomite loses water easily, converting to the hexahydrate $MgSO_4.6H_2O$. Epsomite is often found in association with calcite, aragonite and gypsum (*qq.v.*), and is known from localities such as Stassfurt (Germany), La Mancha (Spain), Vesuvius (Italy), Ashcroft (Canada), Bisbee (Arizona, USA) and Minas Gerais (Brazil).

Watchman *et al.* (2001) identified epsomite in efflorescent crusts covering rock art at the Carpenter's Gap archaeological site (Southern Kimberley, Australia).

Magnesium group; Aragonite; Calcite; Gypsum
Dana (1932) 760; Watchman *et al.* (2001)

ERETRIAN EARTH

White-Grey
Synonym, variant or common name

Eretrian earth is named after the Ionian city Eritria on the island of Evia (ancient Euboea) in Greece where it was sourced. It is mentioned by Pliny (77 AD) as being both used as a pigment and medicinally 'to clean out ulcers … as an ingredient in plasters, and also in cauteries'. He adds that it is extremely difficult to pound up. Pliny also says that it comes in two colours, 'one white and one ash-coloured', including it in two lists, one of 'natural colours' used in paintings, the other of earths. He also cites its use as an absorbent base for a blue pigment made by boiling dried violets, employed to adulterate imported indigo. Two tests are given by Pliny to distinguish it from other earths, based on its softness and 'its leaving a violet tint if rubbed on copper'. The geology of the region is complex and the true source and nature of Eretrian earth does not appear to have been identified thus far.

Pliny (1st cent AD/Rackham 1952) XXXV.liv.192, XXXIII.lvii.164, XXXV.xxi.30, 38

ERLAA GREEN

Green
Synonym, variant or common name

Erlaa green is, according to Riffault *et al.* (1874), made as follows: to copper sulphate, 30% of its weight in sodium chloride is dissolved in water. One hundred parts of this solution is poured into milk of lime and 40–50 parts of white and well-burned lime. As soon as the blue colour appears, add 8 to 12 parts soluble chrome salt, neutral chromate of potassa being preferred.

Copper group
Riffault *et al.* (1874) 549

ERLANGEN BLUE

Blue
Synonym, variant or common name

See: Prussian blue.

ERWAISDA

Blue
Synonym, variant or common name

Historical term associated with woad (*q.v.*; indigoid dyestuff derived from the plant *Isatis tinctoria*; Schweppe, 1997).
See: indigo.

Woad
Schweppe (1997)

ERYTHRITE

Red-Purple
Generic compound

Erythrite is a hydrated cobalt arsenate mineral with ideal chemical composition $Co_3(AsO_4)_2.8(H_2O)$. It forms a complete solid solution series with annabergite (in which cobalt is replaced by nickel; Wildner *et al.*, 1996) and a partial series with hornesite (in which cobalt is replaced by magnesium; Jambor and Dutrizac, 1995); it is often referred as cobalt bloom, red cobalt ochre or cobalt crust. Erythrite commonly occurs as soft red to purple-red earthy or reniform masses and encrustations, which form by the weathering of cobalt-bearing veins and ore deposits; it is found more rarely as striated prismatic crystals (Rutley, 1988). Erythrite occurs in places such as Cobalt (Ontario, Canada), Cornwall (England), Tyrol (Austria), Saxony (Germany), Laurion (Greece), Sonora (Mexico), Broken Hill (Australia), La Paz (Bolivia) and Bou Azzer (Morocco).

Synthetically related analogues such as cobalt arsenate (*q.v.*) have been used in a pigment context. No specific examples of the use of this mineral are currently known; however, Mühlethaler and Thissen (1993) point out that in addition to the main cobalt mineral smaltite, erythrite (and cobaltite) were probably used in the manufacture of smalt (*qq.v.*) in the seventeenth and eighteenth centuries.

Cobalt arsenate; Smalt; Smaltite
Jambor & Dutrizac (1995); Mühlethaler & Thissen (1993); Rutley (1988) 335–336; Wildner *et al.* (1996)

ERYTHRODANUM

Red
Synonym, variant or common name

Historical term associated with madder (Schweppe and Winter, 1997).
See: madder.

Schweppe & Winter (1997)

ERYTHROLACCIN

Red
Generic compound

See: laccaic acid.

ERYTHROSINE

Red
Generic compound

The disodium salt of 2′,4′,5′,7′-tetraiodofluorescein, erythrosine, is listed by the *Colour Index* (1971) as CI 45430/Acid Red 51 and CI 45430:1/Pigment Red 172 as the aluminium salt. It was discovered by Kussmaul in 1876 (*Colour Index*, 1971). Sources such as Weber (1923) and Heaton (1928) say that, along with eosin and related dye compounds, it was used to form lake pigments such as that commonly known as geranium lake (*qq.v.*).

Eosin; *Geranium lake*
Colour Index (1971) 45430; Heaton (1928) 196; Weber (1923) 58–59

ESCHEL

Blue
Synonym, variant or common name

Mühlethaler and Thissen (1993), citing Winckler, explain that the terms *couleur* and *eschel* (also *sumpfeschel*) were part of the Saxonian quality designations for the pigment smalt (*q.v.*), though Riederer (1968) implies that it was a more general German grading system.

Smalt
Mühlethaler & Thissen (1993); Riederer (1968)

ESKOLAITE

Black
Generic compound

Eskolaite is a chromium oxide mineral with composition Cr_2O_3. It occurs as hard, brittle, black (or green-black) prismatic crystals with metallic lustre which are often mistaken for hematite and magnetite (*qq.v.*). Eskolaite was first described by Kuovo and Vuorelainen (1958) from Laguna Salinas, Peru (Dana, 1951); its type locality is now given as Outokumpu mine, Finland. Eskolaite is most commonly found in chromium-bearing metamorphosed carbonate rocks, with calcite (*q.v.*), or as a component in alluvial deposits (such as Bahia, Brazil (Cassedanne and Cassedanne, 1980); San Benito, California, USA; Lake Baikal, Russia (Reznitskii *et al.*, 1980)).

Eskolaite is not known to have been used as a pigment but its synthetic analogue, chromium oxide (*q.v.*), is a well-known green pigment or pigment component (*Colour Index*, 1971; Newman, 1997).

Chromium oxides and hydroxides group; Calcite; Chromium oxide; Hematite; Magnetite
Cassedanne & Cassedanne (1980); *Colour Index* (1971); Dana (1951); Kuovo & Vuorelainen (1958); Newman (1997); Reznitskii *et al.* (1980)

ESTRICH GYPSUM

White
Synonym, variant or common name

In a discussion of mediaeval *gesso* grounds, Federspiel (1995) has noted that anhydrite burnt at temperatures in excess of 900°C will form so-called Estrich gypsum, a mixture of anhydrite and calcium oxide (*qq.v.*). This reacts slowly with water and becomes extremely hard. Federspiel also suggests that the inefficient furnaces of the past could well in part produce such materials.

Calcium oxides and hydroxides group; Calcium sulfates group; Anhydrite; Calcium oxide; Gypsum
Federspiel (1995)

ETTRINGITE

White
Generic compound

Ettringite is a hydrous calcium aluminium sulfate mineral with composition $Ca_6Al_2(SO_4)_3(OH)_{12}.26H_2O$. It was discovered by Lehman in 1874 at Ettringen, Germany. It occurs as small white or sometimes yellow hexagonal prisms or as needle-like crystals. It forms in veins and cavities, particularly in metamorphosed limestones, precipitating from hydrothermal solutions (for example, Ashover, Derbyshire, UK; Kalahari, South Africa), and has been found more recently in treated coal mine drainage sediments (such as Valley View, Pennsylvania, USA; Kirby *et al.*, 1999).

Although ettringite has not been identified in a pigment context, a related synthetic compound – 'calcium sulphoaluminate' – is listed in the *Colour Index* (1971) as CI 77235/Pigment White 33.

Ettringite will grow as a phase in hydraulic lime plasters and may be encountered on supports for frescos, especially those on outdoor walls.

Aluminium group; Aluminium sulfates group; Calcium group; *Calcium sulphoaluminate*
Colour Index (1971) 77235; Kirby *et al.* (1999)

EUCHROME

Brown
Synonym, variant or common name

Salter (1869) reports that this term was a commercial name applied to Cappagh brown, a humic earth related to so-called Vandyke brown. Mayer (1991) on the other hand lists this simply as a synonym for burnt umber, though this may be erroneous.

Burnt umber; *Cappagh brown*; *Vandyke brown*
Salter (1869) 342

EUPHORBIA

Red
Common generic composite

A species of *Euphorbia* (*E. pulcherimma* Willd. ex Klotzsch, the poinsettia) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *cuitla-xochitl.*

Wallert (1995c)

EUXANTHIC ACID

Yellow
Generic compound

Euxanthic acid, 1,7-dihydroxy-9H-xanthen-9-one-7-D-glucoside, is a xanthone dyestuff. It is a major component, along with euxanthone, of the dye Indian yellow (*qq.v.*), where it is found as a monomagnesium salt (Schweppe, 1992).

Xanthones group; Euxanthone; Indian yellow
Schweppe (1992) 430

EUXANTHONE

Yellow
Generic compound

Euxanthone*,* 1,7-dihydroxy-9H-xanthen-9-one, a xanthone dyestuff, is derived from euxanthic acid and is a major dyestuff in the pigment Indian yellow (*qq.v.*; Schweppe, 1992).

Xanthones group; Euxanthic acid; Indian yellow
Schweppe (1992) 430

EXTRACT OF GAMBOGE

Yellow
Synonym, variant or common name

Field (1835) describes an ‘extract of gamboge’ (*q.v.*) which was made by precipitating the colouring matter after dissolving it in alcohol. The result was a powdery material miscible in oil.

Gamboge
Field (1835) 83

EXTRACT OF VERMILION

Red
Synonym, variant or common name

A shade variant of vermilion (*q.v.*). According to Salter (1869), Field was responsible for the introduction of a particularly vivid form of vermilion known as extract of vermilion, though he noted that ‘Now, however, extract of vermilion and scarlet vermilion [*q.v.*] are synonymous terms.’

Scarlet vermilion; *Vermilion*
Salter (1869) 157

F

Factitious ultramarine

Blue

Synonym, variant or common name

See: brilliant ultramarine and ultramarine.

Fast violet

Purple

Synonym, variant or common name

Hackman (1973) lists fast violet among various synonyms for a manganese ammonium phosphate pigment ('manganese violet'), though in practice it may refer to one of several manganese phosphates thought to have been used as pigments.

Manganese phosphates group; *Manganese violet*

Hackman (1973)

Fawn brown

Brown

Synonym, variant or common name

Mayer (1991) describes this as being a mixture of burnt or raw umber with 'dark ochre' (*qq.v.*).

Ochre; *Burnt umber*; *Raw umber*

Mayer (1991) 44

Faypoux yellow

Yellow

Synonym, variant or common name

See: Naples yellow.

Feldspar group

Variable

Group term

The feldspar group consists of a series of aluminosilicate minerals with the general chemical formula $(Ka,Na,Ca)[(Al,Si)_4O_8]$. The feldspars are the most abundant minerals worldwide, occurring in the majority of rock types, and are subdivided according to composition into two main series: the plagioclase feldspar series, $Na[AlSi_3O_8]$-$Ca[Al_2Si_2O_8]$, and the alkali feldspar series, $K[AlSi_3O_8]$-$Na[AlSi_3O_8]$. The plagioclase feldspar series is further subdivided into six members based principally on the Na-Ca content. The end-members of the series are anorthite, $CaAl_2Si_2O_8$, and albite, $NaAlSi_3O_8$, with intermediate compositions (given in terms of percentage anorthite content ($An_{\%}$)) known as bytownite (An_{70-90}), labradorite (An_{50-70}), andesine (An_{30-50}) and oligoclase (An_{10-30}); anorthite and albite are also defined as having a compositional variance of up to 10% (Rutley, 1988). The term plagioclase feldspar may be used to describe any feldspar that lies along this compositional range, with a subsequent listing of the specific composition if known. The plagioclase feldspars are the most common of the feldspars, occurring in most rock types. The particular plagioclase feldspar which forms depends upon the tectonic setting for igneous rocks, the composition of the host rock for metamorphic rocks and the composition of the parent rock from which a sedimentary rock is derived. For a more detailed discussion, see Ribbe (1983), Smith and Brown (1988) and Deer *et al.* (1992). The plagioclase feldspars show disordering of the Al-Si atoms, the degree of which is dependent upon the cooling history of the crystal.

The alkali feldspar series, $K[AlSi_3O_8]$-$Na[AlSi_3O_8]$, is bounded by the end-members albite (Ab), $NaAlSi_3O_8$ and a member with composition $K[AlSi_3O_8]$. The potassium-rich end-member ('K-spar') is known by different names depending upon the cooling history, degree of Al-Si or Na-K ordering and structure of the mineral. Sanadine has been cooled quickly (fully disordered but rare), orthoclase (Or) is cooled more slowly; microcline is the fully ordered form which crystallises at the lowest temperatures. The names of the intermediate members and the compositional ranges of all the members (given in terms of percentage albite or orthoclase content, $Ab_{\%}$ or $Or_{\%}$) are dependent upon the same criteria. For the rapidly cooled albite-sanadine series, the one intermediate member, anorthoclase, has the composition (Ab_{63}-Ab_{90}), so that the composition of sanadine extends from Ab_0-Ab_{63}. In the more slowly cooled albite-orthoclase series, the albite composition extends to Or_{20}, and the orthoclase composition is Or_{20}-Or_{100}, with no intermediate phase. In the slow-cooled albite-microcline series, there are no intermediate members; the composition of albite is Ab_{100}-Ab_{80}, with the composition of microcline given as Ab_{80}-Ab_0 (Or_{100}-Or_{20}). Although alkali feldspars occur in many metamorphic and sedimentary rocks, their occurrence in igneous rocks is usually restricted to alkali and acid types (Hovis, 1986).

The feldspar minerals have similar physical properties and often occur as prismatic or tabular crystals in igneous rocks, or as more anhedral grains in metamorphic and sedimentary rocks. They are colourless when fresh but are more commonly white due to incipient alteration; impurities or inclusions result in coloured varieties, with green-brown alkali feldspars found in some metamorphic rocks, and orthoclase commonly found as pink. The surfaces of feldspar crystals are often iridescent due to twinning on a microscopic scale, with labradorite characterised by blue surface iridescence. Feldspars readily alter under hydrothermal action or chemical weathering to form members of the clay minerals group (*q.v.*). Sodium-rich feldspars commonly decompose to form montmorillonite, in the presence of limited water, or to kaolinite with excess water; alkali feldspars typically form illite or kaolinite sub-group (*qq.v.*) clay minerals (Deer *et al.*, 1992; Rutley, 1988).

In an art context, feldspars are found in sedimentary deposits such as ochres, kaolin (*qq.v.*) and clays. They can therefore occur as relict grains in artists' materials based on these, they are found in particular as components of pottery of all ages as identified, for example, by Uda *et al.* (2000), Wopenka *et al.* (2002), Traore *et al.* (2000), Criado *et al.* (2002) and Shoval (1994). Feldspars have also been identified by Sánchez-Moral *et al.* (2002) as present in cream mortars used in the cave site at Galdar (Grand Canary Island). See individual feldspar entries for further details of uses as pigments.

Clay minerals group; Clay minerals group: Illite sub-group; Clay minerals group: Kaolinite sub-group; Silicates group; Albite; Andesine; Anorthite; Anorthoclase; Bytownite; Kaolinite; Labradorite; Microcline; Montmor-illonite; Ochre; Oligoclase; Orthoclase; *Kaolin*
Brown & Parsons (1989); Criado *et al.* (2002); Deer *et al.* (1992) 391–456; Hovis (1986); Ribbe (1983); Rutley (1988) 416–425; Sánchez-Moral *et al.* (2002); Shoval (1994); Smith & Brown (1988); Traore *et al.* (2000); Uda *et al.* (2000); Wopenka *et al.* (2002)

Feroxyhyte
Red-Brown
Generic compound

Feroxyhyte (δ-FeOOH) occurs naturally in soils in poorly crystallised (disordered) form, but is more common as a synthetic phase, belonging to the hexagonal system (Cornell and Schwertmann, 1996). Natural feroxyhytes occur above weathered basalts and have so far only been identified on Hawaii (Parfitt *et al.*, 1988). Synthetic feroxyhyte may be produced by titrating iron(II) chloride with sodium hydroxide and water (Schwertmann and Cornell, 2000). Identifications in works of art are not yet known.

Iron oxides and hydroxides group
Cornell & Schwertmann (1996); Parfitt *et al.* (1988); Schwertmann & Cornell (2000)

Ferrate of baryta
Red
Synonym, variant or common name

Described by Salter (1869) as 'Produced by adding aqueous ferrate of potash to an excess of dilute solutions of baryta salts.' The exact composition of the resulting pigment is unknown, but is likely to be a barium ferrate or barium potassium ferrate.

Barium group; Iron group
Salter (1869) 165–166

Ferrihydrite
Red-Brown
Generic compound

Ferrihydrite ($Fe_5OH_8.4H_2O$) is common in young soil deposits but readily transforms to more stable iron hydroxides and oxides such as goethite and hematite (*qq.v.*). Ferrihydrite is also called amorphous iron oxide or hydrous ferric oxide, due to its disordered crystal structure; the precise structure or formula of this mineral is not yet known (Schwertmann and Cornell, 2000). Ferrihydrite may be present in samples of naturally occurring raw ochres and siennas (*qq.v.*) but identifications in works of art have not yet been made.

Iron oxides and hydroxides group; Goethite; Hematite; Ochre; Sienna
Schwertmann & Cornell (2000)

Ferrite red
Red
Synonym, variant or common name

Fuller (1973) explains that this term refers to synthetic analogues of calcined yellow ochres or goethite (*qq.v.*); by thermal treatment of synthetic yellow iron oxides a series of red pigments can be produced. These pigments apparently differ from so-called copperas reds (thermally decomposed iron(II) sulfate hydrate) by having acicular (needle-like) particle morphology rather than a spheroidal shape.

Iron oxides and hydroxides group; Goethite; *Copperas*; *Yellow ochre*
Fuller (1973)

Ferrocyanide of iron
Blue
Synonym, variant or common name

Synonym used, for example, by Salter (1869) for Prussian blue (*q.v.*).

Prussian blue
Salter (1869) 203

Ferrous oxalate
Yellow
Generic compound

Salter (1869) describes 'iron yellow' (*q.v.*) as an 'oxalate of protoxide of iron', an identification with which Scott Taylor (1885) concurs.

Iron(II) oxalate; *Iron yellow*
Salter (1869) 118; Scott Taylor (1885) 182

Fiedlerite
White
Generic compound

Fiedlerite is a relatively rare hydrated lead halide mineral, with the recently revised chemical formula $Pb_3Cl_4F(OH).H_2O$ (previously described as $Pb_3Cl_4(OH)$; Merlino *et al.*, 1994). It is related to blixite and laurionite (*qq.v.*) and forms as white or colourless tabular crystals as a result of smelting processes. It was first described from ancient lead slag heaps at Laurion, Attica Peninsula, Greece, by vom Rath in 1887 and by Lacroix (1896), and has been identified more recently by Franzini *et al.* (1992) from the Etruscan iron slags of Baratti, Italy.

Although fiedlerite has not been identified as a pigment in its own right, its synthetic analogue, lead chloride hydroxide (*q.v.*), has been encountered in a paint context. Noble and Wadum (1998), for example, have observed lead chloride hydroxide in the grey ground of *The Anatomy Lesson of Dr. Tulp* by Rembrandt (Mauritshuis, Den Haag), where it appears to be an alteration product.
See: lead halides group and lead chloride hydroxide.

Lead halides group; Blixite; Laurionite; Lead chloride hydroxide
Franzini *et al.* (1992); Lacroix (1896); Merlino *et al.* (1994); Noble & Wadum (1998)

Field's carmine
Red
Synonym, variant or common name

According to Salter (1869) this is an alternate name for madder carmine, a term which he defines as the 'richest and deepest' form of madder lake (*qq.v.*).

Madder; *Madder carmine*
Salter (1869) 142

FIELD'S ORANGE VERMILION

Orange
Synonym, variant or common name

This pigment was described by Salter (1869) as a brighter, purer and clearer version of so-called orange vermilion, while Muckley (1880) stated that it was the same as orange vermilion but 'manipulated more carefully'. Orange vermilion in turn was considered either merely mercury sulfide (i.e. identical to vermilion), a levigated form of vermilion or else compounded with chrome yellow (*q.v.*; normally lead chromate).

This was a product supplied by George Field, the influential English artists' colourman of the early nineteenth century (Field, 1835).

Mercury sulfides group; *Chrome yellow*; *Orange vermilion*; *Vermilion*
Field (1835) 118; Muckley (1880); Salter (1869) 157–158

FIELD'S PURPLE

Purple
Synonym, variant or common name

A madder lake manufactured by the nineteenth century English colourman Field and described by him as 'purple leading to marrone' (Field, 1835). Also called purple madder.
See: madder.

Field (1835) 137

FIELD'S RUSSET

Orange
Synonym, variant or common name

Salter (1869) gives this as a synonym for Rubens' madder, stating that it is 'a very rich crimson russet with a flush of orange, pure, transparent, and of a true middle hue between orange and purple'; he adds that it was made from madder. This was a product supplied by George Field, the influential English artists' colourman of the early nineteenth century and author of *Chromatography* (1835). In Field's original description he states that it is the only available pigment of this colour, also calling it madder brown, which seems to have been a gently calcined madder lake. There is also a recipe in one of the Roberson's recipe books (R.2.N) which is unclear but includes madder and burnt sienna (*qq.v.*; cf. Carlyle, 2001).

Madder; *Burnt sienna*
Carlyle (2001) 489; Field (1835) 146; Salter (1869) 321–322

FINE GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

FISETIN

Yellow
Generic compound

Fisetin, 2-(3,4-dihydroxyphenyl)-3,7-dihydroxy-4H-1-benzopyran-4-one (or 3,3',4',7-tetrahydroxyflavone) belongs to the group of flavonoid compounds (flavonols) which commonly occur in plants and have long found use as dyestuffs. It is the principal component of young fustic (*q.v.*), dye derived from *Cotinus coggyria* (formerly *Rhus cotinus*; commonly known as Venetian or dyer's sumach) (*Merck Index*, 1996; Mills and White, 1994). It is listed by the *Colour Index* (1971) as CI 75620/Natural Brown 1. See: fustic.

Flavonoids group; *Fustic*; *Young fustic*
Colour Index (1971) 75620; *Merck Index* (1996) 4129; Mills & White (1994)

FLAKE WHITE

White
Synonym, variant or common name

Flake white was generally applied to finely crystalline lead white (*q.v.*) produced by the Cremnitz process and subsequent modifications of this. It was accepted to be the best variety of the pigment. However, Field (1835) states that flake white was 'an English white lead … equal or sometimes superior to Crems white', its name supposedly deriving from its form of scales or plates or alternatively as a corruption of 'snowflake'. Heaton (1928) reports that it was suitable as a printer's ink as well as a pigment. A levigated variety was known as 'body white'. Weber (1923) also writes that some flake whites are, in fact, zinc whites (*q.v.*).

Lead carbonates group; *Cremnitz white*; *Lead white*; *Zinc white*
Field (1835) 69; Heaton (1928) 65; Weber (1923) 55

FLAME BLACK

Black
Synonym, variant or common name

See: carbon-based blacks group: flame carbons sub-group.

FLAME CARBON

Black
Synonym, variant or common name

See: carbon-based blacks group: flame carbons sub-group.

FLAVANTHRONE

Yellow
Synonym, variant or common name

Flavanthrone was first synthesised by R. Bohn in 1901 along with indanthrone and has been used for a long time as a vat dye as well as a pigment. Listed by the *Colour Index* (1971) as CI 70600/Pigment Yellow 24 (Herbst and Hunger, 1997; however, some sources such as Wich, 1973 refer to it as CI Pigment Yellow 112). Sometimes known as flavanthrone yellow.
See: polycyclic pigments group: flavanthrone/Indanthrone sub-group.

Polycyclic pigments group: Flavanthrone/Indanthrone sub-group
Colour Index (1971) 70600; Herbst & Hunger (1997); Wich (1973)

FLAVIN LAKE

Yellow
Synonym, variant or common name

According to Gettens and Stout (1966), flavin lake was a lake pigment based on quercitron (*q.v.*). Flavin was in fact a form of quercitron derived from treatment of a boiling decoction of this with sulfuric acid.

Quercitron
Gettens & Stout (1966)

FLAVOKERMESIC ACID

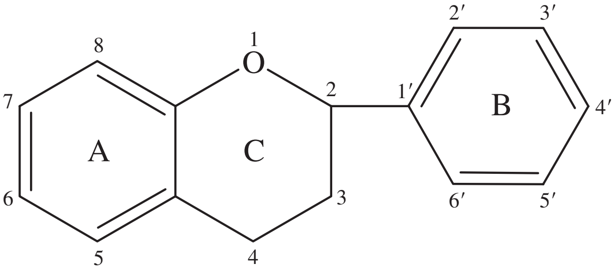
Yellow-Orange
Synonym, variant or common name

See: kermesic acid.

FLAVONOIDS GROUP

Variable
Group term

The flavonoids form a large and important class of polyphenolic compounds derived from the flavone structure. All flavonoids have the same basic chemical structure, comprising a three-ringed molecule with multiple hydroxyl (OH) groups attached. The family of flavonoids arises by varying the chemical nature of the substituents on these rings, and glycosides of flavonoids (that is, flavonoids that contain a sugar molecule such as rhamnose, glucose or galactose, etc., attached to the ring) often occur in foods. Quercetin is known as the 'aglycone' of a number of other flavonoids since it lacks a sugar residue on the central ring, whereas rutin has the same basic structure but bears a sugar residue in place of one of quercetin's hydroxyl groups on the central ring.



Some flavonoids, such as the anthocyanins, are intensely coloured, giving the red to blue colour in flowers, fruit and leaves; others, like the flavones, are essentially colourless. Flavonoids are pervasive throughout the plant kingdom and are present as the principal colourants in many dyestuffs found in nature.

The chemistry of flavonoids is highly complex, though a number of sub-groups are commonly defined (Harborne and Baxter, 1999):

Flavones and flavone *O*-glycosides
Flavonols and flavonol *O*-glycosides
C-Glycosylflavones
Biflavonyls
Anthocyanins
Chalcones
Dihydrochalcones
Aurones
Flavanones
Dihydroflavanols
Flavans and proanthocyanins
Isoflavonoids and neoflavonoids

Examples of flavonol compounds encountered in dyes include quercetin and rutin, while the flavones include apigenin and luteolin.

Berberine; Calcium euxanthate; Euxanthic acid; Euxanthone; Fisetin; Indian yellow; Luteolin; Magnesium euxanthate; Morin; Quercetin; Quercitron; Rhamnus; Weld; *Old fustic*; *Rue*; *Young fustic*
Harborne & Baxter (1999)

FLEMISH BLACK

Black
Synonym, variant or common name

FLEMISH WHITE

White
Synonym, variant or common name

Salter, writing in 1869, states that 'the whites of lead are carbonates of that metal with two exceptions:- Flemish white or the sulphate, and Pattison's white or the oxychloride'. Field (1835) specifically remarks that Flemish white 'is an exceedingly white precipitate from any solution of lead by sulphuric acid much resembling the blanc d'argent'. Harley (1982) states that the chemist and author Bachhoffner (1837), who also acted as an artists' colourman at that time, is recorded as selling the precipitated lead sulfate under the name Flemish white. Mayer (1991) on the other hand gives this term for lead white (*q.v.*).

Lead white; *Pattison's white*
Bachhoffner (1837) 93; Field (1835) 69; Harley (1982) 180; Mayer (1991); Salter (1869) 67–68, 72–73

FLORENCE BROWN

Brown
Synonym, variant or common name

According to Bazzi (1956), Florence (or Florentine) brown is a copper ferrocyanide (copper hexacyanoferrate(II) pigments) and therefore associated with terms such as Hatchett's brown and Vandyke red. Doerner (1935) also gives Roman brown as a directly equivalent term.

Hexacyanoferrate group; Copper hexacyanoferrate(II)
Bazzi (1956); Doerner (1935) 88

FLORENTINE LAKE

Red
Synonym, variant or common name

Salter (1869) classifies this under the general heading of cochineal lakes, stating that Florentine lake differs from scarlet lake (*qq.v.*) only in the way it was prepared and adding that 'Formerly the lake … was extracted from the shreds of scarlet cloth' (see: Cimatura). By the time Heaton was writing in 1928 the term was apparently obsolete or very little used. According to Schweppe and Roosen-Runge (1986) the term is in reference to the early production of the pigment in Florence; however, along with similar terms such as Viennese, Venetian and Parisian lake, it was probably fanciful in derivation. Also sometimes called Florence lake (for example, Osborn, 1845).

Cochineal; *Cimatura*; *Scarlet lake*
Heaton (1928) 381; Osborn (1845) 20; Salter (1869) 137; Schweppe & Roosen-Runge (1986)

FLOREY

Blue
Synonym, variant or common name

A term for indigo (*q.v.*) pigment produced by collecting the froth from the top of a dying vat before the dye is used (Harley, 1982).

Indigo
Harley (1982) 66

FLUORAPATITE

White
Generic compound

Fluorapatite is the commonest occurring variety of apatite. While the formula is commonly given as $Ca_5(PO_4)_3F$, minor substitutions of fluorine by chlorine or the hydroxyl group $[(OH)^-]$

are expected. A variety of metallic elements can also substitute for the calcium. Fluorapatite was considered to be a major constituent of bone (e.g. Mehmel, 1930), although more recent research indicates that the inorganic component of bone is the carbonate-hydroxylapatite, dahllite (*qq.v.*; e.g. Reiche *et al.*, 2002).

Apatite group; Calcium group; Calcium phosphates group; Bone; Dahllite
Mehmel (1930); Reiche *et al.* (2002)

FLUORITE
Variable
Generic compound

Fluorite, also known as fluorspar, is a cubic halide mineral with chemical formula CaF_2. It varies in colour considerably, with purple, green, yellow, white and colourless crystals being the most common. The variation in colour has been attributed to irradiation-induced lattice defect concentrations, which may be replaced by rare earth ions. Fluorite is fluorescent and this property may be correlated with high rare earth concentration. Fluorite commonly forms as interpenetrant cubes and is a late-stage in mineral in granitic or alkali igneous rocks. It is also found in veins associated with hydrothermal or pneumatolytic activity and may also occur as a detrital mineral in sedimentary rocks (such as the Elgin Trias, Scotland). Fluorite is therefore relatively common and forms in association with many minerals; it is most often found with galena, calcite, quartz, pyrite and apatite group minerals (*qq.v.*). Notable occurrences for fluorite are the Peak District (England), Harz and Saxony (Germany), Chihuahua (Mexico), Broken Hill (New South Wales, Australia), Cordoba (Argentina), Minas Gerais (Brazil) and Beira-Beixa (Portugal). The name fluorite, introduced by Napione in 1797, is derived from the Latin *fluere*, meaning 'to flow', which refers to the easily fusible nature of this mineral. Compositional and structural properties of fluorite have been discussed by Allen (1952).

Pliny (77 AD) used the term *myrrhina* for fluorite which was used to make decorative vases and goblets, the name being derived from the fact that they were repaired using liquid myrrh. More crucially, Agricola (1556) mentions in *De Natura Fossilum* that yellow and purple varieties of fluorite were used as pigments and Richter *et al.* (2001) have recently reported that purple fluorite has been identified on a small number of painted works of art from the mid-fifteenth/early sixteenth century in a discreet area of Europe, in particular from southern Germany, the Austrian Tyrol, Switzerland, Hungary and Silesia in Poland. This is a dark purple-black variety of fluorite known as antozonite, which occurs in the form of nodules, often banded, with an internal radiating structure. It is apparently restricted to the Nabburg-Wölsendorf and Kittenrain areas of Bavaria (Germany), Quincié and Lantignié (France), and Joachimsthal in the Czech Republic. In German it is known as *stinkspat* on account of the odour released during grinding of this mineral. A similar purple variety of fluorite is 'Blue John', mined in the Castleton area of Derbyshire (England); actual use of this source as a pigment seems unlikely. The fluorite identified on works of art is often reported as mixed with lead white (*q.v.*) or calcite to enhance its purple colour and to improve its hiding power. Spring has additionally reported on the occurrence of fluorite on a number of Netherlandish paintings of the first half of the sixteenth century (Spring, 2000).

It is likely that other occurrences of fluorite as a pigment exist but that it has been misidentified to date either as amethyst (*q.v.*) or as some other purple pigment.

Apatite group; Calcium group; Calcium halides group; Amethyst; Calcite; Galena; Pyrite; Quartz; *Lead white*
Agricola (1556/trans. Hoover & Hoover, 1950) 380–381; Allen (1952); Pliny (1st cent AD/Rackham, 1952) XXXV.xlvi.164; Richter *et al.* (2001); Spring (2000)

FLUORSPAR
Variable
Synonym, variant or common name

Fluorspar is synonymous with fluorite (*q.v.*).

Fluorite

FOLIUM
Purple
Synonym, variant or common name

A purple dye derived from *Chrozophora tinctoria* (L.) A. Juss., also generally known as turnsole. Thompson (1956) cites fourteenth century texts which relate this colour to the plant 'morella', which is in turn related to the Provençale 'maurelle', this being a term for turnsole which is then shown to refer to *Chrozophora tinctoria* L. Mediaeval accounts show an awareness that berries of this plant could produce a red dye when acid, through violet to blue when alkaline. However, this term generally refers to the purple phase.

The *Book of Master Peter of St. Audemar on Making Colours* (Clarke MS 2790, cf. Merrifield, 1849) states: '*Of Folium* … The purple colour called folium by the laity, by whom (or rather by the English, in whose country it is prepared, and who call it *worina*) it is used in dying wool, is not always tempered in the same manner; for some persons distemper it with urine, or with ley made from the ashes of ash trees, and particularly on walls; while others, on parchment, distemper it with cheese-glue.' However, the same author later adds that 'there are three kinds of folium; one purple, another red, and a third sapphire blue'. Theophilus (c. twelfth century) also describes these three colours of folium. Merrifield has explained that the term folium may have come about as the colour was prepared for use by dyeing cloth with *Chrozophora tinctoria* L. and then dried and stored in between the leaves of books or folios. An alternative explanation is given by Friedman (1995), who suggests that the 's' in the Latin *Torna-ad-soleum* was confused with 'f' by later writers.

For a fuller discussion, see: Turnsole.

Friedman (1995) Appendix A; Merrifield (1849) I, 128; Theophilus (c. 12th cent/Hawthorne & Smith 1963) 38–39; Thompson (1956) 141–142

FORSTERITE
Green
Generic compound

Forsterite is a magnesium silicate mineral with composition Mg_2SiO_4 (Deer *et al.*, 1992; Belov *et al.*, 1951). It is the one of the end-members of the olivine group of minerals and forms a solid solution series with the second end-member fayalite, Fe_2SiO_4. Forsterite is named after the English mineral collector A.J. Forster (1739–1806), and was first reported by Levy in 1824 from Vesuvius, Italy (Dana, 1932). The term forsterite should strictly be used to refer to an olivine with a narrow compositional range, containing up to 10% Fe_2SiO_4; however, it is often used to describe any Mg-rich member of the olivine group. Forsterite occurs as prismatic green vitreous crystals or as aggregates of anhedral crystals. Pure forsterite is found in thermally metamorphosed impure dolomite-rich rocks, often in association with diopside and wollastonite (*qq.v.*); Mg-rich olivines, which may also contain manganese and calcium, are found in ultrabasic and basic igneous rocks in association with augite, hornblende and plagioclase feldspar (*qq.v.*). Mg-rich olivines are common worldwide and are found at Kovdor (Russia), Ojamo (Finland), Eifel (Germany), Zabargad (Egypt) and Sapat (Pakistan). In the presence of water, forsterite alters readily to members of the serpentine and chlorite groups of minerals plus talc and brucite (Deer *et al.*, 1992).

Plesters (1993) indicates from analysis of the X-ray diffraction data of lazurite and ultramarine pigments, that some samples may also contain forsterite as well as quartz, calcite (*qq.v.*) and diopside.

Feldspar group; Magnesium silicates group; Augite; Diopside; Hornblende; Wollastonite
Belov *et al.* (1951); Dana (1932) 599; Deer *et al.* (1992) 3–13; Plesters (1993) 49

FOUNDATION WHITE

White
Synonym, variant or common name

According to Seward (1889) foundation white was a combination of lead white and zinc white (*qq.v.*). Heaton (1928) also lists this as a then-current term, referring to it as 'reduced' lead white.

Lead white; *Zinc white*
Heaton (1928) 381; Seward (1889)

FRANGULIN

Yellow
Generic compound

Two closely related anthraquinone compounds (*Frangulin A* and *B*) are found in the berries, bark and root-bark of various *Rhamnus* species, notably *Rhamnus frangula* L. (formerly *Frangula alnus*?), *Rhamnus carthatica* L. and *Rhamnus purshiana* DC. (Rhamnaceae). Frangulin A is 1,3,8-trihydroxy-6-methylanthraquinone-1-rhamnoside (also: emodin-l-rhamnoside; rhamnoxanthin) while frangulin B is 6-O-(d-apiofuranosyl)-1,6,8-trihydroxy-3-methylanthraquinone (*Merck Index*, 1996). Frangulin is a component of the yellow lake pigments made from *Rhamnus* (*q.v.*) species.

Also known as franguloside, avornin and cascarin (*Merck Index*, 1996).

Anthraquinones group; Rhamnus
Merck Index (1996) 4288

FRANKFORT BLACK

Black
Synonym, variant or common name

According to Field (1835) this was made from 'the lees of wine from which the tartar has been washed, by burning, in the manner of ivory black'. While one might assume that it was a product of the German city of Frankfurt, Watin (1785) states that this black also came from Strasbourg and Mayence. The French variety is said to be superior. Field also noted that inferior Frankfort black 'is merely levigated charcoal', while the Mallet (1870) edition of Field states that it is 'animal charcoal mixed with some fine sort of lamp black' (*qq.v.*). Heaton (1928) however, simply lists Frankfort black as synonymous with 'drop black', a term which otherwise means a bone black.
See: carbon-based blacks group: cokes sub-group.

Carbon-based blacks group: Cokes sub-group; *Animal black*; *Ivory black*; *Lamp black*
Field (1835) 180; Heaton (1928) 381; Mallet (1870); Watin (1773/edition of 1785) 36

FRANKLINITE

Black
Generic compound

Franklinite is a zinc iron oxide mineral with ideal composition $ZnFe_2^{3+}O_4$, although it may also contain appreciable Mn and Fe^{2+}. It is a member of the magnetite series of minerals, which includes magnetite itself and jacobsite (*qq.v.*). Like the other members in this series, franklinite is black, cubic and magnetic, commonly crystallising as octahedral crystals with a metallic lustre; it may also occur as granular or massive varieties. The magnetite series is itself a sub-group of the spinel group, which is comprised of oxides with the general formula $X^{2+}Y_2^{3+}O_4$ and the same cubic crystal structure. Franklinite most commonly forms as lenses or rounded grains in metasomatised limestone, or from the contact metamorphism of existing hydrothermal zinc deposits where it is associated with willemite, zincite and calcite (*qq.v.*). It is named after its occurrence in the zinc ore deposits at Franklin and Sterling Hill, New Jersey, USA (Rutley, 1988).

Although natural franklinite is not known to have been used as a pigment itself, synthetic iron zinc oxide (*q.v.*) is listed in the *Colour Index* (1971) as CI Pigment Yellow 119.

Iron group; Iron oxides and hydroxides group; Zinc group; Iron zinc oxide; Calcite; Jacobsite; Magnetite; Zincite; Zinc oxide
Colour Index (1971) 77496, 77950; Rutley (1988) 282–283

FRAXINUS

Yellow
Common generic composite

A species of *Fraxinus* (*F. americana*) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *ilin*.

Flavonoids group
Wallert (1995c)

FREEMAN'S WHITE

White
Synonym, variant or common name

Freeman's white, also called permanent flake white, was a combination of lead sulfate and zinc white manufactured and patented by Joseph Benjamin Freeman in 1882; it was subsequently manufactured by Messrs Freeman & Co. (Seward, 1889; cf. Carlyle, 2001). Church (1901) describes its preparation by precipitating lead acetate with sulfuric acid; this was then ground with small quantities of zinc white and barium sulfate (*qq.v.*). The addition of barium sulfate was the subject of Freeman's second patent in 1885. Laurie (1895; cf. Carlyle) gives several synonyms for this pigment including new flake white, Cambridge white, and marble white. Toch (1916) describes a pigment with specific proportions called Ozark white (*q.v.*). Heaton (1928) on the other hand lists it as an obsolete or rarely used pigment. Corbeil *et al.* (1999) add that the name 'Freeman' is part of many versions of a name used indiscriminantly for lead sulfate, or for mixtures of lead sulfate and zinc white.

This pigment has been discussed more recently by Corbeil *et al.* and its occurrence in works by the Canadian artist Tom Tompson and the Group of Seven.

Lead sulfates group; Barium sulfate; Zinc oxide; *Ozark white*; *Zinc white*
Carlyle (2001) 515; Church (1901) 133; Corbeil *et al.* (1999); Heaton (1928) 381; Laurie (1895) 49; Seward (1889) 42; Toch (1916) 39–41

French berries
Yellow
Synonym, variant or common name

Various species of *Rhamnus* produce a dyestuff, generally extracted from the unripe berries; these latter are known as yellow berries, buckthorn, French berries or Avignon berries. This is the dye used to produce the various yellow lake pigments called *pinks*. Harley (1982) states that this term also came to be applied to the pigment as the term pink fell into disuse. See also: Avignon berries, pink and *Stil de Grain*.

For a fuller discussion of the species involved, constituent compounds, substrates and alternative terminology, see the entry *Rhamnus*.

Flavonoids group; Rhamnus; *Dutch pink*; *English pink*; *French pink*
Harley (1982) 109

French blue
Blue
Synonym, variant or common name

Synonym for (synthetic) blue ultramarine, specifically of course that known as French ultramarine (*qq.v.*). The term is used, for example, by Salter (1869) and Heaton (1928).

Ultramarine; *French ultramarine*
Heaton (1928) 381; Salter (1869) 215–216

French chalk
White
Synonym, variant or common name

See: talc.

French chrome yellow
Yellow
Synonym, variant or common name

Kühn and Curran (1986), citing Mierzinski (1881), indicate that old forms of this pigment consisted of chrome yellow (*q.v.*) and alum, a hydrous potassium aluminium sulfate. The same pigment mixture is also given for Spooner's chrome yellow and Baltimore chrome yellow (*q.v.*) by the same source.

Lead chromates group; *Baltimore chrome yellow*; *Chrome yellow*
Kühn & Curran (1986); Mierzinski (1881) 134

French green
Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

French pink
Yellow
Synonym, variant or common name

A yellow lake colour. It is called French as this refers to the berries used in its manufacture, these coming from certain species of *Rhamnus* (probably *R. alaternus* and *R. infectorius*) which were grown in France (*OED*, 2002). Dossie (1764), for example, mentions the use of 'French berries' in the preparation of Dutch pink (*q.v.*) and light pink. However, in France the berries of *R. alaternus* and *R. infectorius* were known as '*graine d'Avignon*', a term also used in translation as Avignon berries.
See: rhamnus for a fuller discussion.

Rhamnus; *Ancorca*; *Avignon berries*; *Dutch pink*; *English pink*; *French berries*; *Stil de Grain*
Dossie (1764) 103; *OED* (2002) 'Pink'

French purple
Red-Purple
Synonym, variant or common name

In a discussion of archil – that is, orchil (*q.v.*) a lichen dye – Salter (1869) states that 'Soluble in water and alcohol, this colouring principle yields by precipitation with chloride of calcium a compound known as "Solid French Purple".' Bersch (1901) adds to this, remarking that 'French Purple is a compound of the archil colouring matter with lime … a garnet red precipitate is produced'.

Lichens group
Bersch (1901) 381–382; Salter (1869) 303–304

French ultramarine
Blue
Synonym, variant or common name

Essentially a varietal form of synthetic ultramarine, Salter (1869), for example, relates it to brilliant ultramarine (*qq.v.*; a product of the Guimet process) as 'a rich deep colour … less transparent and vivid'. More recently the term seems to have been used as a general term for any synthetic ultramarine.

Ultramarine; *Brilliant ultramarine*
Salter (1869) 215–216

French veronese green
Green
Synonym, variant or common name

Veronese green appears in France to have originally referred to emerald green (*q.v.*). When describing the latter, Martel (1859) noted that 'By the French it is called Paul Véronèse Green', while Salter (1869) stated that French Veronese green was often adulterated with arsenic. The term was still apparently in use when Heaton was writing in the early twentieth century.

Emerald green
Heaton (1928) 381; Martel (1860) 28; Salter (1869) 268

French white
White
Synonym, variant or common name

Field (1835) considers this to be a high quality lead white, the name synonymous with blanc d'argent and silver white while Scott Taylor (1885) adds that French white was a synonym for ceruse (*qq.v.*). Salter (1869) elaborates that French white 'is brought from Paris in the form of drops, it is exquisitely white, but of less body than flake white'.

Lead carbonates group; *Blanc d'argent*; *Ceruse*; *Lead white*; *Silver white*
Field (1835); Salter (1869) 71; Scott Taylor (1885) 191

FRUITSTONE BLACK

Black
Synonym, variant or common name

See: carbon-based blacks group: chars sub-group.

FUCHSINE

Red
Synonym, variant or common name

See: magenta.

FUCHSITE

Green
Generic variety

See: muscovite.

FULIGINO

Black-Brown
Synonym, variant or common name

See: bistre.

FULIGO

Black-Brown
Synonym, variant or common name

See: bistre.

FULLER'S EARTH

White
Synonym, variant or common name

Fuller's earth refers to a clay which has a particularly high capacity for absorbing water and organic molecules. For this reason, although generally white in colour, it may vary in colour to green, brown, grey or blue (Newman and Brown, 1987). The principal components of this material are the smectite group of clay minerals, with the main consituent being montmorillonite (*qq.v.*). Fuller's earth is formed from the weathering of basic igneous rocks; in southern England this name also refers to a particular stratigraphical formation. This material has been used primarily through the centuries for cleansing cloth and wool ('fulling', from which the name derives) as its absorbent properties allow the removal of oils.

Listed as a pigment term by Gettens and Stout (1966), though not by many other sources. It is sometimes associated synonymously with kaolin (*q.v.*), although the two really have distinct meanings.

Clay minerals group; Clay minerals group: Smectite sub-group; Montmorillonite; Kaolin
Gettens & Stout (1966) 114; Newman & Brown (1987) 80

FURNACE BLACK

Black
Synonym, variant or common name

The furnace black process was developed in the US in the 1920s and, since that time, has been greatly refined. It is a continuous process, carried out in closed reactors, which produces a flame carbon. Using petrochemical and coal tar oils as feedstocks, this material is injected, usually as an atomised spray into a high temperature zone (~1200–1900°C) formed by burning an additional fuel such as natural gas or oil with air. The oxygen, which is in excess to that required by the fuel alone, is also insufficient for the complete combustion of the feedstock; as a result the feedstock is partially pyrolysed to form the carbon black (Buxbaum, 1998).
See: carbon-based blacks group: flame carbons sub-group.

Carbon-based blacks group: Flame carbons sub-group
Buxbaum (1998) 150–156

FUSAIN

Black
Common generic composite

Fusain is fossil charcoal, a coal lithotype sometimes called 'mother-of-coal'. Fusain is dominated by the inertinite maceral group (see: coal) and composed of carbon rich, partially oxidised plant remains. The material has no fuel value but produces a velvety black pigment, similar to charcoal. However, this can also refer to a charcoal crayon made of the wood of the spindle tree (*Euonymus europaeus* L.), called in French *fusain*, and drawings made thereof (*OED*, 2002, citing nineteenth century examples).

Coal
OED (2002) 'Fusain'

FUSTIC

Yellow
Synonym, variant or common name

There were two types of fustic – 'old' and 'young'. Both were used as dyestuffs and they could also be used in the preparation of yellow lake pigments; in practice, only *Maclura tinctoria* is mentioned for this latter purpose (Harley, 1982).

Old fustic was derived from *Maclura tinctoria* (L.) Steudel (formerly *Chlorophora tinctoria* (L.) Gaud. and *Morus tinctoria* L.), the principal colouring matter being the yellow flavonoid dye morin (*q.v.*). This was introduced to Europe from the West Indies and Central America in the sixteenth century and had a limited use as a watercolour. It is referred to in the BL Stowe MS 680 as 'ffusticke yealowe' under the heading fine yellows. It was also used by the colourman's firm Berger in the early nineteenth century in the manufacture of yellow lake pigments (Harley, 1982). There is significant confusion regarding the term 'mulberry', so that, for example, Boyle mentions a yellow dye extracted from mulberry trees (cf. Harley, 1982). This apparently derives from the changing botanical names for what is currently *Maclura tinctoria*. Essentially this species belongs to the Moraceae, which also includes *Morus* ('mulberry'); *Maclura tinctoria* was previously called *Morus tinctoria*.

Young fustic came from *Cotinus coggyria* (formerly *Rhus cotinus*; commonly known as Venetian or dyer's sumach). It is a yellow dye principally containing the flavonoid compound fisetin (*q.v.*) as well as fustin.

Flavonoids group; Fisetin; Morin
Harley (1982) 104–105, 118

G

Gadus herba

Blue

Synonym, variant or common name

Historical term associated with woad (*q.v.*; indigoid dyestuff derived from the plant *Isatis tinctoria*). Listed by Schweppe (1997).
See: indigo.

Woad
Schweppe (1997)

Gahn's ultramarine

Blue

Synonym, variant or common name

J.G. Gahn was one of the early discoverers of cobalt aluminate pigments. Just before 1777, Gahn observed that after moistening aluminium compounds with cobalt solution they turn blue when calcined. For this reason, cobalt aluminate pigments formed according to his methodology are called Gahn's blue or Gahn's ultramarine. Berzelius (1845) states it to be a compound of cobalt oxide and alumina made through precipitation of a mixture of an iron-free alumina salt with a pure cobalt solution that is free of nickel and iron. Alternatively, it can be made by pouring cobalt nitrate over a precipitation of alumina, then drying and calcining it. Depending on the amount of cobalt the colour has a deeper or a lighter tone. 'Gahn's ultramarine' is also specifically described by Riffault *et al.* (1874), as a combination of aluminium oxide with cobalt oxide. It is prepared by taking an alum solution and dissolving in it a nitrate, sulfate or chloride of cobalt, a pink-white precipitate being formed with sodium or potassium carbonate. The product is then washed, dried and calcined in a crucible at high temperature.
See also: cobalt ultramarine.

Cobalt ultramarine
Berzeluis (1845); Mayer (1991) 45; Riffault *et al.* (1874) 340

Galena

Grey

Generic compound

Galena is a dark grey metallic lead sulfide mineral with composition PbS. It commonly crystallises as cubes which may be interpenetrant, although it may also have granular and massive form (Dana, 1944). Galena is a common mineral worldwide in hydrothermal veins or large metasomatic deposits (e.g. Pennines, England; Tri-State Field, Mississippi, USA; Broken Hill, Australia; Magdelena mines, New Mexico; Blyklippen mine, Greenland; Dal'Negorsk, Russia), and as a replacement or detrital mineral in many rock types (such as limestones in Leadville, Colorado, USA). It is one of the most common lead minerals and is often found in association with sphalerite (*q.v.*; Rutley, 1988). Structural aspects of galena have been discussed by Greninger *et al.* (1970).

The term was used by Pliny (77 AD) to describe lead ore. It has more recently been known as lead glance. Galena is used as the starting point for various other compounds used as pigments, notably lead sulfates (*q.v.*), and is a chief component of blue lead (*q.v.*) whose characteristic colour is attributable to lead sulfide and carbon. 'Sulphide of lead' is mentioned in Field's *Chromatography* (1835) as well as the Salter edition of that work (1869). References are otherwise rare, although galena has been recently found on paintings by Maneri and Costa in the National Gallery, London, where it was used to create the grey of armour.

Lead sulfates group; Lead sulfides group; Sphalerite; *Blue lead*
Dana (1944) 200; Field (1835); Greninger *et al.* (1970); Pliny (1st cent AD/Rackham, 1952) XXXIII.xxxi.95; Rutley (1988) 236; Salter (1869) 394

Gall, ox

Yellow

Synonym, variant or common name

See: gallstone.

Gallic acid

White

Generic compound

3,4,5-Trihydroxybenzoic acid. A colourless crystalline organic acid found in gallnuts, sumach, tea leaves, oak bark and many other plants, both in its free state and as part of the tannin molecule. Since gallic acid has hydroxyl groups and a carboxylic acid group in the same molecule, two molecules of it can react with one another to form an ester, digallic acid. Gallic acid is obtained by the hydrolysis of tannic acid with sulfuric acid (*Columbia Encyclopedia*, 2003).

Columbia Encyclopedia (2003)

Gallstone

Yellow-Brown

Synonym, variant or common name

There is mention in a Greek manuscript from the third century AD and an eighth century manuscript in Italy (Thompson, 1956) of fish gall ground with chalk and vinegar to make 'a colour similar to orpiment'. There is also mention of the use of 'tortoise bile'. Thompson indicates that this was 'to make … gilded letters'. Such use of 'guttas agrimonii' is also described in a recipe given in a German manuscript of c. 1470 (Clarke MS 2160; cf. Ploss, 1955) and in the so-called Colmarer Kunstbuch (Clarke MS 150; cf. Oltrogge, 2003) where it is called aureus lombarticus. Gall of eels ('Gaule of Eeles'), bile from the gall bladder of eels and gallstones have also been reported in this context. Thompson also indicates the use of the term Lombard gold to indicate a bile yellow.

Seventeenth century English sources such as Hilliard and Norgate (early 17th C.), as well as French sources such as Boutet (1674), describe the use of gallstones from oxen. This gave a dark yellow pigment, with preparation by grinding. Dossie (1764) recommends as a substitute ox bile, which was taken up by colourmen at the end of the eighteenth century as 'gallstone', although it was clearly rarely then used; by the nineteenth century commercial products were probably largely substitutes formulated from quercitron lakes (Harley, 1982). Salter, writing in 1869, adds that gallstone is 'a deep-toned yellow, affording richer tints than most other yellows […] A true gallstone is an animal calculus formed in the gall-bladder, chiefly of oxen; but the pigment sold under that name is often replaced by a substitute, resembling the original colour, but of greater stability.' Literature has also indicated the use of fish bile or gall to produce bile yellow. By the time Heaton was writing in the early twentieth century, he lists gallstone as an obsolete or little used pigment based on a yellow quercitron lake.

Leechman (1932) describes a yellow derived from buffalo gall bladder as being used as a pigment in the Canadian East Coast Haida and Tsimshian painting technique.

In mammals, about 80% of the bile is recycled through the liver and gall bladder. Bile is composed mainly of bilirubin and biliverdin, which are breakdown products of hemoglobin, and is produced continuously. There are a few studies in fish which suggest that bile serves similar functions. Calculi are usually composed of hydroxylapatite and chemical studies of gallstones has shown that they consist of macromolecules such as proteins, glyco-proteins, polysaccharides, bilirubin polymers and pigment polymers, and biomolecules such as cholesterol, bile salts, fatty acids and bilirubinate as well as various metal ions. The binding of metal ions with bile salts and bilirubin plays important roles in gallstone formation – for example, calcium bilirubinate complex is the major constitute of so-called brown-pigment gallstones, and copper bilirubinate complex is critical in the black colour appearance of black-pigment gallstone (Sun *et al.*, 2001).

Bile yellow; *Gall, ox*; *Lombard gold*
Boutet (1674); Dossie (1764) 106; Harley (1982) 105; Heaton (1928) 381; Hilliard (1624/ Thornton & Cain, 1981) 94; Leechman (1932); Norgate/ Thornton & McCain (early 17th C./1981); Oltrogge (2003); Ploss (1955) 156; Salter (1869) 95–96; Sun *et al.* (2001); Thompson (1956) 178–179

GAMBOGE

Yellow
Generic compound

Gamboge is a brown resin derived from various species of the evergreen trees of the family Guttiferae (Clusiaceae) growing in South East Asia. The main varieties from which resin is harvested are *Garcinia hanburyi* Hook, growing principally in Cambodia and Thailand, *G. morella, G. cambogia* Desrouss (from India and Sri Lanka), *G. elliptica* Wall and *G. heterandra* Wall (from Myanmar). The resin was tapped from the trees from cuts spiralling down the trunks and collected into bamboo canes. The resulting tubes of the solidified pigment (the form in which it was sold) were called pipe gamboge. In its natural hardened state, the resin is a brownish red colour, becoming bright yellow when ground. There is a recent review of gamboge as a pigment by Winter (1997).

Gamboge contains 70–80% resin and 15–25% water-soluble gum (Howes, 1949). Gambogic acid (*q.v.*) appears to be the main constituent of the resin (Venkataraman, 1973). Asano *et al.* (1995) have recently isolated the previously unrecognised xanthones gambogin, morellin dimethyl acetal, isomoreollin B, moreollic acid, gambogenic acid, gambogenin, isogambogenin, desoxygambogenin, gambogenin dimethyl acetal, gambogellic acid and hanburin from resin collected from *G. hanburyi* Hook. The chemistry of these compounds is complex and the interested reader is referred to Asano *et al.* for further discussion. Asano *et al.* (1995) also isolated morellic acid, isomorellin and desoxymorellin from *G. hanburyi* gamboge. These compounds were previously thought to have been restricted to the *G. morella* varieties. Many of the constituents of gamboge are cytotoxins and the pigment is poisonous and a strong diuretic. Fewer analyses have been performed upon the gum fraction of gamboge. Winter (1997) reviews those that have been made, concluding that it is carbohydrate based, containing arabinose, galactose, rhamnose and glucuronic acid plus triterpene alcohols.

The pigment could be used in most media, though it appears likely to react with lime and is therefore unsuitable for frescos. Weber (1923) writes that gamboge is incompatible with white lead, but otherwise it appears to be a stable and non-fugitive pigment. Harley quotes Smith's (1676) simple method for creating a water colour, by making a hole in the solid gum, adding water and stirring until the water became the acceptable deep shade of yellow. The pigment could also be used as an oil colour in a resin or wax tempered medium. Gamboge was mixed with Prussian blue to make green and with burnt sienna to make orange (Harley, 1982). According to Winter (1997), it was often adulterated with pine resin (colophony) and starch and even occasionally sand, rice meal and dextrin. Starch was known to alter the colour and this was corrected by the addition of lead chromate.

Identifications of gamboge in art are scarce and often imprecise, despite the fact that the pigment was well known and apparently frequently used both in the east and the west. Occurrences in Japanese art are listed by Winter (1997) from the eighth through nineteenth centuries; in addition, Nishio (1987) discusses traditional techniques for applying the pigment in Japanese art. In Thailand, gamboge has been found underlying gold paint in the wall paintings of Maitepnimit Temple (Prasartset, 1990).

Early European use of gamboge has been tentatively identified in the Medieval Armenian Glajor Gospel (c. 1300 AD; Orna and Mathews, 1981). According to Harley (1982) de Mayerne (BL MS Sloane 2052) and Smith (1676) recommended gamboge as a watercolour, and it was used for tinting prints during the seventeenth century. The pigment has also been noted (but not authenticated) on a painting by Rembrandt in Dresden (Kühn, 1977). Gamboge has been identified by Townsend (1993) in J.M.W. Turner's water colour box and by Pey (1989) in the stock of the nineteenth century Amsterdam firm of Michiel Hafkenscheid & Son.

Garcinia hanburyi Hook produces the most commonly used 'Siam Gamboge'. 'Ceylon Gamboge' (from *Garcinia morella*) is also known. The name gamboge is derived from Cambodia, via cambodiam (an early name for the pigment), camboja and camboge. The term *cadie gum* was also used; however, the substance is a resin and not a gum. Other historical terms for gamboge include gambogium, gumboge, gum-booge, gumbouch and variants such as gummi gambogia, gummi gutti, gamma gitta, gom guttae (Pey, 1989; Harley, 1982; Dow, 1927). Orthographic variants on gutti are derived from the Malay word for gum, *gatah.* Harley also gives the description *Cambugio quibusdam cartharticum aureum* ('the golden yellow Indian purger') from Parkinson's *Theatrum Botanicum*. Rattan yellow is the literal translation of the Chinese name for the pigment *teng huang*, while Finlay (2002) also gives ivy yellow. The Japanese *to-o* (or alternatively *do-o* or *touo*) is the reading of the same characters, but this is translated as wisteria yellow. *Shio* was used to describe gamboge but was also applied to orpiment and seems to denote simply the colour rather than a specific pigment (Oguchi, 1969; Kitano and Koezuki, 2000). 'Extract of gamboge' was made by precipitating the colouring matter after dissolving it in alcohol and producing a powdery material, miscible in oil (Field, 1835).

Gambogic acid
Asano *et al.* (1995); Dow (1927); Field (1835) 83; Finlay (2002) 244; Harley (1982) 105–107; Howes (1949) 161; Kitano & Koezuki (2000); Kühn (1977); Nishio (1987); Oguchi (1969); Orna & Mathews (1981); Pey (1989); Prasartset (1990); Smith (1676); Townsend (1993); Venkataraman (1973); Weber (1923) 56–58; Winter (1997)

GAMBOGE ORANGE
Orange
Synonym, variant or common name

Salter (writing in 1869) notes that 'on adding acetate of lead to a potash solution of gamboge, a rich bright orange is precipitated', which he calls gamboge orange. He did not, however, recommend it as an artists' pigment.

Gamboge
Salter (1869) 257

GAMBOGIATE OF IRON
Brown
Synonym, variant or common name

A speculative pigment listed by Salter (1869), who describes it as follows: 'Dr. Scoffern read a paper at the Meeting of the British Association of Science, in 1851, describing this combination as a rich brown, like asphaltum, but richer.'

Gamboge; *Asphaltum*
Salter (1869) 357

GAMBOGIC ACID
Yellow
Generic compound

Gambogic acid, [1R-[1a,1(Z), 3aβ,5a,11β-14aS*]]-2-methyl-4-[3a,4,5,7-tetrahydro-8-hydroxy-3,3,11-trimethyl-13-(3-methyl-2-butenyl)-11-(4-methyl-3-pentenyl)-7-15-dioxo-1,5-methano-1H,3H,11H-furo[3,4-g]pyrano[3,2-b]-xanthen-1-yl]-2-butenoic acid, is a principal xanthone component of gamboge from *Garcinia hanburyi* Hook and other *Garcinia* species. It is also known as beta-guttiferin, beta-guttic acid and alpha-guttic acid (Winter, 1997). However, although this is the principal component extracted from gamboge resins, Winter also reports that a number of other compounds such as isogambogic and neogambogic acids can be derived from *G. hanburyi*. Resin extracted from *G. morella* grown in India apparently yielded the structurally closely related morellic and isomorellic acids as opposed to gambogic acid (*Merck Index*, 1996).
See: gamboge.

Xanthones group; Gamboge
Merck Index (1996) 4373; Winter (1997)

GARANCIA
Red
Synonym, variant or common name

A sixteenth century Italian term for madder (*q.v.*; Merrifield, 1849).

Madder; *Warencia*
Merrifield (1849) clxxviii

GARANCINE
Red
Synonym, variant or common name

Garancine is the term for the refined dyestuff from madder root. The technique was developed to increase the brightness and intensity of the natural dyestuff and involved boiling the root in sulfuric acid. This technique was patented by Lagier, Robriquet and Colin in 1828. Further refinements of technique followed. The ground madder was allowed to stand for several days in sulfuric acid, allowing fermentation to begin. The resultant material was then compressed to produce a product sold as *fleurs de garance* or madder flowers (1852). The process continued to be improved and the products were variously named '*Piccofin*' (1854) where the purpurin was removed and the colour, although less strong, was especially pure, 'Kopp's purpurin' (1864) which increased the colouring strength up to 55 times and 'madder extract Pernod' (1867) which produced brilliant shades. Heaton (1928) lists garancine as a 'purified madder lake', indicating that the term was still in current usage at that time. For a fuller discussion of the development of garancine see Chenciner (2000).
See: madder.

Anthraquinones group; Madder
Chenciner (2000) 136–140; Heaton (1928) 381

GARDENIA SEED
Yellow
Synonym, variant or common name

According to Yü (1955), gardenia seed (*Gardenia jasminoides* Ellis) could be bought at Chinese pharmacies. They are pounded to remove the skins, then boiled, and glue is added for use. He considers that it makes a substitute for gamboge ('rattan yellow'). The dyestuff produced contains crocetin (*q.v.*; Schweppe, 1992).

Carotenoid group; Crocetin
Schweppe (1992) 174; Yü (1955/trans. Silbergold & McNair, 1988) 14

GARNET CHROME
Red-Orange
Synonym, variant or common name

Kühn and Curran (1986) state that garnet chrome was an older term for basic lead chromate (lead chromate(VI) oxide) in their discussion of chrome red and chrome orange (*qq.v.*) pigments.

Lead chromates group; Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*
Kühn & Curran (1986)

GAS BLACK
Black
Synonym, variant or common name

A form of flame carbon, gas black was produced by the incomplete combustion of gaseous hydrocarbons. According to Heaton (1928), a form of this was made with coal gas from about 1860, but proved to be too expensive; natural gas deposits provided a cheaper alternative later on. Heaton also associates the term carbon black with gas black.

The Degussa process for manufacturing gas black was developed in 1935 and is described by Buxbaum (1998). Oil vapour is carried in hydrogen, methane or coke-oven gas and combusted. Very fine particle sizes can be generated with the addition of air.

Carbon-based blacks group: Flame carbons sub-group; *Acetylene black*; *Carbon black*; *Channel black*; *Lamp black*
Buxbaum (1998) 156; Heaton (1928) 380

GAS BLUE
Blue
Synonym, variant or common name

Term for a low grade of Prussian blue. Heaton (1928) states that it is prepared from 'cyanides recovered from coal tar', further noting that 'it is dull in colour and muddy' and that 'cyanide groups may be partially replaced by carbonyl groups'.

Hexacyanoferrate group; *Prussian blue*
Heaton (1928) 160

GAUGOLI
Yellow
Synonym, variant or common name

See: Indian yellow.

GELBEISENERZ
Yellow
Synonym, variant or common name

According to Wallert (1995a) the term *gelbeisenerz*, along with the term misy, was (and sometimes still is) used to indicate substances like jarosite, natrojarosite and carphosiderite (hydronium jarosite).

Hydronium-jarosite; Jarosite; Natrojarosite; *Carphosiderite*; *Misy*
Wallert (1995a)

GELBIN'S YELLOW
Yellow
Synonym, variant or common name

According to Salter (1869), 'Gelbin's yellow, or chromate of lime, is a pale whitish yellow, poor in colour.' Kühn and Curran (1986) state that it is an obsolete term for calcium chromate(VI) used in Germany.
See: calcium chromates group.

Kühn & Curran (1986); Salter (1869) 117

GELLERT GREEN
Green
Synonym, variant or common name

The *Colour Index* (1971; CI 77335) lists this as a variant of cobalt green, a cobalt zinc oxide.

Cobalt zinc oxide; *Cobalt green*
Colour Index (1971) 77335

GENERAL
Yellow
Synonym, variant or common name

English documentary sources of the fifteenth to seventeenth centuries show the terms massicot (*q.v.*) and general used largely concurrently and synonymously. For example, Haydocke's edition of Lomazzo (1598) states, 'The matters of yeallowe, are the *yeallowe* of the *Flaunders* fornace and of *Almany*, commonly called *masticot* and *generall.*' Moreover, the appearance of the word general in English sources appears to closely match that for massicot, in around 1460–70, while further references to massicot and general can be traced through the sixteenth and early seventeenth centuries at which point general falls from use (Eastaugh, 1988). Additionally, comparable Spanish documentary sources of the period use the term *genuli* in a similar context. Veliz (1986), for example, found records of *genuli* (or *jenuli*) in colour lists for Spanish royal projects of the 1560s and 1570s. An association must therefore be supposed between general and genuli. Documentary sources such as Nunes (1615) further imply that the Spanish term *machim* was also equivalent, though at the same time drawing a distinction from massicot, Nunes indicating that genuli and machim were of a greener lemon-yellow shade. Contradictory evidence also exists as to whether the term general applied to a pigment produced specifically in one of these countries; for example, mention is made of *anglice generall* in accounts for the University of Cambridge in 1487–48 (Willis and Clarke, 1886), while general is listed among taxable imports to England in 1582 (Willan, 1962). From contextual and other evidence it is assumed that general refers to the pigment now collectively known as *lead tin yellow*, although it should be noted that Palomino (1715–24) provides a recipe for making genuli by roasting lead white. The origin of the term is obscure, though it may be related to the Italian *giallolino* or the French *jaune* (Eastaugh; Veliz).

Massicot; *Lead tin yellow*
Eastaugh (1988); Lomazzo/Haydocke (1584/1598); Nunes (1615) 55; Palomino (1715–24); Veliz (1986) 3, 9; Willan (1962); Willis & Clarke (1886)

GENISTA
Yellow
Generic compound

A dye may be derived from the broom *Genista tinctoria* L.; this principally contains the flavonoid compound genistein (*q.v.*). The seventeenth century British miniaturist Norgate (early seventeenth century) gives a recipe for 'pink' based on *Genestella tinctoria* (cf. Harley, 1982). Genista has been detected by Kirby (2003) on a painting by Nathaniel Bacon of c. 1620 and Sanyova and Wouters (1994) in lake pigments used for polychromed Antwerp altarpieces. See: rhamnus and *Stil de Grain*.

Genistein; Rhamnus; *Stil de Grain*
Harley (1982) 107; Kirby (2003); Norgate/Thornton & McCain (early 17th C./1981); Sanyova & Wouters (1994)

GENISTEIN
Yellow
Generic compound

Genistein, 4′,5,7-trihydroxyisoflavone, a flavonoid (isoflavonoid), is the principal colouring compound in the dye genista derived from *Genista tinctoria* L., Dyer's broom. The glycoside (7-D-glucoside) is called genistin (Schweppe, 1992).
See: genista.

Flavonoids group; Genista
Schweppe (1992) 334

GENTELE'S GREEN
Green
Synonym, variant or common name

See: copper tin oxide.

GENTISIN

Yellow
Generic compound

Gentisin, 1,7-dihydroxy-3-methoxy-9H-xanthen-9-one, is a xanthone compound found with isogentisin in the roots of *Gentiana lutea* L. (Gentianaceae; *Merck Index*, 1996). The latter is used to produce the obscure colouring matter called Wongshy red by Salter (1869).

Xanthones group; *Wongshy red*
Merck Index (1996) 4405; Salter (1869) 180

GENULI

Yellow
Synonym, variant or common name

See: general.

GEORGEITE

Blue
Generic compound

Georgeite is a copper(II) carbonate mineral with chemical composition $Cu_2CO_3(OH)_2$; it is an amorphous analogue of malachite (*q.v.*). Georgeite forms as a secondary mineral in the oxidised zones of copper ore deposits where it usually occurs as soft blue surface crusts. The occurrence of georgeite was first reported by Bridge *et al.* (1979) from the Carr Boyd mine (W. Australia) where it is found in association with malachite and chalconatronite (*q.v.*); a second occurrence has since been reported from the Britannia mine (North Wales) where georgeite is mainly associated with malachite. Experiments by Pollard *et al.* 1989, show that georgeite can react to form malachite or chalconatronite so that georgeite may only exist as an intermediate phase in these reactions.

Georgeite, or its synthetic analogue, is not known to have been used in an art context, but its chemical similarity to malachite and its part in the process of the formation of malachite and chalconatronite requires that it be included here.

Copper carbonates group; Chalconatronite; Malachite
Bridge *et al.* (1979); Pollard *et al.* (1989); Pollard *et al.* (1991)

GERANIUM LAKE

Red
Synonym, variant or common name

According to Weber (1923) 'Soon after the discovery of Eosin dye, in 1876, many lake pigments were introduced having this powerful and brilliant, but exceedingly fugitive dye as the coloring principal on various bases. The Geranium Lakes used principally in the fine arts are precipitated on the transparent alumina hydrate base. This colour, when produced from fugitive dyes such as Eosin, Erythrosine, etc., fades in a very short time and should not be used.' Heaton (1928) gives a fuller list of dye compounds on which Geranium and other red lakes could be based, including resorcin, phloxine and Rose Bengal.

Aluminium oxides and hydroxides group; Eosin; Erythrosine
Heaton (1928) 196; Weber (1923) 58–59

GERHARDITE

Green
Generic compound

Gerhardite is a green copper nitrate mineral which forms as soft green tabular crystals or as a massive crust. It has the chemical formula $Cu_2(NO_3)(OH)_3$ and occurs as a secondary mineral in the oxidation zone of copper ore deposits, or in cavities within massive cuprite (*q.v.*). Gerhardite was first described by Wells and Penfield from its type locality at the United Verde mine, Jerome, Arizona, USA, and is named after C.H. Gerhardt.

Gerhardite has been noted in a pigment context by Van'T Hul-Ehrnreich and Hallebeek (1972) as well as Banik (1989), although the presence of the synthetic analogue copper nitrate hydroxide in these cases cannot be excluded.

Copper nitrates and nitrites group; Copper hydroxide nitrate
Banik (1989); Van'T Hul-Ehrnreich & Hallebeek (1972)

GERMAN BLACK

Black
Synonym, variant or common name

Osborn (1845), citing an unnamed source, refers to 'the black of wine lees' (that is, a 'yeast' black) as being called German black. Heaton (1928) lists German black as a current synonym for drop black, which he in turn defines as a variety of bone black.
See: Frankfort black and carbon-based blacks group: cokes sub-group.

Carbon-based blacks group: Cokes sub-group; Yeast; *Drop black*; *Frankfort black*; *Wine lees black*; *Yeast black*
Heaton (1928) 381; Osborn (1845) 40

GERMAN BLUE

Blue
Synonym, variant or common name

As Thompson (1935) has pointed out, there is a group of terms found in certain MSS of the fourteenth and fifteenth centuries which refer to azurite and may be essentially translated as German blue; those he lists are *lapis almaine, azuro grosso d'alemagna* or *tedesco, laçurum de Alemania, azuro di Magnia, a. todisco* and *lapis lazuli de Alamagna*, though there are others.
See: azure.

Azurite
Thompson (1935) 415, n.5

GERMAN ULTRAMARINE

Blue
Synonym, variant or common name

Listed in a Winsor & Newton catalogue of 1840; presumably a synthetic ultramarine produced by the Gmelin method (Carlyle, 2001).
See: ultramarine.

Carlyle (2001) 476

GIALLO DI VETRO

Yellow
Synonym, variant or common name

In the *Vocabulario Toscano*, Baldinucci (1681) describes *'Giallorino m. Una sorta di colore giallo, che ferue per a olio, e lo portano di Fiandra. Euui un altra sorta di giallorino, che viene di Venezia, composto del giallorino di Fiandra, e del giallo di vetro; e serue ancora esso allo stesso effeto'* ('Giallorino M.: A yellow colour for oils, imported from Flanders. There is another type of giallorino from Venice consisting of Flanders giallorino and glass yellow, which is also used in oils.') The nature of the 'glass yellow' that he mentions is uncertain, although it is surmised to be a pigment from the lead-tin-antimony group of compounds. Roughly contemporaneous Venetian sources such as the Darduin MS do give recipes for the production of yellow opacifiers for glass and the meaning may be that the pigment was produced by or for glassmaking rather than as a vitreous pigment *per se* (Darduin, 1644; Eastaugh, 1988).

Giallolino
Baldinucci (1681) 67; Darduin MS (1644); Eastaugh (1988)

GIALLO SANTO

Yellow
Synonym, variant or common name

A yellow lake called *giallo santo* is described by Borghini (1584) as being of a vegetable origin and to be used in oil. This is clearly a good description as Italian manuscripts give varying sources for the colour. The Paduan MS provides a recipe: '133. To make giallo santo. – Take the berries of the buckthorn towards the end of the month of August, boil them with pure water, until the water is loaded and thick with colour; add a little burnt roche alum and then strain it. You may boil the strained liquor to make the colour deeper, mixing with it some very pure gilder's gesso; then make the colour into pellets, and dry them in the shade' (cf. and tr. Merrifield, 1849). Thus the term relates to *spincervino yellow* ('giallo di Spincervino') 'spincervino' being an Italian term for *Rhamnus cathartica* L. (buckthorn). Merrifield also notes that giallo santo is documented as 'made of the flowers of the *Erba Lizza, Barba di Becco* (yellow goat's beard; *Tragopogon pratensis* L. (Compositae), finally adding that it could consequently be made from various plants. 'Other plants used to produce yellow lakes were dyer's broom (*Genista tinctoria* L.) or weld (*Reseda luteola* L.). The term is also associated historically in Italy with the Latin term *prugna meroli*. English writers sometimes called this Italian pink.
See: rhamnus, genista and weld.

Genista; Rhamnus; Weld; *Italian pink*
Borghini (1584/edition of 1787) I, 249; Merrifield (1849) clxiv, 708

GIALLOLINO

Yellow
Synonym, variant or common name

Term found in numerous Italian documentary sources that relates to various lead-based yellow pigments, most notably the lead tin and lead antimony oxides. Unambiguous references to *giallolino* occur in Italian documentary sources from the fourteenth century onward. It is mentioned, for example, in relation to the decoration of the chapel of S. Jacopo at Pistoia in 1347 (Eastlake, 1847), in the late fourteenth century treatise *De Arte Illuminandi* (Thompson and Hamilton, 1933) and, as *Giallolino da dipintori* in a Florentine *gabella* (list of *taxe*) for 1402 (Dunlop, 1986).

Commonly given as giallolino or giallorino, it is often found in qualified form such as *giallolino da dipintori*, or by the addition of a country as in *giallolino delamagna* or *Giallorino di Fiandra* (Baldinucci, 1681), *Giallolino di Francia* (Pozzo, 1693–1700). In some sources which are essentially Italian, but written in Latin, such as Caesalpinus (1596), the Latinised form *Giallolinum* is used. *Zallulino*, found in documentary sources generally originating from northern Italy, is clearly a dialectal variant and is used, for example, in the Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield, 1849) as *zalulino*, *zallulino* and *zallolino*. Piccolpasso's treatise on ceramics also contains several recipes for *zalulino* (Piccolpasso, 1556–59); the seventeenth century Venetian Darduin MS (1644) on glass manufacture contains recipes for *zallolin*. The Bolognese MS also refers to *giallolino delamagna*, 'German giallolino', which, along with a related reference in Lomazzo (see below), has been taken by some authors to imply a German origin for this pigment (that is, not just manufactured but also discovered). Lastly, the term *Giallolino di Napoli* may be identified with the lead antimony oxide often referred to as Naples yellow.

It has been observed by several authors that the term massicot is found in treatises from northern Europe where otherwise giallolino or another closely related word would be found in an Italian text (Eastaugh, 1988). Several examples may be cited readily, notably the Haydocke translation of Lomazzo's *Treatise on the Art of Painting*, originally published in Milan in 1584 and appearing in English translation in 1598, where the passage '*I colori che fanno il giallo, sono il gialolino di fornace di Fiandra, & di Alamagna*' is translated 'The matters of yeallowe, are the yeallowe of the Flaunders fornace and of Almany, commonly called masticot and generall.'

A relatively small number of sources use the term in the context of descriptions of production methods. However, the so-called Bolognese MS (fifteenth century, Clarke MS 160; cf. and tr. Merrifield, 1849) describes in a section titled *Ad lapides anullorum componendos* ('To make stones for rings') two recipes: '*272.* A fare vetrio giallo per petre nostro o ambre. – *Tolli piombo lb j. stagno lb doj. et fundi et calcina et fa vetrio per patrenostro. 273.* A fare zallolino per dipengiare. – *Havve lb doi de questo stagno et piombo calcinato et doi lb de questo vetrio da patrenostrj et doi lb et ½ de minio et meza lb. de rena de valdarno sotilmente pista et mecti in fornace et fa affinare et sera perfecto.*' ('272. *To make yellow glass for paternosters or beads.* – Take of lead 1 lb., of tin 2 lbs., melt and calcine them, and make glass for paternosters. 273. *To make giallolino for painting.* – Take 2 lbs. of this calcined lead and tin, that is 2 lbs. of this glass for paternosters, 2½ lbs. of minium, and ½ lb. of sand from the Val d'Arno pounded very fine; put it into a furnace and let it fine itself, and the colour will be perfect.') These are currently interpreted as forming the two types of lead tin yellow (*q.v.*). A comparable recipe producing a lead tin-based yellow under the heading 'massicot' is to be found in a sixteenth century Flemish text (Vandamme, 1974), confirming the equivalence of the two terms as noted above. Additionally, the treatises by Piccolpasso and Darduin mentioned above provide recipes under this term where combinations of lead, tin and antimony are used.

Lead antimony oxide; Lead tin oxide; *Lead tin yellow*; *Naples yellow*
Baldinucci (1681); Caesalpinus (1596); Darduin MS (1644); Dunlop (1986); Eastaugh (1988); Eastlake (1847); Merrifield (1849); Piccolpasso (1556–59/edition of 1974); Pozzo (1693–1700); Thompson & Hamilton (1933); Vandamme (1974)

GIALLOLINO DI NAPOLI

Yellow
Synonym, variant or common name

See: Naples yellow.

GIBBSITE

White
Generic compound

Gibbsite is a monoclinic aluminium hydroxide mineral with composition $Al(OH)_3$ (Megaw, 1934). It is named after the American mineral collector G. Gibbs (1776–1833) and was first described by Torrey in 1822. Gibbsite is also known as hydrargillite and is polymorphous with bayerite (monoclinic), doyleite (triclinic) and nordstrandite (triclinic). Gibbsite has the more stable structure and is found more widely in nature than the other polymorphs (Trolard and Tardy, 1987). It occurs as relatively soft nodules, concretions, masses or crusts, or less commonly as small prismatic or tabular pseudohexagonal crystals. It is white when pure but may be pink, green, blue, red, grey or brown if impurities are present; analyses of gibbsite samples usually show the presence of Fe_2O_3 and minor amounts of other oxides (Deer *et al.*, 1992). Gibbsite forms as an alteration product of aluminosilicate minerals under tropical weathering conditions and is an important ore of aluminium. It is found as a principal component of bauxite, usually in association with boehmite, diaspore, goethite, lepidocrocite, kaolinite and halloysite (*q.v.*; Deer *et al.*, 1992; Rutley, 1988), in areas such as Les Baux (France), Vogelsberg (Germany), Los Pijiguaos (Venezuela; Meyer *et al.*, 2002) and Lages (Brazil). It has also been reported as the final product of weathering of plagioclase feldspar (*q.v.*) via the formation of allophane and halloysite. Heating of gibbsite results in its dehydration to form diaspore, with boehmite as an intermediate metastable phase. Empirical studies by Violante and Huang (1993) indicate that the formation of $Al(OH)_3$ polymorphs is dependent on pH conditions and elapsed time, with bayerite forming initially, followed by a mixture of bayerite and nordstrandite, and finally gibbsite.

The synthetic form of $Al(OH)_3$, aluminium hydroxide (*q.v.*), is often encountered as a lake substrate. In such a context, the bayerite polymorph is usually precipitated; however, Greenwood and Earnshaw (1999) indicate that precipitation from warm alkaline solutions can result in the preferential formation of gibbsite.

For a discussion of the various aluminium oxide and hydroxide phases encountered as pigments and the conditions under which they form, see the entry under Aluminium oxides and hydroxides group.

Aluminium oxides and hydroxides group; Bauxite; Bayerite; Boehmite; Nordstrandite

Deer *et al.* (1992) 571–573; Greenwood & Earnshaw (1999); Megaw (1934); Meyer *et al.* (2002); Rutley (1988) 277; Trolard & Tardy (1987); Violante & Huang (1993)

GLASS

White

Generic compound

A glass is a solid of any composition in which the constituent molecules are disordered but still rigidly bound. Glasses are most commonly formed from high temperature liquids that are rapidly cooled so that the atoms have insufficient time to position themselves into the long-range order of a crystalline solid. Typically the term glass is used to refer to a man-made material composed predominantly of silica. Glass can be made from pure silica but this composition requires high temperatures (in excess of 1200°C) for shaping the material. However, even in ancient times it was known that the temperature needed to liquefy glass could be lowered by adding fluxes such as lime and soda to the silica; lead has also been employed historically as a flux in addition to the optical and tactile qualities it can impart to glass (Ernsberger, 1980).

Relatively few identifications of colourless glasses have been made in artefacts and some confusion may exist with very pale smalt. However, in documentary sources, powdered Venetian glass (*cristallo*) and sulfur, probably for miniature painting, is mentioned in the Paduan manuscript; in Merrifield's (1849) edition of this work, she states that it is precisely similar to the opaque white glass used for painting pottery. The Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield) contains the following recipe: '185. *To make a very beautiful white.* Take egg shells and well-pounded glass and mix them together; then put the mass into an earthen jar in a furnace for one natural day. Then take it out and keep it. And when you wish to use it, grind it very well upon marble, and distemper it with gum-water.'

Several ancient sources also mention a material called *annularia* or *angularia* (Pliny, 77 AD, and Vitruvius, first century BC, as '*annularia*'; Heraclius [Jehan Le Begue 1431; Clarke MS 2790; cf. Merrifield] as '*angularia*'). This appears to have been either chalk alone or a mixture of chalk and ground glass, though one modern author suggests it may in fact have been mica (Davidovits; see the discussion under *Ring white*).

Glass is known to occur in a pigmentary context although the function is not always clear and authors often suggest that the purpose of it was to act as a drier. For example, Dommerouth (2002) found glass in the ground of Sebastiano del Piombo's *Holy Family* (Castle Ashby, England). Funders and Möller (1989) found 'calcined glass' pigment applied with oil and resin on columns and pilasters on the outside of a court of a castle in Wolfenbuettel (northern Germany) from the first half of the eighteenth century and on an outside stairway on a town hall in Thuringia, dating from the seventeenth century.

Glass can be found associated with samples of lake pigments as it was used as a siccative in poorly drying lakes. Glass in the sixteenth century contained a high proportion of lead which aids in the drying of paint. This use is mentioned in the Paduan MS (cf. Merrifield): '*per far asciugare prestamente la lacca, indico, e negro di fumo*' ('to make lake*, indico* and lamp black dry quickly'). The presence of glass, smalt in this case, was found in a red lake in a painting by Titian analysed by Birkmaier *et al.* (1995).

Perhaps the most widely recognised pigmentary use of glass is as the cobalt-doped silicate smalt (*q.v.*). However, other doped and pigmented glasses are known to have been employed. For example, samples of coloured glasses are contained in the nineteenth century Hafkenscheid Collection of pigments (Pey, 1987), while there has also been an extensive modern (twentieth century) industry in Japan preparing and using coloured glasses for painting pigments.

Silicates group; Quartz; Smalt; *Ring white*

Birkmaier *et al.* (1995); Dommerouth (2002); Ernsberger (1980) Vol. V, Ch. 1; Funders & Möller (1989); Merrifield (1849) n.6, 250; Pey (1987); Pliny (1st cent AD/Rackham, 1952); Vitruvius (1st cent BC/Grainger 1934)

GLASTUM

Blue

Synonym, variant or common name

Historical term associated with woad (indigoid dyestuff from the plant *Isatis tinctoria*; Schweppe, 1997).
See: indigo.

Woad

Schweppe (1997)

GLAUCONITE

Green

Generic compound

Glauconite is a green monoclinic silicate mineral which belongs to the mica group (*q.v.*). It has composition $(K,Na)(Fe,Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$ and is present in many sandstones and marls deposited as marine sediments. It forms from the alteration of a variety of starting materials, especially Mg,Fe-rich silicate minerals such as biotite (*q.v.*), in a marine environment and therefore occurs worldwide (Rutley, 1988). The variety of mica enriched in Mg and Fe and depleted in Al and Fe^{3+} is called celadonite (*q.v.*) to which glauconite is closely related. Glauconite is a dominant component in some green earth (*q.v.*) pigments where it often occurs as small dark green pellets, which may also contain chlorite and clay minerals such as montmorillonite and illite (*qq.v.*; Grissom, 1986).

It has been specifically identified along with celadonite on Roman wall paintings in Gaul by Odin and Delamare (1986).

Chlorite group; Mica group; Sheet silicates group; Silicates group; Biotite; Celadonite; Green earth; Illite; Montmorillonite
Grissom (1986); Odin & Delamare (1986); Rutley (1988) 400

GLAUCOPHANE

Blue-Purple
Generic compound

Glaucophane is a blue-purple monoclinic silicate amphibole, with composition $Na_2(Mg_3Al_2)Si_8O_{22}(OH)_2$. It is found in glaucophane schists which are derived from the high pressure, low temperature metamorphism of basaltic rocks and sedimentary rocks (blueschists), and may be derived from the alteration of jadeite (*q.v.*). It is frequently found in association with riebeckite and crossite (*q.v.*) which have similar chemistries but are richer in iron. These rocks are abundant in coastal California, Siphnos and Syros (Greece), Italy and Japan, but are otherwise rare. The name glaucophane is derived from the Greek words *glaukos*, meaning 'blue', and *fanos*, meaning 'appearing' (Rutley, 1988).

Riederer (1997) has noted the rare use of glaucophane as a pigment in the Greek islands. This mineral, along with riebeckite, has also been found in association with so-called 'Egyptian blue' (a synthetic calcium copper silicate pigment) in material from Knossos, Crete, dated to 2100 BC, and Thera (Santorini; 1500 BC) (Cameron *et al.*, 1977; Filippakis *et al.*, 1976; Profi *et al.*, 1976).

Aluminium group; Magnesium group; Silicates group; Calcium copper silicate; Crossite; Jadeite; Riebeckite; *Egyptian blue*
Cameron *et al.* (1977); Filippakis *et al.* (1976); Profi *et al.* (1976); Riederer (1997); Rutley (1988) 391–392

GLOBE LAKE

Red
Synonym, variant or common name

Term used for a cochineal-based lake pigment. Listed as a term in the *Colour Index* (1971) under CI Natural Red 4.

Cochineal
Colour Index (1971)

GLOSS WHITE

White
Synonym, variant or common name

According to Patton (1973i) gloss white was a co-precipitated pigment consisting of approximately 75% barium sulfate and 25% aluminium hydroxide (stated formula $3BaSO_4.Al(OH)_3$) in the manner of a lithopone. It was generally prepared by reacting solutions of aluminium sulfate, soda ash and barium chloride. While it mainly found use in inks, it has also been employed for the *in situ* preparation of lake pigments. Listed by the *Colour Index* (1971) under CI 77122/Pigment White 23 with several related formulations.

Aluminium oxides and hydroxides group; Barium sulfate
Colour Index (1971) 77122; Patton (1973i)

GMELINITE

White
Generic compound

Gmelinite is a hexagonal hydrous sodium aluminosilicate mineral with composition $(Na_2,Ca)Al_2Si_4O_{12}.6H_2O$, although some potassium and strontium may also be present (Galli *et al.*, 1982; Passaglia *et al.*, 1978). It is white when pure, but the presence of impurities may result in reddish, pink, yellow or greenish specimens being found. Gmelinite belongs to the zeolite group of minerals on account of its structure and composition although it is a less common member. It is named after the German mineralogist C.G. Gmelin (1792–1860) and was first described by Brewster in 1825 from Glenarm, Northern Ireland (Dana, 1932). Gmelinite usually occurs as prismatic, tabular or hexagonal striated crystals which may be twinned. It forms from sodium-rich fluids within cavities in basaltic rocks and is often found in association with calcite, quartz, and other zeolite minerals such as stilbite and heulandite. It is found worldwide in small amounts in localities such as Cyprus, Nova Scotia (Canada), Illimaussaq (Greenland), Flinders Area (Victoria, Australia) and New Jersey (USA).

Gmelinite, with the orthorhombic hydrated calcium aluminosilicate mineral stellerite, has been identified as minor phases mixed with celadonite in green earth used as a pigment on wall paintings in Cyprus (Kakoulli, 1997).

Aluminium group; Silicates group; Calcite; Heulandite; Quartz; Stellerite; Stilbite
Dana (1932) 651; Galli *et al.* (1982); Kakoulli (1997); Passaglia *et al.* (1978)

GMELIN'S BLUE

Blue
Synonym, variant or common name

The German chemist C.G. Gmelin developed one of the early routes for the preparation of artificial ultramarine (Mérimée, 1830); this term therefore refers to synthetic ultramarine. Listed as a then-current synonym by, for example, Heaton (1928).
See: ultramarine.

Ultramarine
Heaton (1928) 381; Mérimée (1830/trans. Taylor, 1839)

GOETHITE

Yellow-Brown
Generic compound

Goethite is an iron oxide hydroxide, naturally occurring mineral (α-FeOOH). Goethite is typically dark brown or black but produces a yellow streak and powder. It typically forms botryoidal, encrusting masses of acicular crystals or tabular prismatic forms. It also occurs in an earthy form, in effect a yellow ochre, generally called 'limonite' where it is finely mixed with other iron oxides and hydroxides. The term limonite and its synonyms bog iron ore and pea iron ore are considered obsolete today, and have been relegated to field terms. Pea iron ore refers to the oolitic and concretionary varieties of goethite. It is a very stable compound and is frequently the end product of reactions undergone by iron-rich ores.

Goethite is synthesised by a wide variety of methods that are described in Cornell and Schwertmann (1996). The main pigment variety is Mars yellow, which was produced from oxidation of iron(II) sulfate ('green vitriol' or copperas, *q.v.*) mixed with alum and precipitated by means of an alkali. Other methods include the oxidation of iron chloride, and the conversion of the iron oxide hydroxides lepidocrocite and ferrihydrite (*qq.v.*) in alkaline solutions.

Goethite is found in both natural and synthetic iron oxide pigments. The colour changes with increasing particle size from green-yellow to brown-yellow. It is a stable and non-reactive pigment, suitable for all media and works particularly well in frescos. Occurrence of synthetic iron oxides and Mars yellow is discussed under the relevant entry. Natural goethite-based yellow ochres have been used since the Palaeolithic and have been identified in French cave paintings by Pomiès *et al.* (1999a) and Smith *et al.* (1999). Watchman *et al.* (1993) have detected it in aboriginal rock art in North Queensland, Australia. David *et al.* (2001) have recognised goethite in pigment specimens from Tell el Amarna, Egypt and Edwards *et al.* (2002) have identified it in Romano-British wall paintings.

Goethite in the cases mentioned above is the main constituent of the yellow ochres that have been found on the palettes of all artists since antiquity to the present day. They are more fully discussed under the relevant entry.

Goethite is named after the German poet Goethe. It is occasionally referred to in older texts as xanthosiderite or yellow hematite. 'Pure' goethite earths were called brown ochres.

Iron oxides and hydroxides group; Limonite; *Mars yellow*; *Yellow ochre*
Cornell & Schwertmann (1996); David *et al.* (2001); Edwards *et al.* (2002); Pomiès *et al.* (1999a); Smith *et al.* (1999); Watchman *et al.* (1993)

GOFUN
White
Synonym, variant or common name

A Japanese term for (oyster) shell white (Gettens *et al.*, 1993a).

Calcium carbonates group; *Shell white*
Gettens *et al.* (1993a)

GOGILI
Yellow
Synonym, variant or common name

Term denoting Indian yellow (*q.v.*; Baer *et al.*, 1986).

Indian yellow
Baer *et al.* (1986)

GOLD
Metal
Generic compound

Powdered gold is used as a pigment, particularly in watercolour.

Numerous methods and materials have been advanced historically in an effort to produce imitations of gold. Of these, so-called mosaic gold (a tin sulfide, *q.v.*) is perhaps the best known. By way of example Thompson (1935) lists a wide range of substitutes in his survey of fourteenth and fifteenth century MSS, stating that 'The counterfeits depend chiefly on mercury, tin, chalk, orpiment, sulfur, bile, chelidony [sic], and saffron. Other vegetable elements are the juice of the cauda equina … and of poppy flowers. Recipes for an emulsion of egg-yolk and mercury … enjoyed considerable popularity.'

Gold group; Metal pigments
Thompson (1935) 419, n.8

GOLD BLUE
Blue
Synonym, variant or common name

Comparing this to Purple of Cassius, Salter (1869) states that 'a like compound of tin and gold may be made to yield a blue. Resembling indigo, the colour is not remarkably brilliant, and, unless several precautions are carefully observed, is rather violet than blue.' He also implies that it was unlikely to have been used as a painting pigment.
See: purple of Cassius.

Gold group; *Purple of Cassius*
Salter (1869) 231

GOLD GROUP
Variable
Group term

Gold is contained in several pigments as well as having been used in powdered form. These are gold red, gold blue, purple of Cassius and gold silver sulfide (Egyptian red gold).

Gold; Gold silver sulfide; *Gold blue*; *Gold red*; *Purple of Cassius*

GOLD OCHRE
Yellow
Synonym, variant or common name

According to a *Composition of Pigments* list given in a Winsor & Newton catalogue of 1896, this was an earth pigment 'more powerful than Oxford Ochre' (cf. Carlyle, 2001). Salter (1869) describes 'transparent gold ochre' as resembling 'in a great degree Roman ochre, but is clearer in its tints, and more transparent'.

Ochre; *Roman ochre*
Carlyle (2001) 526; Salter (1869) 108

GOLD PURPLE
Purple
Synonym, variant or common name

See: purple of Cassius.

GOLD RED
Red
Synonym, variant or common name

A number of mediaeval recipies describe producing a red or purple colour from gold, for a discussion of which see: Purple of Cassius. Additionally, Salter (1869) discusses what he terms gold reds; these were primarily 'organic substances added to gold solutions [that] throw down either the metallic gold or the red oxide, which then unites with the organic compound more or less decomposed [forming] a red precipitate. Sugar, gum, the decoctions of cochineal, gamboge, fustic, turmeric, sumach, catechu, and Brazil wood, all afford red pulverulent colours. Boiled with sugar, gold solution gives first a light and then a dark red.' Salter then also mentions Purple of Cassius, a compound usually used for colouring glass but which he implies was also used for painting.

Gold group; *Purple of Cassius*
Salter (1869) 166

GOLD-SILVER SULFIDE
Red
Generic compound

A gold-silver sulfide, Ag-Au-S, has been reported by a number of authors on artefacts from dynastic Egypt (Frantz and Schorsch, 1990; Hatchfield and Newman, 1991; Colinart, 2001). Also known as Egyptian red gold.

Gold group
Colinart (2001); Frantz & Schorsch (1990); Hatchfield & Newman (1991)

GOLD SOLDER
Green
Synonym, variant or common name

Harley (1982) states that this is a term for chrysocolla (*q.v.*) used in the Middle Ages.

Chrysocolla
Harley (1982) 77

GOLDEN ANTIMONY SULPHIDE
Red-Orange
Synonym, variant or common name

See: antimony(V) sulfide.

GOLDEN CHROME YELLOW
Yellow
Synonym, variant or common name

See: chrome yellow.

GOLDEN ORANGE YELLOW
Orange
Synonym, variant or common name

In their review of chrome red and chrome orange (*q.v.*) pigments, Kühn and Curran (1986) state that golden orange yellow was an older term used for basic lead chromate (lead chromate(VI) oxide, *q.v.*).

Lead chromates group; Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*
Kühn & Curran (1986)

GOLDEN ORPIMENT
Yellow
Synonym, variant or common name

According to Terry (1893) the finest quality naturally occurring orpiment was derived from Persia, and he refers to this as golden orpiment.

It should be noted here that orpiment pigments found on twentieth century Persian miniatures also contain the minerals portlandite, calcite and quartz and the pigment was 'ground from a stone which comes from Kasivin Quarry' (FitzHugh, 1997). These phases may occur as a result of adulteration; however, it is feasible that these minerals species could have occurred together as a natural mix, but proof is forthcoming.

Orpiment
FitzHugh (1997); Terry (1893) 280

GOLDEN SULPHUR OF ANTIMONY
Orange
Synonym, variant or common name

Mentioned in Field's *Chromatography* (1835), and in the later edition by Salter (1869). The composition is unclear. Associated terms include antimony orange and golden yellow.
See: antimony sulfides group.

Antimony orange; *Golden yellow*
Field (1835); Salter (1869) 256

GOLDEN YELLOW
Orange
Synonym, variant or common name

Mentioned by Field (1835) and Salter (1869). Closely associated with the terms antimony orange and golden sulphur of antimony.

Antimony orange; *Golden sulphur of antimony*
Field (1835); Salter (1869) 256

GOLDSCHWEFEL
Orange
Synonym, variant or common name

A term for antimony orange (Brachert, 2001). Found by Richter and Härlin (1974a) in a collection of nineteenth century pigments. See: antimony orange.

Brachert (2001) 104; Richter & Härlin (1974a)

GOTHAERGELB
Yellow
Synonym, variant or common name

A synonym for chrome yellow mentioned by Tschelnitz (1857; cf. Kühn and Curran, 1986), along with *Zwickauergelb* (Zwickau yellow).

Chrome yellow
Kühn & Curran (1986); Tschelnitz (1857) 44

GOYAZITE
Yellow
Generic compound

Goyazite is a hexagonal hydrated strontium aluminium phosphate hydroxide mineral with composition $SrAl_3(PO_4)_2(OH)_5.(H_2O)$; it may also contain barium and fluorine. It is named after the Goyaz district in Brazil and was first described by Damour in 1884 from the Minas Gerais, Brazil. Goyazite occurs as flat rhombohedral, tabular or bladed crystals which have a resinous or pearly lustre (Dana, 1932). It forms as a secondary mineral in shallow marine environments (e.g. Rasmussen *et al.*, 1998), in cavities in extrusive igneous rocks, in bauxites, or in kaolin deposits formed from the alteration of igneous rocks, where it is found with kaolinite, quartz and muscovite (Dana, 1932). Goyazite is found in areas such as Valais (Switzerland), Clara mine (Germany), Alto Adige (Italy), Kovdor massif (Russia; e.g. Liferovich *et al.*, 1999), Para (Brazil; e.g. Angelica and Costa, 1993), NW Peru (Dill *et al.*, 1997), Colorado and New Hampshire (USA) and the Yukon Territory (Canada).

Huq *et al.* (2001) have tentatively identified goyazite in Punic cosmetic pigments using synchrotron radiation X-ray diffraction (SR-XRD) techniques.

Aluminium group; Strontium group; Bauxite; Kaolinite; Muscovite; Quartz
Angelica & Costa (1993); Dana (1932) 711; Dill *et al.* (1997); Huq *et al.* (2001); Liferovich *et al.* (1999); Rasmussen *et al.* (1998)

GRADE BLACK
Black
Synonym, variant or common name

According to the *Colour Index* (CI 77268/Pigment Black 8), grade black or coke black is a fine product obtained from the coke produced in the Thuringian lignite industry.

Carbon-based blacks group: Cokes sub-group; Coal
Colour Index (1971) 77268

GRAIN LAKE

Red
Synonym, variant or common name

A kermes lake.
See: grana.

GRANA

Red
Synonym, variant or common name

Grana, derived from the Latin, literally meaning grains, generally refers to the kermes (*Kermes vermilio* Planchon; *q.v.*) insect which, when dried, resembles seeds or grains. The term *per se* should not only be associated with kermes, as all the *coccoidea* family insects can be said to resemble grains, although its main association is with kermes.

Dyers clearly distinguished between grana on the one hand and cochineal on the other, for example the 1466 Genoese dyer's regulations distinguished between grana and *chremisi* (Old world cochineal), indicated by the colour of the cloth selvage (Campbell *et al.*, 2001). Thompson (1935), however, lists numerous recipes from fifteenth century technical MSS for colours produced from grana, or *granetum*, where he points out that more than one insect dyestuff was used in the middle ages and the writers themselves may have been confused as to the sources. Campbell *et al.* cite, for example, a commentary on the works of Dioscorides published in 1548, where the author speaks of *cremesino* (grains) related to the roots of *Pimpinella*. This appears to indicate that he thought the grains were derived from the so-called polish cochineal.

Other literature is confusing, as it appears that grana could have been more generally used as a term for cochineal (*q.v.*) and there are some texts where grana is clearly referring to cochineal. The Paduan Manuscript (sixteenth–seventeenth century; cf. Merrifield, 1849), for example, gives two distinct recipes to make a beautiful or fine lake using '*grana fina, o cocciniglia*' ('fine grain or cochineal') or '*cocciniglia, o grana fatta in polvere*' ('cochineal, or grains which have been powdered'). The Mariani Treatise (1620, Beineke Library MS 370) relating to *lacca di grana* says '*due sorte si fanno di lacca, una di grana, è cosi detta perché si fà delle grana del chremisi, o della cimatura de panni tinti co detto colore il quale viene di Spagna in Italia*' ('they make two sorts of lake, one of grains, so called because they are made from grains of cochineal, or from the clippings of cloth dyed with the colour which comes to Italy from Spain'). This reference to a Spanish source indicates that this is likely to be from New World cochineal imported into Spain. In the middle of the eighteenth century the *Libro de segretti di Chimica* (Ferguson MS 151, Glasgow University Library; cf. Seccaroni, 2001) has a recipe entitled '… *il cremisi dalla grana di Coxiniglia*' ('crimson from the grains of cochineal') and finally there is a fourteenth–fifteenth century manuscript, *Trattato dell'arte della seta* (Bibl. Riccardiana 2580, Clarke MS 1036) in which '… *la cocciniglia prendono il nome di grana de'tintori*' ('the cochineal takes the name dyer's grain'). It is therefore very difficult to determine precisely which of the *coccidea* is meant by this term.

Grana in a pigment context was generally prepared by using cimatura (*q.v.*). Wallert (1991b) states that identification of the grana colourants remains problematical, the kermes was almost exclusively used in the middle ages for dying expensive materials such as silk and is therefore less likely than other scale insects to have been used to make '*cimatura di grana*' which was generally made with the 'shearings of the finest woollen cloath' (Neri, 1612). This would appear to indicate once again that the term grana refers to cochineal as opposed to kermes.

Cochineal; Kermes; *Cimatura*
Campbell *et al.* (2001); Clarke (2001) 30; Mariani (1620/Hermans 2002) Ch.15 v.; Merrifield (1849) 703; MS Riccardiana 2580 (nd) 150; Neri (1612/Merrit 1662) 172–173; Seccaroni (2001); Thompson (1935) 422 + n.4; Thompson (1956) 114–116; Wallert (1991b)

GRANZUOLLI

Red
Synonym, variant or common name

A sixteenth century Italian term for madder (*q.v.*; Schweppe and Winter, 1997).

Madder
Schweppe & Winter (1997)

GRAPE BLACK

Black
Synonym, variant or common name

That is, vine black (*q.v.*); this specific term is listed by Mayer (1991).

Vine black
Mayer (1991) 46

GRAPHITE

Black
Generic compound

Graphite is a crystalline form of carbon which is also known as plumbago or black lead. Although ideally it is pure carbon, natural samples may contain silica, iron oxide and clay group (*q.v.*) minerals. Graphite occurs as soft grey metallic flexible laminae or as columnar masses, with tabular crystals rare (Rutley, 1988). Its soft nature makes it ideal to write with and hence it is named after the Greek word *γραφω* meaning 'I write'. Graphite is associated with volcanic or metamorphic activity, although the carbon required for its formation is usually derived from the surrounding country rocks or sediments containing organic material. It is most commonly found in metamorphosed sediments usually in association with pyrite and coal (*qq.v.*), or it occurs in veins, lenticles or disseminated grains in igneous rocks and limestone (*q.v.*; Rutley, 1988). Graphite is common worldwide and occurs in localities such as Borrowdale (Lake District, England), Broken Hill (New South Wales, Australia), Tyrol (Austria), Alsace (France), Tsumeb mine (Namibia), Sonora (Mexico), Bogola (Sri Lanka), Cheshire County (New Hampshire, USA). It is the hexagonal form of carbon and the most stable and common form found at ambient conditions (Lipson and Stokes, 1942). Other forms of carbon found in nature include the amorphous shungite, and crystalline lonsdaleite (*qq.v.*) and diamond which are only rarely found. It may also be produced synthetically, notably from so-called 'graphitisable' carbons. Synthetic graphite has been available since about 1897.

Graphite has been used as a pigment or a drawing material since ancient times. Zuo *et al.* (1999) have also shown that it has been used in the decoration of ancient (c. 4300–2800 BC) pottery from Xishan (Henan, China). Harley (1982) found only a few references to the use of graphite in the seventeenth to nineteenth century English documentary sources she surveyed, citing *Limming* (1573), Haydocke (1598; actually a translation of Lomazzo), Bate (1634) and the *Arts Companion* (1749). Toch (1916) indicates that graphite was widely used as a pigment at that time, primarily discussing the mineral form but also describing a synthetic form, a product of the electrochemical industry at Niagara Falls (USA/Canada) and sold under the name Acheson graphite. Graphite is used in the manufacture of modern paints and it may also form during the synthesis of carbon-based black (*q.v.*) pigments (Winter, 1983).

Also known as black lead (various sources) and stove polish (Toch, 1916). Toch also mentions various 'misnomers' such as green, red and brown graphite.

Carbon-based blacks group: Crystalline carbons sub-group; Clay minerals group; Chaoite; Coal; Lonsdaleite; Pyrite; Shungite; *Black lead*; *Mineral black*; *Plumbago*
Arts Companion (1749); Bate (1634); Harley (1982) 157; *Limming* (1573); Lipson & Stokes (1942); Lomazzo/Haydocke (1584/1598); Rutley (1988) 223; Toch (1916) 104; Winter (1983); Zuo *et al.* (1999)

Grecian purple

Purple
Synonym, variant or common name

Synonym for Tyrian purple listed by Mayer (1991).

Tyrian purple
Mayer (1991) 46

Green ashes

Green
Synonym, variant or common name

Apparently a calcium copper arsenic compound. Riffault *et al.* (1874) give a recipe for green ashes involving mixing 'caustic lime … with arsenious acid and sufficient water, then boiled together'. This was decanted or filtered; while still hot, copper sulfate solution was added.

Arsenic group; Calcium group; Copper group
Riffault *et al.* (1874) 548

Green bice

Green
Synonym, variant or common name

See: green verditer.

Green chalk

Green
Synonym, variant or common name

Vitruvius (first century BC) records what has been translated as 'green chalk': '*Creta viridis item pluribus locis nascitur, sed optima Zmyrnae; hanc autem Graeci* Theodoteion *vocant, quod Theodotus nomine fuerat, cuius in fundo id genus cretae primum est inventum.*' ('Green chalk is found in many places, but the best is from Smyrna, which the Greeks call Theodoteion, because Theodotus was the name of the man on whose land it was first found.'). This is probably a green earth (*q.v.*).

Vitruvius (1st cent BC/Grainger, 1934) VII.vii.4

Green cinnabar

Green
Synonym, variant or common name

Described in late eighteenth century sources as a combination of copper and tartar ('cuprous tartar' – copper tartrate; *A Practical Treatise* (1795), de Massoul (1797)), then as copper and arsenic (Mérimée, 1830), finally a mixture of lead chromate and Prussian blue (Salter, 1869); the latter stated that Prussian blue would be destroyed by lead chromate and was better compounded with barium or bismuth chromate, and that green cinnabar was a synonym for Brunswick green. Kühn and Curran (1986) list this as a compound of strontium chromate and Prussian blue.

An aqueous formulation for green cinnabar is given by Riffault *et al.* (1874) whereby a solution of 'yellow chromate of potassa mixed with another of ferrocyanide of potassium' is poured into another separate mixture of neutral lead acetate and 'proto-acetate of iron' (made by decomposition of a solution of subacetate of lead with one of iron sulphate). Clearly this would result in a chrome green, a composite pigment where Prussian blue is deposited onto a substrate of lead chromate ('chrome yellow') or similar. Riffault *et al.* also describes this as a mixture using the term cinnabar green as a synonym for chrome green (chrome yellow and Paris blue or Berlin blue, *qq.v.*). Mierzinski (1881) uses mineral green and English green as synonyms for green cinnabar. He provides several recipes including dissolving Berlin blue in water with a little amount of oxalic acid; this solution was mixed with a solution of potassium chromate, then added to a solution of lead acetate for precipitation. According to another recipe bismuth nitrate was used instead of lead acetate or barium chloride. Jännicke (1893) describes green cinnabar as either a cobalt and zinc mixture or as a mixture of Berlin blue and chrome yellow with a little indigo carmine. Linke and Adam (1913) describe green cinnabar and chrome green as mixtures of Paris blue or smaragd green (in this instance chromium oxide hydrate) with various yellow pigments, or ultramarine with yellow pigments such as cadmium yellow, zinc yellow, strontium yellow, chrome yellow, gamboge or yellow lacquers. The pigment mixtures referred to by Riffault *et al.* and Heaton show great similarity to those from other nineteenth century sources (Liebig *et al.*, 1842; Salter, 1869) for which the term 'cinnabar green' (*q.v.*) is used instead. Heaton (1928) lists cinnabar green as a then-current term for chrome green.

Linke and Adam also give a number of trade names, including oil green, olive g., bronze g., silk g., moss g., chrome green extract, *permanentgrün*, Victoria green, Nürnberg g. and Paul Veronese g., all of which they indicate consisted mostly of smaragd green (see above), zinc yellow and little 'barite white'; others that they list, such as *Saftgrün* ('sap green' but here not meaning the rhamnus green also called by that name), and Prussian green and Hooker's g., consisted principally of Paris blue and gamboge or a yellow lacquer.

Lead chromates group; Barium chromate(VI); Copper tartrate; Gamboge; Lead chromate(VI); Strontium chromate; *Brunswick green*; *Cadmium yellow*; *Chrome green*; *Chrome yellow*; *Prussian blue*; *Strontium yellow*; *Ultramarine blue, synthetic*; *Viridian*; *Zinc yellow*
Heaton (1928) 380; Jännicke (1893) 77; Kühn & Curran (1986); Liebig *et al.* (1842); Linke & Adam (1913) 69–70, 72; Massoul (1797); Mérimée (1830/trans. Taylor, 1839); Mierzinski (1881) 185; *Practical Treatise* (1795); Riffault *et al.* (1874) 553; Salter (1869) 280

Green earth

Green
Common generic composite

The main colouring agents in green earths are the green clay minerals glauconite and celadonite (*qq.v.*), which have very similar chemistries but distinctly different environments of formation (see: Buckley *et al.*, 1978). The term green earth may reasonably be extended to cover numerous geological deposits of what are, essentially, broadly defined mixtures of minerals containing celadonite or glauconite plus or minus the green mineral chlorite and other minerals such as cronstedite, quartz, feldspar, amphiboles, the clay minerals montmorillonite, illite, kaolinite, saponite and the iron oxides. Celadonite and glauconite do not occur together. Celadonite, which has a bluish green tinge occurs as the alteration product of basaltic igneous rocks and is therefore known from certain regions of onshore and offshore volcanic activity. Though abundant in basaltic volcanic areas, celadonite occurs in limited deposits infilling small cavities (including amygdales) and fractures. The authors have examined celadonite forming encrusting layers a few millimetres thick covering basalts and infilling fractures (in association with chalcedonic silica) in the Akaki River valley (Nicosia, Cyprus). The grass green glauconite forms authigenically *only* in marine settings and is well known as a mineral dispersed in sandstones and clay deposits of this origin. It is very difficult to distinguish celadonite from glauconite when the pigments have been ground; both appear a pale, slightly greyish green. The accompanying impurities are not diagnostic because they are ubiquitous phases. Both minerals are indistinguishable optically.

Deposits of glauconite-bearing green earths are known from Russia, Baltic States, Bohemia, the south of England (the Cretaceous greensands) and from the Missouri River Basin in the USA and these were used by Native Americans according to Gettens (cited in Grissom, 1970). It would appear that the green earths regarded as having superior quality were celadonite based, and these would certainly be purer and require less preparation than glauconite-based pigments.

Major celadonite deposits are known from Cyprus and these have been identified as important sources of the pigment throughout history; they remain to be worked on a small scale to this day. Cypriot, celadonite-based green earths have been identified in western European Roman art by Béarat *et al.* (1996).

Cennini (c. 1400, Clarke MS 590) describes how his father Andrea took him to see green earth deposits in Colle di Val d'Elsa above a town called Dometaria. Verona was also a well-reputed source of the pigment and generally regarded as the best by many authors. Grissom (1970) has identified *Verona earth* as being a celadonite-based pigment. Field (1835) writes that similar greens were known from the Mendip Hills and France (as well as Cyprus and Italy). Tirolean (Tyrolian) green earth (from the Zillertal) is also a celadonite-based pigment. Other celadonite green earth sources are known from Brazil (Buckley *et al.*, 1978).

Green earths are permanent, stable and unreactive pigments suitable for painting in all media. They are prepared by washing, grinding and picking to remove impurities. Chemical leaching of impurities and levigation may also be used to refine the pigment.

Occurrence, characterisation and identification of green earths in art has been extensively reviewed in Grissom (1986). Like the other earth pigments, the material has had a long period of use. Vitruvius describes a green pigment he calls *creta viridis* and says the best variety of this came from the estates of Thedoteos in Smyrna (Izmir, Turkey) and was thus called *Theodoteion*. Pliny (77 AD) also mentions the pigment *appianum* as a green earth. However, Grissom (1970) suggests that this may be a (green?) earth adulterated with a plant-based green, possibly parsley (*apiacum* in Latin). Jehan le Begue also describes the best green earth as *creta cirina* as also being called *Theodote* (1431; Clarke MS 2790; cf. Merrifield, 1849). Green earth has been identified on many examples of Roman wall paintings (for examples see Odin and Delamare, 1986; Béarat *et al.*, 1996; Bugini and Folli, 1997; Corbeil *et al.*, 1996).

Cennino Cennini (c. 1400, Clarke MS 590) writes extensively on green earths, recommending them for underpainting flesh tones (and particularly for the lurid pallor of corpses), for foliage in the foregrounds of paintings (and malachite for background foliage), for draperies, for painting water, etc. and as a base for gilding (as an alternative for (red) bole). He particularly recommends green earth as a watercolour paint and for use on frescoes.

The use of the pigment is worldwide. Examples of identifications include its occurrence in first century AD frescos at Ajanta, India (Kahn, 1949) and Best *et al.* (1995) have detected green earths colouring a Tsimshian stone mask from the Pacific coast of Canada. Green earth has been recorded in rock paintings in Argentina (Wainwright *et al.*, 2002) and in Japan on early wall paintings (Yamasaki and Emoto, 1979) and on painted stone buddhas (Kuchitsu and Yamada, 2000). It was used in Coptic art (Le Fur *et al.*, 1990) and in Irish medieaval wall painting (McGrath, 1984). It occurs on a fourteenth century Icelandic manuscript (Best *et al.*, 1995) and in early colonial Mexican maps and manuscripts by Haude (1998). Like other earth pigments, green earths were particularly popular in Byzantine and Orthodox Greek and Russian art (see Plesters, 1963 and Connor, 1991). The pigment's use was routine in Western art. Grissom (1986 and references therein) record identifications in works by such diverse artists as Michelangelo, Saloman van Ruysdael, Vermeer, Turner and others. More recently, green earth has been identified in Corregio's murals in San Giovanni Evangelista in Parma (Bonazzi *et al.*, 1990).

Grissom (1986) has discussed the evolution of the term green earth and linguistically related forms such as the French *terre vert*, Italian *terra verde* and German *Grünerde*. The earliest linked reference she found was to *terra verdi*, in a description of the mineral celadonite by DeLisle in 1783. Hoffmann describes Grünerde in 1788 and De Brignoli de Brunnhoff writes about *la terre verte* in 1820. Verona earth is a synonymous term. Verona brown is a burnt variety of green earth. Ancient terminology not mentioned above includes variations on *prason* and *prasina*, from the ancient Greek for leek (*πρασινα* is modern Greek for green), although this name has been applied to several green pigments. Verditer (an unrelated copper acetate pigment) may be a corruption of green earth '*verde terra*'. Confusion could arise from the fact that chrysocolla appears to have been often called *terra viridis* (Burmester and Resenberg, 2003). Other terms related to green earth include Belgian earth, green stone, hessian earth, rhenish earth, Saxon earth, stone green, *terra di Verona*, Verona earth and Veronese green. Field (1835) also lists *verdetto* and Holy green.

Chlorite group; Earth pigments group; Celadonite; Cronstedtite; Glauconite; *Belgian earth*; *Green stone*; *Hessian earth*; *Rhenish earth*; *Saxon earth*; *Stone green*; *Terra di Verona*; *Verona earth*; *Veronese green*

Béarat *et al.* (1996); Best *et al.* (1995); Bonazzi *et al.* (1990); Brignoli de Brunnhoff (1820); Buckley *et al.* (1978); Bugini & Folli (1997); Burmester & Resenberg (2003); Cennini (c. 1400/Thompson, 1960) 27; Connor (1991); Corbeil *et al.* (1996); DeLisle (1783) II, 502; Field (1835) 128; Grissom (1970) 6, 26; Grissom (1986); Haude (1998); Hoffmann (1788); Kahn (1949); Kuchitsu & Yamada (2000); Le Fur *et al.* (1990); McGrath (1984); Merrifield (1849); Odin & Delamare (1986); Plesters (1963); Pliny (1st cent AD/Rackham, 1952) XXXV.xxix; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.4; Wainwright *et al.* (2002); Yamasaki & Emoto (1979)

GREEN EARTH, BURNT

Brown

Synonym, variant or common name

The production of 'burnt' (calcined) green earth has been noted since classical antiquity (Vitruvius, first century BC). Darrah (1995) has made a study of burnt green earth, including the analysis of historical samples such as two bladders in a paint box said to have belonged to J.M.W. Turner and held by the Victoria and Albert Museum, London. These are labelled *Gebr. Terra di Verte* and *Gebr. Grune Erde*, 'gebr.' (short for *gebrannte*) meaning 'burnt'. Analysis of them revealed iron as a major element, with traces of manganese and titanium; calcium, and traces of potassium, rubidium and strontium, were also found. That author also reports that she has tentatively identified burnt green earth in paintings by Peter de Wint and J.F. Millet as well as English wall paintings and cartoons by Verrio, Laguerre, Thornhill and Robert Adam.

Verona brown was apparently a calcined green earth, the term appearing in a number of nineteenth and early twentieth century English sources.

Green earth; *Verona brown*
Darrah (1995); Vitruvius (1st cent BC/Grainger 1934)

GREEN FRIT
Green
Synonym, variant or common name

Janis (1999) identified a green frit on a Ptolomaic mummy (323–30 BC), which she describes as an intermediate product in glassmaking consisting of green glass, cuprowollastonite and silicon dioxide. Some cristobalite was probably also present. This pigment was distinct from so-called Egyptian green, malachite or copper acetate.

Calcium copper silicate; *Blue frit*; *Egyptian blue*; *Egyptian green*
Janis (1999)

GREEN GOLD
Green
Synonym, variant or common name

The *Colour Index* (1971) lists green gold as CI Pigment Green 10; it appears to be a nickel-azo yellow pigment (see: azo pigments group: metal complex sub-group).

Azo pigments group: Metal complex sub-group
Colour Index (1971)

GREEN LAKE
Green
Synonym, variant or common name

A term of seemingly flexible application, Field (1835) states that it was prepared from copper sulfate. Riffault *et al.* (1874) on the other hand indicate that green lake was a form of Scheele's green (*q.v.*) while according to Church (1901), green lake was prepared from Prussian blue and a quercitron lake (*qq.v.*).

Copper sulfates group; Quercitron; *Prussian blue*; *Scheele's green*
Church (1901) 202; Field (1835); Riffault *et al.* (1874) 554

GREEN OCHRE
Green
Synonym, variant or common name

Salter (1869) describes green ochre as being produced by 'partially decomposing yellow ochre with prussiate of potash … a fine dark blue-green, resembling Prussian green, of great depth and transparency'. The author indicates that it was not easy to make though. However, according to Church (1901) the pigment is prepared from Prussian blue (various blue hexacyanoferrate pigments) and a quercitron lake.

Toch (1916) on the other hand states that green ochre 'is similar in composition to gray ochre [which Toch identifies as "silica, clay, and carbonaceous coloring matter"], excepting that it contains a larger percentage of ferrous hydroxide … It has little or no hiding power of itself, but is very largely used as a base for cheap lakes on account of its adsorbent quality for certain aniline colors.'

The green mineral annabergite, $Ni_3As_2O_2.8H_2O$, also known as 'nickel bloom', is sometimes called 'nickel ochre'.

Quercitron; *Prussian blue*; *Yellow ochre*
Church (1901); Salter (1869) 287; Toch (1916) 80

GREENOCKITE
Yellow
Generic compound

Greenockite is a yellow-orange cadmium sulfide mineral with composition CdS. It usually occurs as a granular crusting surface deposit on zinc ores (especially sphalerite and wurtzite (*qq.v.*)) and more rarely as hexagonal or equant euhedral crystals in ore veins. It is fairly common around metaliferous sulfide deposits but it forms in limited quantities which are difficult to remove from the substrate, in which case analyses often show the presence of Zn. It is also known as xanthochroite. Named by Connell in 1840 after Lord Greenock (C.M. Cathcart, 1783–1859) who discovered the mineral while excavating the Bishopton tunnel near Port Glasgow, Scotland. It is also found in locations such as Derbyshire (England), Harz (Germany), Attica (Greece), Salzburg (Austria), Catalonia (Spain) and Tsumeb (Namibia). It is isostructural with wurtzite (*q.v.*) and is often found in association with galena and sphalerite (*qq.v.*). It is a polymorph of the cubic hawleyite (*q.v.*) (Winchell, 1931).

Several authorities claim that greenockite has been used as an artists' pigment for nearly 2000 years, but no evidence is known to support that claim (for example, Patton, 1973k). The synthetic analogue, cadmium sulfide, greenockite type (*q.v.*), has been manufactured since the early nineteenth century and used widely since the 1840s (Curtis and Wright, 1954; Fiedler and Bayard, 1986; Huckle *et al.*, 1966).

The pure cadmium sulfide pigment is designated by the *Colour Index* as CI 77199/Pigment Yellow 37.

Cadmium group; Cadmium sulfides and selenides group; Galena; Hawleyite; Sphalerite; *Cadmium yellow*
Colour Index (1971) 77199; Curtis & Wright (1954); Fiedler & Bayard (1986); Huckle *et al.* (1966); Patton (1973k); Winchell (1931)

GREEN OXIDE OF CHROMIUM OPAQUE
Green
Synonym, variant or common name

See: chromium oxide.

GREEN PINK
Green
Synonym, variant or common name

According to Harley (1982), the term green pink is found in certain seventeenth century British sources derived from Norgate's *A More Compendious Discourse* … (early seventeenth century). It refers to a mixed colour based on a yellow lake ('pink') with a blue, typically bice.

Bice; *Pink*
Harley (1982) 109; Norgate/Thornton & McCain (early 17th C./1981)

GREEN STANNATE OF COPPER
Green
Synonym, variant or common name

See: copper tin oxide.

GREEN STONE
Green
Synonym, variant or common name

See: green earth and volkonskoite.

GREEN ULTRAMARINE
Green
Synonym, variant or common name

See: ultramarine green.

GREEN VERDITER
Green
Synonym, variant or common name

Green verditer is a historical term referring to a synthetic green copper carbonate hydroxide with a crystal structure identical to malachite, although unlike the natural mineral adopting a distinctive spherulitic habit, which some authors have referred to as spherulitic malachite (*q.v.*). It appears likely that the pigment first appeared in the fifteenth century as attested by identifications on works of art and sculpture of that period. Green verditer can be synthesised by adding sodium bicarbonate to copper sulfate solution, whereby it forms as a precipitate. 'Another of the copper greens which has practically disappeared from the modern painter's list of pigments … manufactured by treating copper solutions with carbonate of soda, or of potash' (Terry, 1893). This process has been replicated by Naumova *et al.* (1990). Earlier recipes (see Scott, 2002; Gettens and FitzHugh, 1993b) describe combining copper nitrate with chalk. The pigment was reputedly of paler colour than natural malachite.

Notable occurrences have been listed in detail by Gettens and FitzHugh and Scott. The pigment has less common usage than the similar blue verditer; however, further identifications using optical microscopy may be forthcoming. Naumova *et al.* (1990) have recognised the pigment in use in Russian Orthodox frescoes where it contains impurities of platy alloys of copper and calcium, plus iron, magnesium and aluminium.

The pigment has commonly alternatively been known as green bice. Salter (1869) states that 'green bice or green verditer, is the same in substance as blue verditer, which is converted into green verditer by boiling'. Weber (1923) calls the pigment malachite green, which he says is 'made artificially. The product is usually less brilliant, but possesses the chemical and physical properties of the native mineral.' Other associated terms include *verde granillo* and terms usually applied to malachite may also be applied to green verditer (for example, mountain green). Heaton (1928) lists green verditer as an obsolete or little used term by that time.

Copper carbonates group; Copper group; Copper carbonate hydroxide, malachite type; Malachite; *Green bice*; *Refiner's verditer*; *Spherulitic malachite*; *Verde granillo*; *Verditer*
Gettens & FitzHugh (1993b); Heaton (1928) 381; Naumova *et al.* (1990); Salter (1869) 287; Scott (2002) 113–116; Terry (1893) 136; Weber (1923) 87

GREEN VERMILION
Green
Synonym, variant or common name

Listed in a catalogue of the British colourmen Reeves for 1862 (cf. Carlyle, 2001), constitution unknown. It is probably related to the pigment known as green cinnabar (*q.v.*).

Green cinnabar
Carlyle (2001) 496

GRENOBLE VERDIGRIS
Green
Synonym, variant or common name

Mérimée (1830) states that Grenoble was a chief place of manufacture of verdigris and, according to Kühn, south-east France, especially the Rhone Valley and surrounding regions, were known as manufactories of verdigris as a by-product of the wine industry (Kühn, 1993a).

Copper acetate group; *Montpellier green*; *Verdigris*
Kühn (1993a); Mérimée (1830/trans. Taylor, 1839) 175

GRES DE THIVIERS
Red-Orange
Synonym, variant or common name

See: périgord orange.

GREY ANTIMONY
Grey
Synonym, variant or common name

See: stibnite.

GREY OXIDE
Grey
Synonym, variant or common name

Apparently a mixture of lead(II) oxide and metallic lead. Tingry (1804), for example, in a discussion of the preparation of litharge (*q.v.*) from metallic lead, describes how a grey coloured compound is formed first. Martin (1813), however, refers to this as 'ashes of lead' and, according to Bristow (1996b), it was this material that was also known as 'grey oxide'.

Lead oxides and hydroxides group; Litharge; *Ashes of lead*
Bristow (1996b); Martin (1813); Tingry (1804) 343–344

GRIFFITH'S WHITE
White
Synonym, variant or common name

Griffith's white was essentially lithopone, which is formed through co-precipitation of zinc sulfide and barium sulfate. Heaton (1928) lists Griffith's patent zinc white as an obsolete or rarely used form of lithopone.

Barium sulfate; Zinc sulfide; *Lithopone*
Heaton (1928) 381

GRÜNSPAN
Blue-Green
Synonym, variant or common name

Grünspan is the German term for the synthetic green copper acetates known generally as verdigris (*q.v.*). The name is believed to have been derived from *viride hispanicum*, 'Spanish green' (Kühn, 1993a).

Copper acetate group; *Verdigris*; *Viride Hispanicum*
Kühn (1993a)

GUATTUM
Blue
Synonym, variant or common name

Historical term associated with woad (Schweppe, 1997).
See: indigo.

Woad
Schweppe (1997)

GUIGNET'S GREEN

Green
Synonym, variant or common name

Guignet's green is a synonym for viridian (chromium oxide hydrate), the term deriving from the name of the French chemist who in 1859 patented the method still generally used for its manufacture (Newman, 1997). Riffault *et al.* (1874) give two recipes attributed to Guignet. The term was still apparently current at the time Heaton was writing (1928).

Chromium oxide hydrate; *Viridian*
Heaton (1928) 146; Newman (1997); Riffault *et al.* (1874) 564

GUIMET'S BLUE

Blue
Synonym, variant or common name

See: ultramarine.

GUIS MATE

White
Synonym, variant or common name

Veliz (1986), in an examination of seventeenth and eighteenth century Iberian treatises, defines *Guis mate* as a chalk and clay mixture usually prepared as a kind of drawing chalk that was also used for sketching on prepared canvases.

Clay minerals group; Chalk
Veliz (1986) 195, n.31

GULF RED

Red
Synonym, variant or common name

Heaton (1928) mentions this term as a then-current synonym for a 'natural iron oxide from Persia'. It is not clear whether there is any relationship to 'Persian red' (*q.v.*) which could mean both a red ochre and lead chromate.

Lead chromate; *Persian red*; *Red ochre*
Heaton (1928) 381

GUMMI GAMBOGIA

Yellow
Synonym, variant or common name

Term used for gamboge (Winter, 1997).

Gamboge
Winter (1997)

GUMMI GUTTI

Yellow
Synonym, variant or common name

Term used for gamboge (Winter, 1997).

Gamboge
Winter (1997)

GYPSUM

White
Generic compound

Gypsum is the most common sulfate mineral, occurring mainly in sedimentary deposits associated with limestones, shales, marls and clays, and in evaporite deposits (Deer *et al.*, 1992). Three main hydrated phases occur; strictly speaking gypsum is $CaSO_4.2H_2O$, bassanite $CaSO_4.0.67H_2O$ and hemihydrate $CaSO_4.0.5H_2O$, though bassanite and hemihydrate are not normally distinguished within the geological literature and are meta-stable. Anhydrite is the anhydrous phase, $CaSO_4$.

In evaporite deposits gypsum is often associated with anhydrite ($CaSO_4$) and halite (NaCl). Gypsum has low solubility and is the first mineral to be precipitated from seawater. Strontium is a common substitution for calcium in evaporite gypsum, again deriving from seawater deposition (see celestite, $SrSO_4$). It is also formed where sulfuric acid fumes (produced, for example, by the oxidation of iron(II) pyrites) react with calcareous (limestone) rock faces (Deer *et al.*, 1992). Gypsum can also be produced by the secondary hydration of anhydrite and through the production of plaster of Paris (*q.v.*).

The word gypsum comes from the Greek *gyps*, meaning 'burned' mineral. There are several varieties of gypsum: satin spar is a fine, soft, fibrous mineral; alabaster is a more massive, fine-grained, and often banded form and selenite (*q.v.*) a clear/translucent form which shows good crystal habit. Extensive beds of selenite are worked in the Mediterranean basin, notably in southern Spain and Cyprus.

While references to gypsum (or, more properly, plaster of Paris) grounds, sculpture and walls carrying paint are insurmountable, there are few references to gypsum as a pigment in its own right. Theophrastus perhaps describes it as a pigment and calls it Tymphaic earth. Wainwright *et al.* (2002) have detected it in Argentinian rock paintings. Harley (1982) records that reference to it occurs in *Limming* in 1573 and in Haydocke's translation of Lomazzo, where it is recommended as suitable to mix with orpiment. Harley classifies it generally as one of the 'white earths'. The selenite variety of gypsum was occasionally used in pigments to add a pearlescent texture. Its uses are further discussed under the relevant entry. Satin white (*q.v.*) is used by some sources to refer to a gypsum-based white pigment. However, this term has varied applications. Heaton (1928) lists *terra alba* or mineral white as gypsum-based pigment, either using natural sources or manufactured as a by-product in the aluminium industry. Calcium sulfate is produced when alum (aluminium sulfate) is reacted with calcium acetate to produce aluminium acetate.

Gypsum may be calcined and slaked to produce gypsum plaster, also known as *gesso* or plaster of Paris (*q.v.*). This was used as a ground for panel paintings, of which these are numerous examples documented in paintings from Southern Europe (Gettens and Mrose, 1954; Martin *et al*., 1992).

Calcium sulfate pigments, both natural and synthetic, are well recognised in ancient Egyptian art of all periods (see Heywood, 2001) but they are not abundant. Gypsum has been identified by Middleton and Humphrey (2001), who found small amounts of a white gypsum-based pigment on some Middle Kingdom coffins. Gypsum has been identified in trace amounts in white pigments employed in rock paintings in Argentina (Wainwright *et al.*, 2002), and Prasartset (1990) has identified gypsum in white pigments used as fillers in paints of various colours at the Maitepnimit Temple in Thailand.

Calcium sulfates group; Alabaster; Anhydrite; Selenite; *Satin white*
Deer *et al.* (1992) 612–616; Gettens & Mrose (1954); Harley (1982) 164–165; Heaton (1928) 108; Heywood (2001); Martin *et al.* (1992); Middleton & Humphrey (2001); Prasartset (1990); Theophrastus (c. 315 BC/Caley & Richards, 1956) VIII.50–60; Wainwright *et al.* (2002)

GYPSUM, BURNT

White
Synonym, variant or common name

Burnt gypsum applies to the heating of gypsum to temperatures exceeding 200°C, whereby all water is driven off and anhydrite formed. Plaster of Paris normally involves heating gypsum to lower temperatures, forming partially hydrated phases (hemihydrate or bassanite, *qq.v.*) which revert to gypsum on slaking and drying.

The pigment literature uses the terms 'burnt gypsum' and 'plaster of Paris' to a large extent synonymously; Koller (2000), for example, has used the term 'burnt gypsum' to describe the composition of '*pastiglia*' (plaster reliefs on paintings).

See also plaster of Paris and the discussion regarding gesso in the calcium sulfates group entry.

Calcium sulfates group; Anhydrite; Bassanite; Gypsum; *Plaster of Paris*
Koller (2000)

H

HAARLEM BLUE

Blue

Synonym, variant or common name

A number of seventeenth century sources mention Haarlem ultramarine or H. ashes. Harley (1982) points out that the later version of Norgate's treatise on miniature painting describes H. ultramarine as suitable for landscape, though the composition is not given. Eastlake (1847) cites Hoogstraten: '*Wy hebben tot ons blaeuw, Engelsche, Duitsche, en Haerlemse Assen, Smalten, blaeuwe Lakken, Indigo, en den onwaerdeerlijken ultramarijn*' ('We have English, German and Haarlem ashes, smalts, blue lakes, indigo, and the invaluable ultramarine'); as Eastlake adds, 'The "ashes" so often mentioned by writers of the seventeenth century, never mean ultramarine ashes, but light blues derived either from silver (the "Indian bice"), from carbonates of copper, or from smalt.' However, the seventeenth century English visitor to Rome, Richard Symonds, records that Haarlem ultramarine was 'a blew clay earth that is washt … tis not any way produc'd from lapis lazuli' (cf. Beal, 1984). Harley and Beal make several speculations as to the nature of this 'blew clay', suggesting both ilsemannite and vivianite (*qq.v.*); the latter was even known as blue ochre, but actually it could have been any one of a number of blue-coloured mineral deposits. The term must have largely died out with the pigment, since Weyerman, writing in 1729, remarks that the grey colours found in the works of the Dutch landscape artist van Goyen (1595/6–1656) were due to deterioration of 'a colour [that] was in fashion called Haarlem blue' (cf. Eastlake, 1847). Salter (1869) lists Haerlem blue among synonyms for Antwerp blue, a term of variable meaning that included synthetic copper pigments and forms of Prussian blue (*qq.v.*). Haarlem blue is also listed among numerous synonyms and formulation variant terms for Prussian blue by Berrie (1997) in her review of that pigment.

Ilsemannite; Vivianite; *Antwerp blue*; *Prussian blue*

Beal (1984) 101–102; Berrie (1997); Eastlake (1847) I, 453; Harley (1982) 59; Hoogstraten (1678) 221; Salter (1869) 207–208

HAEMATIN

Red

Generic compound

Haematin, 6a,7-dihydro-3,4,6a,10-tetrahydroxybenz[b]indeno-[1,2-d]pyran-9(6H)-one, is a neoflavanoid dyestuff found in heartwood of the commercially traded *Haematoxylum* species *H. campechianum* L. and *H. brasiletto* Karsten ('Logwood', *q.v.* and other related common names; *Merck Index*, 1996; Mabberley, 1998; Nowik, 2001). This is also listed in some sources as hematein and should not be confused with the blood compound hematin. *Colour Index* (1971) reference CI 75290/ Natural Black 1 and 2.

Flavonoids group; Logwood

Colour Index (1971) 75290; Mabberley (1998) 323; *Merck Index* (1996) 4667; Nowik (2001)

HALITE

Variable

Generic compound

Halite is a simple halide mineral, with general chemical formula NaCl. It is colourless or white when pure, but often appears red, orange, yellow or blue due to the presence of impurities, halobacteria or defects in the crystal lattice. Halite commonly forms cubic crystals which often have hollow faces ('hopper' crystals); it may also occur as granular masses in which individual crystals cannot be distinguished (Dana, 1932). Also known as rocksalt, halite occurs worldwide in sedimentary rocks formed from the evaporation of enclosed bodies of seawater or salt lakes; it also occurs as a surface deposit in arid regions and as a volcanic sublimate. It is often associated with gypsum and anhydrite (*qq.v.*). The largest European deposits are at Salzburg (Austria), Cheshire (England), Lorraine (France), Wieliczka (Poland) and Wurtemberg (Germany).

There is limited evidence that halite has been found on rock art although it is more typically encountered as a weathering or alteration crust on art objects. There are also various reports of halite in wall paintings, the origin most probably being from mineral transport or deposition rather than specific employment (Kuchitsu and Duan, 1993; Tennikat, 1994).

Anhydrite; Gypsum

Dana (1932) 459; Kuchitsu & Duan (1993); Tennikat (1994)

HALLOYSITE

White

Generic compound

Halloysite is a white mineral with composition $Al_4[Si_4O_{10}](OH)_8.8H_2O$. It belongs to the kaolinite sub-group of clays minerals group and is therefore very similar to kaolinite (*qq.v.*) itself, the main difference being that it contains more water than kaolinite between the structural layers (Rutley, 1988). It occurs with kaolinite in deposits of china clay and also forms from the alteration of feldspars group minerals (*qq.v.*) in granites and readily loses water to form metahalloysite (Deer *et al.*, 1992). The mineral is named after O. d'Halloy (1707–89). Lithomarge is a white, red or yellow clay variety composed of a mixture of halloysite and kaolinite; red bole (*q.v.*) is the name given to the soft red weathered clay material often found on the surfaces of lava flows and includes impure halloysite (Rutley, 1988).

Halloysite has been identified by Scott and Hyder (1993) in white pigment samples from a rock art site in the Indian Wells

Canyon area of California. Hill (2001) remarks that white clays used for painting ethnographic artefacts in Papua New Guinea also contain halloysite. Halloysite has also been identified by Sánchez-Moral *et al.* (2002) as a white pigment used in cave paintings at Galdar (Grand Canary Island, Spain). The related metahalloysite has been tentatively identified in a set of late seventeenth century Tibetan *thangkas* (Duffy and Elgar, 1995).

Aluminium group; Clay minerals group; Clay minerals group: Kaolinite sub-group; Feldspar group; Silicates group; Kaolinite; *Bole*; *China clay*
Deer *et al.* (1992) 353–362; Duffy & Elgar (1995); Hill (2001); Rutley (1988) 412; Sánchez-Moral *et al.* (2002); Scott & Hyder (1993)

HAMBURG BLUE
Blue
Synonym, variant or common name

See: Prussian blue.

HAMBURG GREEN
Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

HAMBURG WHITE
White
Synonym, variant or common name

According to various nineteenth century sources such as Salter (1869) and Church (1901), Hamburg(h) white was a composite pigment formed of lead white and baryte (*qq.v.*) in a ratio of 1:2.

Baryte; *Lead white*
Church (1901) 130; Salter (1869) 74

HAMBURGH LAKE
Red
Synonym, variant or common name

Salter (1869) classifies Hamburgh lake as a cochineal lake (*q.v.*), describing it as ‘a lake of great power and depth of colour, purplish or inclining to crimson’.

Cochineal
Salter (1869) 137

HAN BLUE
Blue
Synonym, variant or common name

A modern term proposed by FitzHugh and Zycherman (1983, 1992) to denote a synthetic blue barium copper silicate ($BaCuSi_4O_{10}$) pigment found on painted ceramic and metal objects from the Chinese Han dynasty (208 BC–220 AD) and the Warring-states period (475–221 BC). The substance is synthetic and similar in composition (and presumably manufacturing processes) to that of Egyptian blue (*q.v.*; calcium copper silicate) and the two materials have very similar optical properties (see Riederer, 1997). Identifications of the pigment on works of art have also been made by Bouherour *et al.* (2001). The chemistry is identical to the naturally occurring phase effenbergite (*q.v.*).

Manufacture of the pigment has been recreated by Pabst (1959) and reviewed by FitzHugh and Zycherman (1983). Further discussion of the methodology is to be found under the entry for Barium copper silicate, blue type.

The pigment has also been referred to as Chinese blue (Bouherour *et al.*, 2001; Wiedemann *et al.*, 1998); however, the name Han blue has been adopted to avoid confusion between barium copper silicates and other blues more commonly recognised as Chinese blue (*q.v.*; FitzHugh and Zycherman).

Barium copper silicate, blue type; Effenbergerite; *Chinese blue*; *Egyptian blue*; *Han purple*
Bouherour *et al.* (2001); FitzHugh & Zycherman (1983); FitzHugh & Zycherman (1992); Pabst (1959); Riederer (1997); Wiedemann *et al.* (1998)

HAN PURPLE
Purple
Synonym, variant or common name

Han purple is a modern term proposed by FitzHugh and Zycherman (1983, 1992) to denote a purple barium copper silicate, $BaCuSi_2O_6$, pigment found on artefacts from the Chinese Han dynasty (208 BC–220 AD) and the Warring-states period (475–221 BC). Although produced only over a relatively short time period, this colour is almost unique in that it represents pre-industrial manufacture of an inorganic, true purple pigment. Spurrell (1895) described apparently similar traces of ‘lilac’-coloured materials from the excavations of Egyptian blue (*q.v.*) manufactories at Tell El-Amarna (Egypt). These materials have otherwise not been found in the west. In unreproduced experiments, Russell (1892) suggested that this material was made by adding excess copper and lime to the mixture and firing at precisely controlled temperatures. Methods of synthesising purple barium copper silicates are discussed in further detail under the entry barium copper silicate, purple type.

The crystal structure and spectroscopic properties of the purple or ‘magenta’ $BaCuSi_2O_6$ have been recently rediscovered and described by Finger *et al.* (1989) and McKeown and Bell (1997).

Pigments often contain blue impurities (see Han blue) and the colour is known to fade during burial and by the action of acid (FitzHugh and Zycherman, 1992).

Bouherour *et al.* (2001) have identified Han purple on paint layers from the Terracotta Army from X’ian, China, as well as artefacts from the Warring-states period and later Han dynasty (208 BC–220 AD). FitzHugh and Zycherman (1992) analysed Han purple pigment sticks from the Han dynasty plus painted pottery and metal vessels. Zuo *et al.* (2003) have identified $BaCuSi_2O_6$ purple on painted pottery figurines from the Han dynasty Yangling Tombs (141–157 BC).

The name has been derived by analogy with the similar compound Han blue (FitzHugh and Zycherman); other authors (such as Bouherour *et al.*, 2001) refer to it as Chinese purple.

Barium copper silicate, purple type; Effenbergerite; *Egyptian blue*; *Han blue*
Bouherour *et al.* (2001); Finger *et al.* (1989); FitzHugh & Zycherman (1983); FitzHugh & Zycherman (1992); McKeown & Bell (1997); Russell (1892) 44–48; Spurrell (1895); Zuo *et al.* (2003)

HANSA PIGMENTS
Yellow-Orange
Synonym, variant or common name

See: azo pigments group: monoazo sub-group and arylide pigments.

HARDING’S TINT

Grey
Synonym, variant or common name

Salter (1869) mentions *Harding’s* and *Macpherson’s tints*; these were commercial compound products ‘sold ready prepared in cakes and boxes for miniature and water painting’.

Salter (1869) 380

HARRISON RED

Red
Synonym, variant or common name

See: toluidine red.

HARTSHORN

White
Synonym, variant or common name

Merrifield (1849) notes that calcined ‘harts-horn’ (‘horn or antler of a hart’; *OED*, 2002) or bones were used occasionally as a white pigment (for example, British Library Sloane MS 1754; *Strasburg MS*; Clarke MS 2000) and as the only pigment which could be added to orpiment (*q.v.*) to lighten it. Tingry (1830) states that calcined hartshorn is ‘a useful earthy white for watercolours’. It is also sometimes known as horns of hind (ash).
See: bone, calcined and antler.

Bone; Bone, calcined; *Antler*
Merrifield (1849) clv; *OED* (2002) ‘Hartshorn’; *Strasburg MS* (15th cent/tr. Borradaile, 1966) 54; Tingry (1830) 62

HATCHETT’S BROWN

Brown
Synonym, variant or common name

Bersch (1901) gives a recipe for this compound, which is a copper hexacyanoferrate(II) (*q.v.*) pigment. Other associated terms include Florence brown and Vandyke red.

Hexacyanoferrate group; Copper hexacyanoferrate(II)
Bersch (1901) 280

HAUSMANNITE

Black-Brown
Generic compound

Hausmannite is a manganese(II,III) oxide mineral with chemical formula $Mn^{2+}Mn_2^{3+}O_4$. It forms as brown-black prismatic crystals, which are often twinned, and with massive or granular habits. Hausmannite is a commonly occurring manganese mineral and forms in high temperature hydrothermal veins associated with certain volcanic (acid igneous) rocks. It is formed as an oxidation product of rhodochrosite which breaks down at high temperatures to MnO and then oxidises to Mn_3O_4. The natural alteration of rhodochrosite results in a layer of complex manganese oxides which may eventually alter to manganite or pyrolusite (*qq.v.*). Other related minerals include bixbyite and braunite (*qq.v.*; Deer *et al.*, 1992; Rutley, 1988). Hausmannite was first discovered in 1827 by Jean-Frédéric-Louis Hausmann in Ilmenau, Thuringia, Germany. Other localities where hausmannite has been found to occur are Broken Hill (Australia), the Wyndham mines (Cumbria, England) and Vesuvius (Naples, Italy).

Panev (1979) has identified hausmannite, with pyrolusite, in Bulgarian icons of the Middle Ages and the Renaissance.

Manganese oxides and hydroxides group; Bixbyite; Braunite; Manganite; Pyrolusite
Deer *et al.* (1992) 636; Panev (1979); Rutley (1988) 284–285

HAÜYNE

Blue
Generic compound

Haüyne is a feldspathoid mineral which belongs to the sodalite group, being closely related to lazurite (*qq.v.*). It has a similar composition and structure to a feldspar (*q.v.*) but differs in that it contains less silica. Haüyne has composition $(Na,Ca)_{4-8}\,[Al_6Si_6O_{24}]\,(SO_4,S,Cl)_{1-2}$ and is commonly blue in colour, although white haüyne is found in volcanic rocks of the Alban Hills, Italy. It is found primarily in alkali igneous rocks and is common in the Eifel district, Germany and the East African Rift Valley. Haüyne is named after the French crystallographer R.J. Haüy (1743–1822).

Possible identification of haüyne in relation to ultramarine on paintings has been discussed by Derrick *et al.* (1999); a fuller discussion of the issues is given under the entry for ultramarine.

Feldspar group; Silicates group; Lazurite; Sodalite; Ultramarine
Derrick *et al.* (1999) 134–138

HAWLEYITE

Yellow
Generic compound

Hawleyite is a cubic cadmium sulfide mineral with chemical composition CdS. It is named after the Canadian mineralogist J.E. Hawley (1897–1965). It occurs as a soft yellow crust with metallic lustre, often coating sphalerite (*q.v.*) as a secondary mineral (Traill and Boyle, 1955). It is a rare mineral and is polymorphous with greenockite (*q.v.*) with which it is often intimately mixed. These minerals form around metaliferous sulfide deposits usually in small quantities only so that their removal often results in traces of zinc from the substrate being present. The type locality for hawleyite is the Hector-Calumet mine, Yukon Territory (Canada); it is also found at Broken Hill (Australia), Atacama (Chile), Attica (Greece), Derbyshire (England) and Indiana (USA; e.g. Coveney *et al.*, 1984).
See: cadmium sulfide, hawleyite type for a discussion of the synthetic analogue.

Cadmium sulfides and selenides group; Cadmium sulfide, hawleyite type; Greenockite; Sphalerite
Coveney *et al.* (1984); Traill & Boyle (1955)

HAYSTACK GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele’s and/or emerald green (*qq.v.*).

Emerald green; *Scheele’s green*
Fiedler & Bayard (1997)

HEAVY SPAR

White
Synonym, variant or common name

See: baryte.

HELIO BLUE

Blue

Synonym, variant or common name

See: phthalocyanine group.

HELIO GREEN

Green

Synonym, variant or common name

See: phthalocyanine group.

HEMATITE

Red

Generic compound

This entry deals primarily with the naturally occurring iron(III) oxide, hematite, as opposed to the synthesised compounds, which are further discussed under iron(III) oxide, hematite type and burnt ochre (*qq.v.*).

Hematite (haematite) is the commonest occurring ore of iron, α-Fe_2O_3. It is commonly a dull red and usually adopts an encrusting, botryoidal habit from which it derives its common name kidney ore. More rarely occurring, coarsely crystallised, unweathered hematite is silvery and reflective and called specular ore (or specular iron). Finely divided red hematite is abundant in weathered rocks (ochres, gossans and soils) and imparts a strong colour. Aluminium may substitute into hematite up to 15 wt%. Aluminium-substituted hematites have been studied by de Grave *et al.* (1982, 1988). The high stability of the compound means that it forms as the end product of alteration of other iron oxides (and therefore accounts for its abundance in soils) but also furnishes its value as a strongly coloured, inert and non-fugitive pigment. Hematite is the principal colourant in red, brown and purple iron oxide-based pigments, both natural and synthetic, and these have been recorded from all cultures usually in the form of hematite-rich earths, ochres (*q.v.*).

Several recent authors (Helwig, 1997; Béarat and Pradell, 1997) have also described what they call ‘disordered’ hematite. This is characterised by being poorly crystalline. Disordered hematite can be produced by heating goethite (or a goethite-containing material such as a yellow ochre, *qq.v.*) at temperatures below 850–900°C, when it undergoes dehydration. It has been suggested that this process can take place naturally (‘taphonically’) as well as artificially (‘anthropically’), but most authors consider that occurrences as pigments are of the latter (Masson, 1986; Béarat, 1996a).

Hematite occurs very commonly in the oxidised regions of iron deposits (above the water table). It is a valuable iron ore (70% iron) and has been worked in many localities worldwide. The best known UK occurrence is in Florence mine in Cumbria and Church (1901) notes that this is the source of a particularly bright red pigment. Similar deposits occur in the Forest of Dean (at Crawshay mine) but Heaton (1928) says that the supplies of ‘Crawshay Red’ were exhausted around 1900. The world’s largest hematite deposits are in the Great Lakes region of the USA. Other important deposits are in Spain (Bilbao), Elba, Cuba and Brazil.

The recognition of hematite on works of art is common; however, in many cases, the hematite is identified as a component of an ochre, umber or sienna (*qq.v.*). Hameau *et al.* (2001) list hematite (as distinct from ochre) as a pigment from post-glacial French Palaeolithic sites. A neolithic pot containing unused hematite pigment has been found in Greek Macedonia (Maniatis and Tsirtsoni, 2002). Hematite adulterated with chalk, carbon and sand has been identified in Romano-British wall paintings by Edwards *et al.* (2002). They also note a variety of hematite producing a purple paint (adulterated with kaolinite) that they call ‘*caput mortuum*’ (*q.v.*) though it appears that they are referring to a natural substance in this case. Several sixteenth and seventeenth century authors cited by Merrifield (1846) describe a pigment known variously as *lapis matita*, *l. amatita*, *amatito* and *albin* which she convincingly argues refer to hematite. See the entry for *amatito*.

The name hematite is derived from *haima*, referring to blood. The synonyms and names for natural hematite-based pigments are numerous, and many are listed under the entries for ochres. Names applied specifically from hematite ore deposits are Cumberland red and Crawshay red. Heaton (1928) says that the latter is sometimes referred to as Indian red, though Rivington (1901) describes Indian red as a ground hematite coming from Bengal. Weber (1923) describes a series of red iron(III) oxide pigments that he says are ‘purer than ochres’. Some refer particularly to the synthetic varieties of the compound (such as caput mortuum), but other terms may be used to describe both natural and synthetic forms. These are colcothar, rouge, Persian red, Venetian red and *terra pozzuoli*. Weber also describes the varieties Tuscan red and Pompeiian red as Fe_2O_3 mixed with ‘Alizarin madder’. Persian red or Persian Gulf oxide appears to be a natural hematite deposit or a particularly pure red ochre, although the name has been applied to other pigments.

Brown hematite is another name for limonite, a mixture of iron oxides and hydroxides.

Iron oxides and hydroxides group; Goethite; Iron(III) oxide, hematite type; Kaolinite; Limonite; Ochre; Sienna; Umber; *Amatito*; *Burnt ochre*; *Caput mortuum*; *Red ochre*; *Yellow ochre*

Béarat (1996a); Béarat & Pradell (1997); Church (1901); Edwards *et al.* (2002); Grave *et al.* (1982); Grave *et al.* (1988); Hameau *et al.* (2001); Heaton (1928) 116; Helwig (1997); Maniatis & Tsirtsoni (2002) 414; Masson (1986); Merrifield (1846) clxxii; Rivington (1901) 414; Weber (1923)

HEMIHYDRATE

White

Synonym, variant or common name

See: calcium sulfate, bassanite type.

HEMOGLOBIN

Red

Generic compound

Hemoglobin is found in the erythrocytes (‘red blood cells’) of all vertebrates. It is a conjugated protein with the prosthetic group heme which contains iron. The heme group is involved with the transport of oxygen from the lungs to tissues, while the globin portion of hemoglobin plays a major role in transporting carbon dioxide from the tissues to the lungs.

The structure of the hemoglobin molecule has been extensively studied. Most of the mammalian hemoglobins are composed of four sub-units, consisting of four peptide chains to each of which is attached a heme group. But, among the mammalian hemoglobins, there are structural differences in terms of the amino acid residues and their sequences in the polypeptide chains. The molecular weight of hemoglobin is about 66,000 and the iron content is about 0.34%.

A hemoglobin molecule consists of four polypeptide chains: two alpha chains, each with 141 amino acids and two beta chains, each with 146 amino acids. The protein portion of each of these chains is called globin. The α and β globin chains are very similar in structure. In this case, α and β refer to the two types of globin. Each α or β globin chain folds into eight helical segments (A–H) which, in turn, fold to form globular tertiary structures that look roughly like sub-microscopic kidney beans. The folded helices form a pocket that holds the working part of each chain, the heme. The heme group is a flat ring molecule containing carbon, nitrogen and hydrogen atoms, with a single Fe^{2+} ion at the centre. Without the iron, the ring is called a porphyrin. In a heme molecule, the iron is held within the flat plane by four nitrogen ligands from the porphyrin ring. The iron ion makes a fifth bond to a histidine side chain from one of the helices that form the heme pocket.

When oxygenated, the compound is called oxyhemoglobin; when the iron, which is normally in the Fe(II) state, is converted to the Fe(III) state, the compound loses its oxygen binding capacity and is called methemoglobin. Oxyhemoglobin is an article of commerce (where it is often called hemoglobin); it has the form of a brownish red powder or scales and is the source of colour where blood (*q.v.*) was used to tint paint.

Porphyrins group; Blood

HEPATITE

White
Synonym, variant or common name

Given as a synonym for baryta white (synthetic barium sulfate, *q.v.*) by Riffault *et al.* (1874).

Barium sulfate; *Baryta white*
Riffault *et al.* (1874) 193

HERCYNITE

Black
Generic compound

Hercynite is an iron aluminium oxide of composition $Fe^{2+}Al_2O_4$. The term comes from the old Latin *hercynia silva*, meaning ‘forested mountains’. It is usually black or dark green in colour and occurs in ultra-basic, basic and metamorphic rocks (Deer *et al.*, 1992). The type locality is in Pobezovice, Czechoslovakia.

Identified by Stos-Fertner *et al.* (1979) with various iron oxides, huntite and metakaolinite on Minoan painted pottery.

Iron oxides and hydroxides group
Deer *et al.* (1992) 558–566; Stos-Fertner *et al.* (1979)

HERZENBERGITE

Black
Generic compound

Herzenbergite is an orthorhombic tin(II) sulphide mineral with chemical composition SnS (Dana, 1944; Sirina *et al.*, 1982). It is related to the hexagonal tin(IV) sulfide mineral berndtite (SnS_2, *q.v.*), and may also contain significant lead in the structure as it forms a series with teallite ($PbSnS_2$). Herzenbergite is named after the German chemist R. Herzenberg and is sometimes known as kolbeckine. It is a relatively rare mineral and occurs as soft black grains or fine masses with metallic lustre (Dana, 1944). Herzenbergite was first discovered by Ramdhour in 1934 at the Mari-Theresa mine (Oruro, Bolivia) and is also known from Cornwall (England), Medelpad (Sweden; e.g. Smeds, 1993), Bleikvassli (Norway), Viitaniemi (Finland), Salamanca (Spain; e.g. Pascua *et al.*, 1997) and Aluchin (Russia). It occurs with cassiterite and other sulfide minerals such as pyrite, sphalerite and galena (*qq.v.*), in tin deposits associated with granite emplacement and hydrothermal activity.

The berndtite form of tin sulfide is encountered as a pigment (Speleers, 1999; Smith *et al.*, 1981) and is more commonly known as mosaic gold (*q.v.*).

Tin sulfides group; Berndtite; Cassiterite; Galena; Pyrite; Sphalerite; *Mosaic gold*
Dana (1944) 259; Pascua *et al.* (1997); Sirina *et al.* (1982); Smeds (1993); Smith *et al.* (1981); Speleers (1999)

HEXACYANOFERRATE GROUP

Variable
Group term

Compounds based around the hexacyanoferrate ion (principally the iron(II) ion, $[Fe(II)(CN)_6]^{4-}$) form a significant and historically important group, not least because so-called Prussian blue (*q.v.*) is a member, a term which might reasonably be considered applicable to any of the blue hexacyanoferrate(II) pigments.

The composition and crystal structure of the hexacyanoferrate pigments has been the subject of prolonged and extensive argument. So as recently as the 1970s, Wilde *et al.* (1970) could observe that ‘In spite of a large number of powerful physical methods [of analysis] having been brought to bear on the structural problem of Prussian blue, there is still uncertainty as to the actual constitution of Prussian blue and the large number of Prussian blue analogues.’ In part this derives from the proliferation of methods used to prepare these pigments, but also more fundamentally it is as a result of the chemistry of this structure, whereby surface adsorbed ions can give an erroneous idea of the composition. Current understanding of the structure involves a cubic network of Fe(III)—C—N—Fe(II) units with some metal and cyanide sites left vacant (the so-called ‘Keggin–Miles’ structure and modifications thereof) with an essentially identical compound being formed under a wide variety of conditions. Water also forms part of the structure, giving a generally agreed formula approximating to $Fe_4[Fe(CN)_6]_3.xH_2O$, where $x = 14–16$ (Herren *et al.*, 1980). However, it should be noted that a second compound, $KFe[Fe(CN_6)].H_2O$, is also frequently mentioned in the literature and (although this is not currently considered a valid structure for this group) variations on this are still cited, such as the generalised formula $M^IFe^{III}Fe^{II}(CN)_6.nH_2O$ given in the review of the pigment by Berrie (1997). Importantly, this latter structure is related to the supposition that potassium and other forms based on sodium or ammonium substitution are also possible.

Other transition metals can be substituted into the framework replacing Fe(II) and Fe(III) ions, thus forming a group of closely related compounds. Copper hexacyanoferrates were known historically (called, variously, Prussian brown, Hatchett’s brown or Vandyke red), while zinc, nickel and cobalt substitutions are also documented. It has also been believed that several M(I) ions – Na^+ and NH_4^+ – could be substituted for the supposed potassium, or to make up charge with other ionic species. The known structure for hexacyanoferrate(II) is such that there is the possibility of filling particular vacant sites in the lattice with different ions, with the insertion of these ions possibly occurring from components present during the synthesis. Consequently, relatively minor changes to the method employed might give rise to differently substituted (and differently coloured) materials. However, work by the present authors suggests that all forms of the pigment contain the same iron(III) hexacyanoferrate(II) compound without substitution of M(I) ions such as K, Na and NH_4 into the structure as previously assumed, while at the same time showing that a number of other ions such as Cu, Sb and Zn can freely enter the structure. Other historical recipes involve the use of compounds of antimony, cobalt, titanium, tungsten, tin and vanadium reacted with hexacyanoferrates; further comparable analogues may therefore conceivably exist.

There is also much discussion in the literature regarding so-called ‘soluble’ and ‘insoluble’ Prussian blues. Supposedly the formulae were different, being formed from relative excesses of either the potassium hexacyanoferrate or the iron(III) chloride and giving either the ‘insoluble’ $Fe_4[Fe(CN)_6]_3.xH_2O$ or the ‘soluble’ $KFe[Fe(CN_6)].H_2O$ (Kirby, 1993). In the current view there should basically be no difference and the results of studies of material produced under both circumstances tend to support this. However, when the route to the so-called ‘soluble’ form is prepared it is noticeable that the supernatant liquid is strongly coloured blue. While the level of hydration could affect the solubility, interestingly Dix and Rae (1978) comment that the particle size is such that the precipitates have colloidal properties, thus affecting the ability to crystallise and causing an effective difference in ‘soluble’ and ‘insoluble’ forms; this might give some plausible explanation for the phenomena observed.

Finally, there are a number of other related compounds such as Fe(II)/Fe(II) and Fe(III)/Fe(III) cyanides; ‘Prussian white’ (also known as ‘Everitt’s salt’) is given as $K_2Fe^{II}[Fe^{II}(CN_6)]$ while so-called ‘Berlin green’ is stated to be $Fe^{III}[Fe^{III}(CN_6)]$. These are often used in recipes as precursors, but are not forms employed as pigments.

The conventional forms of iron(III) hexacyanoferrate(II) are widely documented in the historical and modern literature; a fuller discussion of these may be found under Prussian blue. The several copper(II) hexacyanoferrate pigments, copper dipotassium hexacyanoferrate(II) and dicopper hexacyanoferrate(II) hydrate, are of a red-brown colour and preparation is discussed in, for example, Bersch (1901) and the *Colour Index* (1971); the supposed structures have not apparently been confirmed by modern analyses although X-ray diffraction studies by the authors indicated that the crystal structure follows the same form as reported above. Cobalt and zinc-substituted Prussian blues have also been recorded by Salter (1869). An antimony-substituted hexacyanoferrate compound, antimony blue, is also known. Prussian blue treated with ammonia was known as ammonium Prussian blue or Monthiers blue after the inventor.

Cobalt hexacyanoferrate(II); Copper hexacyanoferrate(II); *Ammonium Prussian blue*; *Antimony blue*
Berrie (1997); Bersch (1901) 280; *Colour Index* (1971); Dix & Rae (1978); Herren *et al.* (1980); Kirby (1993); Salter (1869) 203; Wilde *et al.* (1970)

HIBERNIAN UMBER
Brown
Synonym, variant or common name

See: Cappagh brown.

HIGH GREEN
Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele’s and/or emerald green, though according to Zerr and Rübencamp (1906) high green was a mixture of 60–80 parts emerald green and 20–40 parts baryte (*qq.v.*).

Baryte; *Emerald green*; *Scheele’s green*
Fiedler & Bayard (1997); Zerr & Rübencamp (1906/1908)

HOFMANN’S VIOLET
Purple
Synonym, variant or common name

Hofmann’s violet was produced from magenta (*q.v.*) and (m)ethyl bromide/iodide; use as a pigment is uncertain.

Magenta

HOGAR BLUE
Blue
Synonym, variant or common name

Hogar blue is listed as a synonym for a copper phthalocyanine blue by Lefranc et Bourgeois in the late 1980s.
See: phthalocyanine group.

Phthalocyanine group

HOLLANDITE
Black
Generic compound

Hollandite is a black barium manganese oxide mineral. The composition may be given as $BaMn_8O_{16}$, though Post (1999, in a review of manganese oxides) prefers to discuss the ‘hollandite group’ with a generic formula of $R_{0.8\text{–}1.5}[Mn(IV),Mn(III)]_8O_{16}$, where R is barium, lead, potassium or sodium; hollandite itself is the barium mineral, but studies show that the various members are typically intermixed and, in some cases, even grade from one to another in a single crystal. They are usually found as fibrous crystals, often in compact botryoidal masses or, less commonly, as prismatic crystals in hydrothermal vein deposits.

According to Guineau *et al.* (2001), the mineral has been used as a pigment in European Palaeolithic cave art, notably at the caves of Peche Merle in France (the ‘Black Frieze’). The pigment has been found in these contexts mixed with variable amounts of carbon-based black, calcite, quartz, goethite, clays and traces of romanechite (*qq.v.*). Evidence points to the fact that the pigment was semi-synthetic, derived through burning local manganese hydroxide deposits (the mineral romanechite).

Barium group; Carbon-based blacks group; Clay minerals group; Manganese group; Manganese oxides and hydroxides group; Calcite; Goethite; Quartz; Romanechite
Guineau *et al.* (2001); Post (1999)

HOLLY GREEN
Green
Synonym, variant or common name

Listed by Mayer (1991) as a synonym for green earth (*q.v.*), though perhaps equivalent to holy green since ‘holy’ and ‘holly’ have historically had interchangeable spellings for the two principal meanings (*OED*, 2002).

Green earth
Mayer (1991) 46; *OED* (2002) ‘Holy’, ‘Holly’

HOLY GREEN
Green
Synonym, variant or common name

See: verdetto.

HOOKER'S GREEN

Green
Synonym, variant or common name

Field (1835) states that this is similar to a mixed green of Prussian or Antwerp blue and gamboge (*q.v.*). The identification of the constituents of Hooker's green as Prussian blue and gamboge is given by various authors such as Salter (1869) and Church (1901). However, a Reeves catalogue of c. 1896 states that their '*Permanent Hooker's green*' is an alizarin colour (cf. Carlyle, 2001). It was also apparently available in several grades, Salter indicating No. 1 was a 'light grass green', while No. 2 was a 'deeper and more powerful green'. Heaton (1928) lists Hooker's green as an obsolete or rarely used term.

Hooker's green belongs to the category of mixed greens discussed in several nineteenth century sources such as Field (1835).

Gamboge; *Antwerp blue*; *Prussian blue*
Carlyle (2001) 495; Church (1901) 202; Field (1835) 128; Heaton (1928) 381; Salter (1869) 281

HÖPFNER BLUE

Blue
Synonym, variant or common name

See: cerulean blue.

HOPPER WHITE

White
Synonym, variant or common name

According to Riffault *et al*. (1874), hopper white is the oxide formed on the surface of molten zinc during manufacture of zinc white (*q.v.*), the material being raked off into hoppers.

Zinc oxide; *Zinc white*
Riffault *et al*. (1874) 183–184

HORACE VERNET GREEN

Green
Synonym, variant or common name

See: vernet green.

HORN

Black-White
Generic variety

In cattle, sheep, Old World antelopes and related animals, the horns are permanent, unbranched and are usually present in both sexes. They are composed of a sheath of keratin (a tough fibrous material derived from epithelial tissue) overlying a bony core projecting from the skull. In pigment terms the references to horn do not actually refer to horn, but to the antlers of deer (stags or hinds) which are not strictly horns (*Columbia Encyclopedia*, 2003)
See: antler.

Columbia Encyclopedia (2003) 'Horn'

HORN BLACK

Black
Synonym, variant or common name

See: antler, horn and carbon-based blacks group: cokes subgroup.

HORNAZA

Yellow
Synonym, variant or common name

Hornaza (or *ornacha*) is a term found in Spanish treatises for a dark yellow pigment. Veliz (1986) links this to a term for glassmakers' furnaces – *hornillo* – and thereby to the *giallo di vetro* (*q.v.*) described by Borghini (1584), which is thought to be a lead-tin-antimony pigment.

Giallo di vetro
Borghini (1584/edition of 1787); Veliz (1986) 198, n.9

HORNBLENDE

Green
Generic compound

Hornblendes are dark green or greenish black amphibole group minerals with compositions which vary about $Ca_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$. Those varieties containing more iron are darker in colour. Hornblendes are widespread minerals and are common in intermediate and acid igneous rocks as well as regionally metamorphosed basic rocks.

Hornblende is listed by the *Colour Index* (1971) in connection with CI 77718/Pigment White 26.

Aluminium group; Calcium group; Iron group; Magnesium group; Silicates group
Colour Index (1971) 77718

HORNS OF HIND

White
Synonym, variant or common name

See: hartshorn, antler and bone, calcined.

HOSTAPERM PIGMENTS

Variable
Synonym, variant or common name

Trade name currently owned by the Clairant Corporation and used for a wide range of modern synthetic pigments of the azo and polycyclic types.

Azo pigments group; Polycyclic pigments group

HUBBOCKS WHITE

White
Synonym, variant or common name

This term refers to a form of zinc white (*q.v.*; Kühn, 1986).

Zinc white
Kühn (1986)

HUMBOLDTINE

Yellow
Generic compound

Humboldtine is an iron(II) oxalate mineral with chemical composition $Fe(C_2O_4).2H_2O$. It is related to the calcium oxalate minerals whewellite and weddellite (*qq.v.*) and is also known as oxalite. Humboldtine occurs as relatively soft prismatic crystals or as crusts and aggregates with a dull or resinous lustre. It was first reported by Rivero in 1821 from Kolosuruk (Czech Republic) and is also found in Cornwall (England), Bavaria (Germany), Durango (Mexico).

Although no known example of the use of humboldtine in a pigmentary context is currently known, Salter (1869) describes the pigment iron yellow (*q.v.*) as an 'oxalate of protoxide of iron'.

Organo-iron group; Iron(II) oxalate; Weddellite; Whewellite; *Iron yellow*
Salter (1869)

HUME'S PERMANENT WHITE

White
Synonym, variant or common name

This is probably a very early synthetic barium sulfate (*q.v.*). Samuel Parkes (1816) states that 'many years ago' a Mr Hume had discovered a method of making a colour from baryte (*q.v.*) which was 'sold under the name Hume's permanent white'. Harley (1982) seemingly supports this with her statement that the pigment was proposed by 'a Mr. Hume of Long Acre' (London, UK).

Barium sulfate; Baryte
Harley (1982) 175; Parkes (1816) 129–131

HUMIC EARTH

Black-Brown
Generic compound

Humic earth results from the decomposition of organic matter, particularly cellulose from dead plants. The organic phase contains humic acids, allomelanins with complex phenolic macromolecular structure. Humic substances fall between plants and geological materials (coals and petroleum). Degraded organic matter when released into the environment will form relatively soluble fulvic acids which will condense to form humic acids and then humins with lower solubilties. Humic earths are transitional between the low grade coal lignite (*q.v.*) and peaty soils.

Humic substances contain both humic and fulvic acids; the term humic acids is normally used to indicate the fraction (c. 10%) that precipitates at very low pH; fulvic acids refer to acid-soluble compounds, usually of lower molecular weight. Both fractions are usually defined operationally by a method of extraction. Humic acids are chocolate brown in colour, slightly soluble in water, usually with much swelling. Although their overall structure may be complicated and ill-defined, humic compounds appear to contain reasonably simple and consistent functional groups: carboxyls, alcohols and phenols. However, humic substances will have substantially different chemistry depending on their source. So, for example, studies of these materials in the environment have shown that in open ocean, where organic matter is almost always authigenic (formed *in situ*) humic compounds are formed by condensation, polymerisation and partial oxidation of smaller molecules such as triglycerides, sugars, or amino acids with little aromatic character; near land organic matter is largely allochthonous (imported from foreign sources), derived from decaying material of higher plants, particularly lignins – the resulting humic compounds retaining a relatively high degree of aromaticity from their precursors. Thus carboxylic and alcoholic functional groups are characteristic of all humates, but phenolic groups are found predominantly in humic compounds near land. We should also note that humates have affinities for metals (that is, they have chelation properties).

The term humus originally meant all organic compounds of plant origin in the soil; the term humic acids is used for the brown-black, polymeric, alkali-soluble acids found in soils, plants, seagrasses, fungi, sediments and terrestrial and marine waters.

Earth pigments which have significant organic matter (such as the siennas and some ochres, *qq.v.*) will contain humic and fulvic acids. Nocera earth, Cassel earth, Cologne earth and Vandyke brown are terms which have been used to refer to humic earth/lignite-based pigments (Feller and Johnston-Feller, 1997).

Earth pigments group; Hydrocarbons group; Lignite; Ochre; Sienna; *Cassel earth*; *Cologne earth*; *Vandyke brown*
Feller & Johnston-Feller (1997)

HUNGARIAN GREEN

Green
Synonym, variant or common name

According to Watin (1785), Hungarian green is 'a greenish mineral or fossil or more likely a chalk of green copper which is found in small grains, like sand in the mountains of Kernhausen in Hungary. It must be well ground both for oil and distemper with much stirring as it darkens colours.' He links it also to the term mountain green; it would therefore appear to refer to either malachite or chrysocolla (*qq.v.*). Kernhausen may refer to Krnov, a town on trade routes at the foot of the Nizký Jeseník Mountains in Czech Silesia.

Chrysocolla; Malachite; *Mountain green*
Watin (1773/edition of 1785) 30

HUNTITE

White
Generic compound

Huntite is a magnesium calcium carbonate mineral with chemical formula $Mg_3Ca(CO_3)_4$. It belongs to the carbonate group of minerals and is structurally and chemically similar to calcite, magnesite and dolomite (*qq.v.*), which also belong to this group. Huntite occurs as soft, white, fine-grained, compact and porous masses that crumble easily. It commonly forms as an alteration product of dolomite- or magnesite-bearing rocks, or it may precipitate in vugs, caves and fault zones. Huntite was first described by Faust in 1953 at Current Creek, Nye County (Nevada, USA) and named after W.F. Hunt. It has since been found in places such as Herault (France), Attica (Greece), Dorog (Hungary) and Queensland (Australia).

Huntite was first identified in a pigment context by Riederer in 1974 on ceramics from Nubia (1600 BC) and Green (2001) indicates that huntite, as well as calcite and gypsum (*q.v.*), was used widely as a white pigment by the ancient Egyptians. McCarthy (2001) reports that huntite is used as an underlying white layer overpainted with yellow ochre and orpiment (*qq.v.*) in wall paintings from the ancient Egyptian (c. 1430 BC) tomb-chapel of Suemniwet. Middleton and Humphrey (2001) report huntite as a white pigment used on Middle Kingdom Egyptian coffins. Heywood (2001) shows that it was used as a pigment earlier than this, during the Old Kingdom, from analysis of white pigments taken from various Egyptian artefacts (rock and wooden painted statues). Other Egyptian examples are given by Noll (1981), Bimson (1987), Mora *et al.* (1990) and Palet and Porta (1990). The use of huntite as a white pigment in ancient Egypt has also been reviewed by Heywood (2001).

In other contexts, Stos-Fertner *et al.* (1979) recorded the presence of huntite on Minoan painted pottery; Barbieri *et al.* (1975) have identified it as present on a second century AD Roman shipwreck; Clarke (1976) observed its use in Western Australian cave art, while Watchman *et al.* (1993) and Ford *et al.* (1994) have also identified huntite in Australian cave painting. A more general discussion of the use of huntite from an archaeological perspective is given by Meschel (1978).

Calcium carbonates group; Calcium group; Magnesium carbonates group; Magnesium group; Calcite; Dolomite; Gypsum; Magnesite Orpiment; *Yellow ochre*
Barbieri *et al.* (1975); Bimson (1987); Clarke (1976); Faust (1953); Ford *et al.* (1994); Green (1995); Green (2001); Heywood (2001); McCarthy (2001); Meschel (1978); Middleton & Humphrey (2001); Mora *et al.* (1990); Noll (1981); Palet & Porta (1990); Riederer (1974); Stos-Fertner *et al.* (1979); Watchman *et al.* (1993)

HYDROCARBONS GROUP

Yellow-Brown
Group term

The hydrocarbons are naturally occurring, gaseous, liquid and solid compounds composed predominantly of the elements hydrogen and carbon, but with small amounts of sulphur, oxygen and nitrogen present. The group may be broadly classified as petroleum (natural gas, crude oil, bitumens) and coals. Also included in this classification is the fossilised tree resin, amber. The organic chemistry of these materials is complex and the materials are impure mixtures of several classes of compound and phases. The majority of the materials and compounds are derived from plant remains that have been transformed due to the actions of increasing temperature over geological time (maturation). Coals (*q.v.*) and most natural gases are derived from terrestrial plant material, humic organic matter (carbohydrates, lignins and proteins) whereas petroleum is derived from the preservation of sapropelic organic matter (aquatic plant and animal material; primarily lipids and proteins).

Breakdown of organic matter in an oxidising environment does not lead to the preservation of fossil fuels. In the terrestrial environment, anoxic conditions and increasing temperature lead to the transformation of woody plant materials, cellulose to lignins releasing humic acids and methane. Humic and the related fulvic acids are found in soils, coals and peats, as well as various water bodies throughout the environment.

Coals are solid hydrocarbons. The term ‘rank’ refers to the successive transformation of coal with increasing temperature and increase in rank is characterised by the decrease in volatile components (water, carbon dioxide, etc.) accompanied by a corresponding increase in the amount of carbon present. Lowest grade coals are the fissile, friable and porous humic earths or lignites (*q.v.*). All volatiles are driven off and coals become black, compact and non-porous at temperatures of c. 60°C (maintained over geological time), where they become bituminous coals, the rank normally associated with the term ‘coal’. The highest rank of coal, anthracite (*q.v.*), forms at temperatures between 120 and 150°C and has greatly reduced hydrogen compared to bituminous coals. All hydrogen is lost and coal is metamorphosed into pure carbon, graphite (*q.v.*), at temperatures exceeding 200°C.

Bituminous coals are analogous to rocks in that they are impure substances made up of various constituents, called macerals. The chemistry of these materials is poorly understood, therefore the components are described in terms of their original organic material. Macerals are the equivalent to minerals in rocks and can be divided into three main groupings: vitrinites which are derived from woody plant material and are the commonest group of constituents; liptinite (also called ‘exinite’) derived from algae and the waxy and lipid-rich fractions of plants and inertinite which is similar to charcoal in that it is woody plant material which has been oxidised at an early stage of its formation. Macerals may be identified using reflected light microscopy. Based on the type, distribution and relevant amounts of macerals present, coals can be classified into four main types: vitrain, clarain, durain and fusain which commonly form banded seams. Non-banded coals are called cannel coals and are often sapropelic (aquatic) in origin. Vitrain is dominantly composed of vitrinites and is characteristically a brightly reflective black coal, breaking up along cubic fractures. Clarain has a silky lustre and is finely banded, and is also reflective but less so than vitrain. It too is dominantly composed of vitrain with minor amounts of liptinite and inertinite present. The major constituents of durain are inertinites, but minor amounts of vitrinite and liptinite are also present and it forms grey-black bands with a dull greasy lustre. Fusain is soft and friable with a charcoal-like appearance and contains predominantly inertinites. Additionally coals contain trace amounts of inorganic mineral impurities. Sulfates and sulfides, the latter often in the form of iron pyrites, are also a common constituent of coals. Clays, carbonates, pyrites and quartz are frequently present. The geology and petrology of coals is described by Stach *et al.* (1982) and Stopes (1935).

The petroleums are fluid and semi-solid hydrocarbons derived primarily from liptinites and are composed of the aliphatic compounds, the paraffins and naphthenes. The simplest chemistries and structures are related to the paraffin series (*n*-alkane series or methane series) with a general formula C_nH_{2n+2}: methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), hexane (C_6H_{14}), etc. The naphthenes (cycloparaffins, alicyclic hydrocarbons) are the ring compounds cyclopropane, cyclobutane, cyclopentane and so forth, and have a general formula C_nH_{2n}.

Aromatic compounds, based on the benzene ring structure, with the general formula C_nH_{2n-6}, occur in petroleums in amounts usually less than 10%. Aromatics are at their most concentrated in the denser grade heavy oils, bitumens and asphalts. Other minor constituents are acyclic isoprenoids (a series based on isoprene, C_5H_8, from which synthetic rubbers are derived), steroids (complex ring alcohols based on cyclohexane) and triterpenoid alcohols (with general formula, $[C_5H_8]_n$).

The physical state of the hydrocarbon is in part dictated by the length of the carbon polymer chain. Methane, ethane, propane, cyclopropane and cyclobutane are gases at standard temperature and pressure. Butane is generally a gas but may form condensates of very light oils. Pentane, cyclopentanes, hexanes, etc. are liquids. Liquid phases containing paraffins and naphthenes with between 4 and 40 carbon atoms are classified as oils (gasoline, kerosene, diesel, heavy gas oil, lubricating oils and heavy fuel oils with increasing carbon). Solid petroleum hydrocarbons are the bitumens (*q.v.*; kerobitumens, graphitic bitumens, asphaltic bitumens and pyrobitumens) with between 22 and 50 carbon atoms present.

Maturation of petroleum occurs over an equivalent geological timescale and temperature range as coals. Oil is produced at temperatures between 60 and 110°C (the ‘oil window’) and gas at temperatures exceeding 110–120°C (the ‘gas window’). Hydrocarbons formed below 60°C are said to be ‘immature’, and are equivalent to lignites and sub-bituminous coals. Post-mature carbon deposits form at temperatures exceeding c. 200–230°C (see North, 1985, for further discussion).

Amber (*q.v.*) is primarily composed of the terpene series, which includes the compounds pinene and menthol among many others. Like the other hydrocarbons amber is a fossil product and requires a period of maturation, which thus differentiates it from other solidified (but unfossilised) plant resins (copal).

The hydrocarbons have found use as transparent, richly coloured brown and black pigments. Most important is the use of bitumens (asphaltic bitumens) and their derivatives. Rivington (1901) describes a range of petroleum-based paints used for industrial and weatherproofing purposes. Low-grade humic coals are used as pigments in the form of Vandyke brown (*q.v.*) and similar compounds. Higher rank coals are, perhaps surprisingly, less frequently used as pigments. Amber has been used as a varnish (Carlyle, 2001), but due to it low solubility (c. 20%) solid, non-fused amber may be associated with the pigment fraction rather than in the varnish alone.

The applications as pigments are described in further detail under their respective entries.

Carbon-based blacks group; Amber; Anthracite; Asphalt; Bitumen; Coal; Graphite; Humic earth; Lignite; *Vandyke brown*
Carlyle (2001) 129; North (1985); Rivington (1901) 424, 426; Stach *et al.* (1982); Stopes (1935)

HYDROCERUSSITE

White
Generic compound

Hydrocerussite is a lead carbonate hydroxide mineral with the composition $Pb(CO_3)_2(OH)_2$. It occurs as white tabular hexagonal crystals and forms as a secondary mineral from the weathering of native lead. It is found in areas of lead deposits such as Broken Hill (New South Wales, Australia), Alsace (France), Ashover (Derbyshire, England), Attica (Greece) and Bisbee (Arizona, USA). Hydrocerussite is a comparatively rare mineral, closely related to plumbonacrite and cerussite (*qq.v.*), and may occur as an intermediate phase between these minerals.

The term hydrocerussite should properly refer to the natural mineral form only although it is sometimes applied to the synthetic analogue. The artificial form, which falls under the umbrella term 'lead white' (*q.v.*), has been synthesised since ancient times, with production methods described by the classical authors Vitruvius (first century BC) and Pliny (77 AD); according to Needham (1974), the technique was probably used as early as 300 BC in China. Such early knowledge of manufacture combined with the relative scarcity of natural hydrocerussite proper means that the mineral has only rarely found use as a pigment. For example, Pérez-Rodríguez *et al.* (1998) have reported its apparent occurrence as a white pigment, or admixed with iron oxides and azurite (*q.v.*), on polychrome ceramic statues at Seville Cathedral, Spain; in some areas the hydrocerussite was reported to have discoloured and this was attributed to the formation of lead sulfide. Hydrocerussite will, of course, undergo the same kinds of degradation patterns as those found with the synthetic lead carbonates.

Hydrocerussite and the related synthetic analogue have been discussed in the context of 'lead white' by Kühn (1967), Lancelot *et al.* (1987) and Gettens *et al.* (1993c).
See: lead carbonate hydroxide and lead carbonates group.

Lead carbonates group; Azurite; Cerussite; Lead carbonate hydroxide; Plumbonacrite; *Lead white*
Gettens *et al.* (1993c); Kühn (1967), Lancelot *et al.* (1987); Needham (1974); Pérez-Rodríguez *et al.* (1998); Pliny (1st cent AD/Rackham, 1952); Vitruvius (1st cent BC/Grainger, 1934)

HYDROLYSABLE TANNINS GROUP

Black-Brown
Group term

Hydrolysable tannins ('HTs') are, with the proanthocyanidins ('condensed tannins'), one of the two principal classes of tannins. HTs are molecules with a polyol (generally D-glucose) as a central core. The hydroxyl groups of these carbohydrates are partially or totally esterified with phenolic groups like gallic acid (gallotannins) or ellagic acid (ellagitannins). Two additional classes of hydrolysable tannins are sometimes also defined, which are taragallotannins (gallic acid and quinic acid as the core) and caffetannins (caffeic acid and quinic acid).

For a fuller discussion see the entry under tannins group.

Proanthocyanidins group; Tannins group

HYDROMAGNESITE

White
Generic compound

Hydromagnesite is a hydrous magnesian carbonate mineral with composition $Mg_5(CO_3)_4(OH)_2.H_2O$ (Akao *et al.*, 1974). It is named for its composition and was first described by Wachmeister in 1827. It is closely related to artinite (*q.v.*) and occurs as white acicular crystals, aggregates or crusts. It commonly forms as an alteration product of brucite and periclase (*qq.v.*; Deer *et al.*, 1992). Hydromagnesite is known from many locations worldwide including Vesuvius (Italy), Tyrol (Austria), Attica (Greece), Buskerud (Norway) and Crestmore (California, USA).

Using infra-red spectroscopy and thermal analyses, Bruni *et al.* (1998) identified hydromagnesite, magnesite and calcite (*qq.v.*) in ancient mortars from northern Italy. These phases were reported to have formed from the natural carbonation of the original lime paste mortar (which contained brucite) during curing. The presence of hydromagnesite in the coating materials of the walls of S. Maria della Grazia hypogean church (Laterza, near Taranto, Italy) has been ascertained by Garavelli *et al.* (1990). This hydrated basic magnesium carbonate occurs in one of the white coats in successive stages applied on the walls. It is thought that hydromagnesite arises from the use of whitewashing of a milk of lime prepared from local limestone, which sometimes has a very high magnesium content. The milk of lime rich in magnesium was used as white pigment before the application of the coloured paintings (that is, before the sixteenth to seventeenth centuries); it was no longer used for the later whitewashing applied on the frescos.

Magnesium carbonates group; Artinite; Brucite; Calcite; Magnesite; Periclase
Akao *et al.* (1974); Bruni *et al.* (1998); Deer *et al.* (1992) 570; Garavelli *et al.* (1990)

HYDRONIUM-JAROSITE

Yellow-Brown
Generic compound

Hydronium-jarosite, also known as carphosiderite, is an iron sulfate hydroxide hydrate mineral with composition $Fe_3(SO_4)_2(OH)_5.2H_2O$. It is named after its composition and relationship with jarosite (*q.v.*; Moss, 1957; Reinsch, 1882). Hydronium-jarosite was first described by Kubisz in 1960 and occurs as yellow to brown-red tabular crystals, aggregates and crusts. It is closely related by solid solution exchange to natrojarosite (*q.v.*) and jarosite (Brophy and Sheridan, 1965), but is less well characterized; other forms of jarosite such as plumbojarosite and argentojarosite are also known. Hydronium-jarosite forms as an alteration product of jarosite and feldspar group (*q.v.*) minerals in the presence of water, in sulfidic marine sediments and soils, and in acid environments such as mine waste deposits (Wills and Harrison, 1996). Its similarity to jarosite may mean that it is difficult to distinguish it optically.

Wallert (1995a) has identified hydronium-jarosite on a fourth century BC Greek marble basin. Hydronium-jarosite has also been identified by the authors among pigments excavated at Pompeii (Walsh *et al.*, 2004).

Feldspar group; Iron sulfates group; Jarosite; Natrojarosite
Brophy & Sheridan (1965); Moss (1957); Reinsch (1882); Wallert (1995a); Walsh *et al.* (2004); Wills & Harrison (1996)

HYDROXYLAPATITE

Variable
Generic compound

Hydroxylapatite is the hydroxyl-rich member of the apatite group (*q.v.*) of minerals, as the name indicates. It has chemical composition $Ca_5(PO_4)_3(OH)$. It occurs as detrital grains and authigenic masses in sedimentary rocks, and as a recrystallised mineral in metamorphic rocks. Hydroxylapatite varies in colour considerably due to the incorporation of additional elements such a manganese, iron and rare earths into the crystal structure (Deer *et al.*, 1992). Related isomorphous minerals are chlorapatite, fluorapatite and dahllite (*qq.v.*). Biogenic hydroxylapatite and calcium phosphate are important constituents of bone (*q.v.*) which has been used in a pigment context since antiquity. The inorganic component in ivory and bone has often been termed hydroxylapatite. However, studies show that this component usually contains significant carbonate, and therefore some authors have termed it dahllite (LeGeros *et al.*, 1960; McDonnell, 1965; McLellan and Lehr, 1969). Diagnetic changes which may occur in bone and ivory over time can result in the precipitation of other members of the apatite group.

Apatite group; Calcium group; Calcium phosphates group; Bone; Chlorapatite; Dahllite; Fluorapatite
Deer *et al.* (1992) 663–666; LeGeros *et al.* (1960); McDonnell (1965); McLellan & Lehr (1969)

HYPERCINNABAR

Red
Generic compound

Hypercinnabar is a hexagonal red mercury sulfide mineral with composition β-HgS. It is named after its relationship with cinnabar (*q.v.*), of which it is a polymorph. Hypercinnabar has been identified as tiny crystals present in metacinnabar (*q.v.*), the black cubic form of HgS, at Mount Diablo (California, USA), where it was reported to be slightly deficient in mercury (Hey, 1993); it has also been reported as found at Chauvay (Alai, Kyrgyzstan) (Kolesar *et al.*, 1993). It may be encountered in the black alteration products of vermilion (*q.v.*) pigments.

Mercury group; Cinnabar; Metacinnabar; *Vermilion*
Hey (1993); Kolesar *et al.* (1993)

HYPOCASTANUM

Brown
Synonym, variant or common name

According to Salter (1869), ‘Hypocastanum, or Chestnut Brown, is a brown lake prepared from the horse-chestnut. This now obsolete pigment is transparent and rich in colour, warmer than brown pink.’

The horse chestnut, *Aesculus hippocastanum* L. (Hippocastanaceae; also sometimes given as *A. hypocastanum*), is a familiar tree, being native to temperate regions of the northern hemisphere. Other chestnut (*Castanea*) species yield brown dyestuffs – for example, *C. dentata* (Marsh.) Borkh. (Schweppe, 1992) is known to have been used by the Native American Cherokee for this purpose (Moerman, 1998) – however, none are known to have been converted into pigments.

Tannins group
Moerman (1998); Salter (1869) 357; Schweppe (1992) 331

HYSGINUM

Red
Synonym, variant or common name

The classical author Vitruvius (first century BC) mentions *hysginum*, which is generally considered to be a dye derived from one of the scale insects (usually considered to be kermes, *q.v.*).

Kermes
Vitruvius (1st cent BC/Grainger, 1934) VII.xiv.1

I

IBERICIN

Red
Generic compound

This is a principal colouring matter found in the roots of *Rubia iberica* C. Koch (Stikhin *et al*., 1968; cf. Schweppe and Winter, 1977).
See: madder.

Schweppe & Winter (1997); Stikhin *et al*. (1968)

ILLITE

White
Generic compound

Illite is a potassium aluminosilicate hydroxide mineral with composition $KAl_4[Si_7AlO_{20}](OH)_4$, although impurities such as Na, Ca and Fe may be present. It belongs to the clay minerals group and is the principal member of the illite group (*qq.v.*) of clays. Illite, also known as gumbelite, occurs as soft earthy masses of microscopic crystals which are white when pure, although coloured varieties (yellow, brown, green) caused by impurities are often found. Illite is common worldwide and forms from the weathering of potassium-rich members of the feldspar and mica groups, such as orthoclase and muscovite, or from the metamorphism of smectite group (*qq.v.*) clay minerals; it is a common component in sedimentary rocks such as mudrocks and shales where it is often found interlayered with smectite clays. Hydro-muscovite, or hydromica, is a hydrated form of illite in which H_3O^- ions replace K to form a structure similar to that of members of the mica group (Deer *et al*., 1992; Srodon and Eberl, 1984; Rutley, 1988).

Illite has been identified as a component of some green earth pigments rich in glauconite, where it occurs in the form of pellets containing a clay mixture of glauconite, montmorillonite, kaolinite and members of the chlorite group (*qq.v.*; Grissom, 1986). Watchman *et al.* (1993) found illite, with kaolinite and muscovite, as a white mineral in rock paintings in the Laura Region (North Queensland, Australia). Ford *et al.* (1994) also identified illite in rock art pigments from the Kimberley region of Western Australia. Illite has been used admixed with kaolinite, montmorillonite and chlorite minerals in plasters at the ancient cave site of Galdar (Grand Canary Island, Spain), as detailed by Sánchez-Moral *et al.* (2002), while Couraud (1987) mentions it generally as a pigment of prehistory. It has also been found by Price *et al.* (1998) occurring on paintings by Vincenzo Foppa (1427/30–1515/16).

Aluminium group; Chlorite group; Clay minerals group; Clay minerals group: Illite sub-group; Clay minerals group: Smectite sub-group; Sheet silicates group; Glauconite; Green earth; Kaolinite; Montmorillonite; Muscovite; Orthoclase

Couraud (1987); Deer *et al*. (1992) 363–368; Ford *et al*. (1994); Grissom (1986); Price *et al*. (1998); Rutley (1988) 410, 412; Sánchez-Moral *et al*. (2002); Srodon & Eberl (1984); Watchman *et al*. (1993)

ILMENITE

Black
Generic compound

Ilmenite is a black or sub-metallic black mineral of composition $FeTiO_3$. Ilmenite is found worldwide in primary massive ore deposits and secondary alluvial deposits (sands). Two-thirds of the total known ilmenite economic reserves are in China, Norway and the CIS; however, the greatest output is currently from Australia, Canada and South Africa. It forms the principal source of raw material for the production of titanium dioxide white pigments. The material known as leucoxene is a form of ilmenite enriched in titanium dioxide through weathering; it is used as a minor source of ore for processing into pigment (Buxbaum, 1998).

Colinart (2001) reports finding grains of ilmenite present within yellow ochre on Egyptian artefacts such as the stela of Djehuty from the eighteenth dynasty. The presence of ilmenite in coloured grounds of paintings from the seventeenth to eighteenth century French School has been noted by Duval (1992), among natural impurities in earth pigments. There is also some limited modern use of the mineral as the pigment 'ilmenite black' (Heaton, 1928).

Iron group; Iron oxides and hydroxides group; Titanium group; Titanium oxides and hydroxides group; Anatase; Rutile; *Ilmenite black*; *Leucoxene*; *Yellow ochre*

Buxbaum (1998) 45–47; Colinart (2001); Duval (1992); Heaton (1928) 94, 182

ILMENITE BLACK

Black
Synonym, variant or common name

According to Heaton (1928), the ore ilmenite ($FeTiO_3$), otherwise used to prepare titanium dioxide pigments, may be prepared and used as a black pigment. For more information see: ilmenite.

Ilmenite
Heaton (1928) 182

ILSEMANNITE

Black
Generic compound

Ilsemannite is a hydrous molybdenum oxide mineral with composition $Mo_3O_8.nH_2O$. It is one of the rarer molybdenum-bearing minerals, with Mo more commonly found as molybdenite, MoS_2, or wulfenite (*q.v.*). Ilsemannite is a relatively hard amorphous material that is found as black or blue-black crusts, formed as an alteration product of molybdenite or from volcanic fumarole activity. It is soluble in water and is often found in association with gypsum, limonite, pyrite, chalcopyrite, galena, anatase and vivianite (*qq.v.*); it is also related to sidwillite, $MoO_3.2H_2O$. Ilsemannite was first described by Hoefer in 1871 from Austria, but it is also known from Saxony (Germany), Bamford (Australia), Kudriavyi volcano (Russia; e.g. Bykova *et al*., 1995), and Arizona and New Mexico (USA).

Harley (1982) has discussed the possible interpretation of the 'molybdic' recorded in the stock of the British colour-manufacturing firm of Berger for 1805. Classed alongside blue verditer and various green pigments she suggests that it was in fact ilsemannite, linking it to other terms such as molybdenum blue and blue carmine. These latter terms, however, appear to be molybdenum compounds produced synthetically using aqueous routes.

Molybdenum group; Molybdenum oxides and hydroxides group; Wulfenite; *Blue carmine*; *Molybdenum blue*
Bykova *et al*. (1995); Harley (1982) 59

IMPERIAL GREEN
Green
Synonym, variant or common name

According to Zerr and Rübencamp (1906) imperial green was 'one of the numberless products owing their existence to more or less advantageously chosen proportions of arsenic, copper sulphate, and vinegar … the dull imperial green is neither a decided lime nor an oil colour of any special covering power, and may be regarded as occupying a position between emerald green and Neuwied lime green'.

Mayer (1991) simply indicates that this is a variety of emerald green containing an inert filler.

Emerald Green
Mayer (1991) 46; Zerr & Rübencamp (1906/1908) 221

IMPERIAL RED
Red
Synonym, variant or common name

Heaton (1928) lists imperial red as a then-current synonym for an eosine lake.

Eosin
Heaton (1928) 381

INDACO
Blue
Synonym, variant or common name

Italian for indigo (*q.v.*). Baldinucci (1681) describes it as the juice of a grass called guado (woad) used by painters to make '*un colore tra turchino e azzurro*' ('a colour between turquoise and azure'), which he says was unknown in Italy before Pliny. A sample labelled *indaco* from the collection of pigments belonging to the Swiss Symbolist painter Arnold Böcklin (1827–1901) has been identified as a mixture of smalt and indigo (Richter and Härlin, 1974b).

Indigo
Baldinucci (1681) 75; Richter & Härlin (1974b)

INDANTHRENE
Blue
Generic compound

Indanthrene is the registered name of 6,15-dihydro-5,9,14,18-anthrazinetetrone, or, N,N′-dihydro-1,2,1′,2′-anthraquinonazine. It is a blue vat dye discovered in 1901 by Rene Bohn. There are several commercial pigment grades, such as the usual Indanthrene Blue R, and a purer grade called Indanthrene Brilliant Blue FF (de Keijzer, 1990; *Merck Index*, 1996).

Polycyclic pigments group: Flavanthrone/Indanthrone sub-group
Keijzer (1990); *Merck Index* (1996) 4968

INDANTHRENE BLUE
Blue
Synonym, variant or common name

See: polycyclic pigments group: flavanthrone/indanthrone sub-group.

INDE BLEW
Blue
Synonym, variant or common name

Historical term for indigo (*q.v.*); listed by Schweppe (1997).

Indigo
Schweppe (1997)

INDEBAUDIAS
Blue
Synonym, variant or common name

Historical term used in connection with indigo and woad (*qq.v.*; Schweppe, 1997). Peacham (1622) refers to this term as meaning indigo, and also to English indebaudias, which is described as inferior, therefore probably derived from woad (cf. Harley, 1982).

Indigo
Harley (1982) 66; Peacham (1622); Schweppe (1997)

INDIAN BLUE
Blue
Synonym, variant or common name

Indian blue is a synonym for indigo (*q.v.*), India being a major source of this (Schweppe, 1997).

Indigo
Schweppe (1997)

INDIAN LAKE
Red
Synonym, variant or common name

According to Salter (1869), Indian lake was obtained from lac, discriminating between two forms thus, 'The roughly prepared coating [of lac resin] is imported in two forms, called lac-lake and lac-dye, which contain about 50 per cent of colouring matter, combined with more or less resin, and with earth matters, consisting chiefly of carbonate and sulphate of lime and silica.' He further adds that 'Indian lake is rich, transparent, and deep.'

Seward, writing in 1889, concurs that Indian lake was derived from lac dye and the British colourmen Winsor & Newton record in their 1896 catalogue that lac was still used; however, by c. 1898 the firm of Reeves state that they used alizarin (cf. Carlyle, 2001). See: lac.

Carlyle (2001) 507; Salter (1869) 138–139; Seward (1889)

INDIAN PURPLE
Purple
Synonym, variant or common name

Salter (1869) describes this as being prepared by 'precipitating an extract of cochineal with sulphate of copper. It is a very deep-toned but rather cold and subdued purple, neither so red nor so brilliant as burnt carmine.' In the 1896 catalogue of the British colourmen Winsor & Newton the above description was given for the water-colour pigment, but it was stated that the oil colour was based on 'Madder lake and French ultramarine' (cf. Carlyle, 2001).

Copper sulfates group; Cochineal; *Burnt carmine*
Carlyle (2001) 502; Salter (1869) 298–299

INDIAN RED

Red
Synonym, variant or common name

Chambers' *Cyclopaedia* (1738, Supplement, 1753) states that Indian red was 'a name used by the colourmen and painters for a kind of purple ochre, brought from the island of Ormus in the Persian gulf'. However, Dossie (1764) records that, while this was once so, the colour then sold under the name was in fact prepared from *caput mortuum* (*q.v.*). Ure (1875–78) was also aware of this, noting it as a red pigment originally obtained from the East Indies in the form of an earth containing iron oxide but which by that time was prepared artificially by roasting iron sulfate. Toch (1916) also gives several explanations for the origin of the name: '[Indian red] is supposed to have been named by Benjamin West, a celebrated American artist … who as a boy used a few primary earth colors as pigments for paint. One of these was a natural hematite, and he observed that the Indians used this for painting their faces. The name is also supposed to have had its origin in the fact that "Persian Gulf Ore," which was found in the Orient, was exported to England under the name "East Indian Red."' Zerr and Rübencamp (1906) use this as the leading term for ferric oxide-rich red ochre. Finally, Riffault *et al.* (1874) cite a Professor Dussauce who describes this pigment in 1861 as an organic colour obtained from sandalwood; this appears to be an uncommon use of the term.
See: red ochre.

Hematite; *caput mortuum*; *Red ochre*
Chambers (1738) 'Red'; Dossie (1764) 53; Riffault *et al.* (1874) 486; Toch (1916) 64–65; Ure (1875–78) II. 890; Zerr & Rübencamp (1906/1908) 390–391

INDIAN YELLOW

Yellow
Common generic composite

Indian yellow is a complex compound the coloration of which is primarily due to calcium and magnesium salts of the xanthone compound euxanthic acid. It seems to have been primarily produced in India between the fifteenth and nineteenth centuries, from where it was widely exported. The preparation is also somewhat infamous in that it is generally thought to be derived from urine collected from cows fed on mango leaves (*Mangifera indica* Linn.), this being evaporated and the resultant precipitate formed by hand into balls, these becoming the item of trade. The practice was reputedly inhumane, said to cause suffering and premature death to the animals; however, documentary sources diverge to some degree on this point even though production of the pigment appears to have been halted, at least in part, because of this. (Note that recent research by Finlay (2002) has cast some doubt on this.)

Perhaps the best description of the production of Indian yellow is that of Mukharji (1883–84), who studied the process in Mirzapur, Monghyr, north-east Bihar, India. He describes how the urine was collected in small earthen pots, cooled, then concentrated over a fire. The liquid would be strained through cloths and the sediment collected formed into the aforementioned balls, dried over a charcoal fire and then in the sun. The product was relatively crude and required refinement before use; importers in Europe would wash and purify the pigment, separating yellowish and greenish phases, the former of which would be redried and then used as a base for water or oil colours.

Chemical composition was the subject of extensive research in the later nineteenth century. Baer *et al.* (1986) summarise this, indicating that the principal constitution of Indian yellow is a mixture of calcium and magnesium salts of euxanthic acid, the latter predominating and the salts usually being present as the basic hydrate. Mango leaves are a rich source of euxanthone, the bovine metabolic process serving to effect the conversion into the salts. Different grades of the pigment could typically contain anywhere between about 34 and 65% of euxanthic acid (Wehlte, 1975; Zerr and Rübencamp, 1906), though other analyses indicate even lower levels in some products; calcium and magnesium are present to a few per cent each.

Earlier European historical sources (notably the nineteenth century authors) speculate wildly on the true nature of this pigment. Osborn (1845), for example, asserts that it is 'a vegetable extract', though presents information in his footnotes to the effect that some (French) authors believe it to be an extract of a 'large shrub' *Memecylon tinctorium* while other (English) sources say it appears to be a 'urio-phosphate of lime', made from the urine of camels. Osborn adds that he believed it to be manufactured in Calcutta, and to reach France from England. Other contemporary authors seem to have had a better knowledge; the British colourman Field, for example, records that it was 'said to be produced from the wine of the (buffalo/camel after feeding on Mangoes) in India' (Field MS 1809 f. 337v./transcr. Harley, cf. Baer *et al.*, 1986).

Numerous later nineteenth and earlier twentieth century sources also attest to an interest in the structure and synthesis of Indian yellow, extending from the 1844 publications of Erdmann and Stenhouse to those of Reindel and Anschutz and Karrer in 1947. However, although synthetic analogues of Indian yellow can be produced, these do not appear to have been commercially supplied (Wehlte, 1975).

Baer *et al.* also list a number of terms used in India with respect to this pigment, largely orthographic variants of *piuri*: *peori*, *purree*, *pioury*, *purrea Arabica*, *Hardwari peori*, *peri rung*, *peoli*, *Monghyr puri* as well as *gogili* and *gaugoli*; Chandra (1949a,b; cf. Baer *et al.*) records that *gogili* was an Indianised form of a Persian term meaning 'cow earth', the author further suggesting on this basis that the pigment originated in Persia. While in Europe and the US Indian yellow was the primary term, according to Maerz and Paul's *Dictionary of Color* (1950) the term 'snowshoe yellow' was also used, though the origin and derivation of this particular appelation remains obscure. The *Colour Index* lists Indian yellow as CI 75320. Some confusion also exists in the literature as a result of cobalt yellow ('aureolin') being sold under the name Indian yellow (Cornman, 1986). Finally, because of substitution, pigments labelled Indian yellow may also be composed of alternatives such as azo yellow dyestuffs (typically CI Acid Yellow 23, Acid Yellow 63 and Acid Orange 1).

The pigment has been reviewed by Baer *et al.* (1986).

Calcium group; Magnesium group; Xanthones group; Calcium euxanthate; Euxanthic acid; Euxanthone; Magnesium euxanthate; *Cobalt yellow*; *Gaugoli*; *Gogili*; *Monghyr puri*; *Peori*; *Piuri*; *Puree*; *Purree*; *Snowshoe yellow*

Baer *et al.* (1986); Chandra (1949a) 83; Chandra (1949b) 27; *Colour Index* (1971) 75320; Cornman (1986); Finlay (2002); Harley (1982) 105; Mukharji (1883–84); Osborn (1845) 12–13; Wehlte (1975) 53, 94–95; Zerr & Rübencamp (1906/1908) 438

INDICH

Blue
Synonym, variant or common name

Term used historically in mediaeval German texts in connection with indigo (*q.v.*). For example, the sixteenth century Nürenburg Manuscript (see: Ploss, 1962) gives a recipe for making indigo under this name. *Indisch* in German translates as the adjective 'Indian' and is probably the word *endisch* in texts such as the *Illuminierbuch* of 1549 by Boltz.

Indigo
Boltz von Ruffach (1549/Benziger, 1913) 81; Ploss (1962) 113

INDICUM

Blue
Synonym, variant or common name

The classical Roman authors Vitruvius (first century BC) and Pliny (77 AD) mention *indicum*, which may be adduced to be an indigo probably traded from India. Pliny adds that it may be adulterated by boiling violets in water.
See: indigo.

Indigo; *Iris blue*
Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii.163; Vitruvius (1st cent BC/Grainger, 1934) VII.ix.6

INDIGO

Blue
Common generic composite

Indigo is a blue pigment as well as a major dye derived from the leaves of various *Indigofera* species, members of the Leguminosae family native to India, South and Central America, Asia, etc. (only some of the 800 *Indigofera* known contain a high quantity of the colouring matter, the most widely used being *Indigofera tinctoria* L.) and other plant species such as *Isatis tinctoria* L. (*woad* native to the Mediterranean and Western Asia grown in Europe and North America) and *Isatis indigota* Fortune ex Linl. (woad from China); *Polygonum tinctorium* L. (dyer's knotweed or Chinese or Japanese indigo native to eastern Asia); *Strobilanthes flaccidifolius* (Assam indigo from Asia); *Lonchocarpus cyanescens* (Yoruba indigo from West Africa and Malasia); *Wrightra tinctoria* (dyer's oleander from India, Burma and Malasia) and *Baptista tinctoria* Roxb. (wild or false indigo formerly known as *Sophora tinctoria* L. from North America). Chemically 2-(1,3-dihydro-3-oxo-2H-indol-2-ylidene)-1,2-dihydro-3H-indol-3-one, it is listed in the *Colour Index* as CI 75780/Natural Blue 1 and the synthetic form is CI 73000/Pigment Blue 66/Vat Blue 1. Various derivatives, both natural and synthetic, are also known as dye compounds; examples are the bromine compounds found in Tyrian purple and the sulfonated forms prepared by treating indigo with sulfuric acid.

The word indigo derives from the Greek *ινδικον* and the Latin *indicum*, meaning 'Indian' or 'coming from India'; however, there is an extensive historic terminology for indigo which reflects the importance of this material both as a dye and as a pigment. A distinction needs to be drawn between indigo used in these two ways. The terms also reflect the different sources of the dye, woad being called *isatis* by the ancient Greeks, *vitrum* by Vitruvius (first century BC), *glastum* by the Gauls and by Pliny (77 AD), *weit* or *weid* in old High German, *guado* or *guato* in Italian, *pastel* in France. Indigo from *Indigofera* species was called *Indicum* by Dioscorides (1st cent AD) and Vitruvius, *lulax*, *indich* or *endich* (*q.v.*) in mediaeval German, *indebaudias* and *inde blew* in mediaeval English. A pigment labelled *Indaco* was found in a collection of German nineteenth century pigments; however, this was a mixture of indigo and smalt (Richter and Härlin, 1974b). Other terms refer to the place of manufacture or route of import, thus: Baghdad indigo (*indigo bagdadel*, *inde baudias*, *bandas indacca indigo del golfo* from Baghdad (Merrifeld, 1849)); Lombardy indigo (Genoese and Venetian merchants brought the indigo to Italy, from where it was traded on to the rest of Europe) and Tripoli indigo, being trade routes; Guatemala indigo; tropical indigo referring to sources of manufacture, etc. In China the terms include *lan cao*, *dian hua*, *hua ging*; the Japanese terms include *ai*, *seitai*, *aibana*, *tenka*; in India the term was *nilah*, leading to the arabic term *anil*; in Mexico there was *matlalli*, and the Mayans used *jiquilite* (Schweppe, 1997). The quality of the indigo also gave rise to specific names such as rich indigo which appears later to have been corrupted into rock indigo or stone blue (Harley, 1982). This may also have derived from the fact that there was some confusion over the source of indigo as it was often thought to have been a mineral. The terms florey or flowers of indigo or their many translations into other languages (*florée*, *fiore*, *plumen*, *bloem*, etc.) refers to the method of manufacture (see below). For a more detailed discussion of the various terms for indigo see the individual entries. Merrifield (1849) cites a manuscript where it may have been called *folium indicum.* (For a possible explanation see: folium.)

Indigo is produced by first steeping the leaves (heat is not required for woad, whereas this is necessary for indigo species). The water must be alkaline in order to begin the process of fermentation and as such recipes call for the addition of urine, ash or slaked lime. The fermentation could also be begun by first composting the leaves (this method is always used for processing woad). The soaked leaves are then beaten to a pulp or stirred vigorously to oxidise the mass until the indigo forms as a precipitate which is then dried and often formed into balls. The indigo was most easily imported in this form. (For a full discussion of the production of indigo see Balfour Paul, 1998.) It was then possible to grind the extract and use this as a pigment. The production of indigo was not well understood by all the early writers, Dioscorides (first century AD) believing that it 'comes of its own accord being … the froth of Indian reeds'. Dioscorides also describes 'flower of purple' which was produced by taking the froth, which is finely dispersed indigo, off the top of the vat being used for dying. Eikema Hommes (2002) states that this was most likely to be from woad but that imported indigo was increasingly being added to woad dye during the sixteenth century in Europe. Indigo pigment was also extracted from dyed wool which was then broken down by drenching in a strong alkaline solution and neutralising. The resultant mass was filtered through cloth and dried. Ploss (1962) cites several German sources for recipes for the production of pigment from dyed textile shearings, for example a Nürnberg manuscript (Clarke MS 2270) from circa 1390 and a fifteenth century Bamberg manuscript (Clarke MS 80). For a fuller description of this process see: *cimatura*.

The method for the synthetic production of indigo from a coal tar base (using isatin) was discovered by Baeyer and Emmerling in 1870. This was finally commercially produced as indigo pure (*Indigo rein BASF*) in 1897 (Schweppe). Synthesis is achieved by three different means, conversion of N-phenylglycene into pseudoindoxyl which is then oxidised in air; conversion of phenylglycene-*o*-carboxalic acid into indoxylic acid and then air oxidation in alkaline solution; or treating thiocarbanilide with potassium cyanide and lead carbonate in aqueous-alcoholic solution, converting the resultant *a*-cyano-*N,N′*-diphenyl-formamide into 2-anilino-a(phenylimino)-pseudoindixyl (isatin-*a*-anilide) by heating with sulfuric acid, isolating the hydrochloride and converting to indigo with ammonium sulfide. For a fuller description see the *Colour Index* (1971).

The pigment was generally considered too dark for direct use and was therefore mixed with various white pigments and 'in the Middle ages certain [mixtures] … assumed the character of independent pigments' (Thompson, 1935). Maya blue (*q.v.*) was produced in this way by mixing the indigo with palygorskite. Many bulking materials were used in the production of the dye and Pliny even mentions pigeon droppings. Eikema Hommes adds that ashes and soot, sand, blue wool and silk, starch, resin and rust can be found as adulterants. She also indicates residual salts from the plants which may also be found in conjunction with indigo: calcium and magnesium carbonate, and aluminium and iron oxide. Church (1901) outlines a number of different processes for preparing indigo as well as listing starch, gypsum, clay, chalk, steatite (talc) and Prussian blue among its common adulterants. Woad was also made into crayons called pastel (*q.v.*).

Literature on the pigmentary use of indigo is ample. Several classical authors describe indigo as coming from India and Pliny describes its use as a fresco pigment. Indigo has been identified in Roman wall paintings of the first century AD where of the organic blues, indigo (*indicum*) was the most valued, another of the 'florid' colours. (Vitruvius also mentions as an aside that a colour akin to indigo may be produced by burning the lees of the finest wines. See: vine black.) It is not always clear whether the early authors are referring to indigo or woad as the source and analysis is not yet capable of distinguishing between these in historic samples (Eikema Hommes); however, from the context the source can sometimes be inferred. Mediaeval manuscripts indicate that imported oriental indigo was used as a pigment and the Bolognese manuscript, *I Segreti per Colori* (fifteenth century, Clarke MS 160; cf. Merrifield), gives nine methods for the preparation of indigo from woad for use as a pigment. It is probable that the prohibitive cost of imported indigo would have meant that it was not used in Europe as a dye until the late sixteenth century.

Indigo has been found on Mayan pottery and frescos from the third century and on a German document examined by the Doerner Institute from 972 AD. Riederer (1997b) found indigo on sixth century Central Asian wall paintings and Duffy and Elgar (1995) have identified pigmentary indigo in a group of late seventeenth Tibetan thankas. The pigment has also been identified on British cathedral polychromy from the thirteenth century (Sinclair, 1995) and Norwegian altars of the same period (Plahter, 1995). Identification of indigo in painting has also been found from fifteenth century Italy (Dunkerton *et al.*, 1987) and the Netherlands (Bomford *et al.*, 1986) through to nineteenth century Britain (Townsend, 1993b). There is increasing evidence of the use of indigo as a pigment in European painting of the seventeenth and eighteenth centuries; for a full discussion of this, see Eikema Hommes (2002). Extensive reports are also cited in Schweppe (1997). There are several excellent modern reviews of the origin, composition, analysis and use of indigo as a historical pigment, notably those by Schweppe and Eikema Hommes, while there is also a more general text on indigo by Balfour Paul.

It is given the *Colour Index* designation CI Natural blue 1.

Indigoid group; *Anil*; *Azorium Romanum*; *Baghdad indigo*; *Inde blew*; *Indebaudias*; *Indich*; *Indicum*; *Indigo Bagadel*; *Lamptschen endich*; *Lombardy indigo*; *Lulax*; *Pastel*; *Rich indigo*; *Rock indigo*; *Stone blue*; *Uvatum*

Balfour Paul (1998); Bomford *et al.* (1986); Church (1901) 217–223; Clarke (2001) 44; *Colour Index* (1971); Duffy & Elgar (1995); Dioscorides (1st cent AD/Osbaldeston & Wood, 2000) 5107; Dunkerton *et al.* (1987); Eikema Hommes (2002) 109–170; Harley (1982) 69; Merrifield (1849) ccxv–ccxiv, 412–416; Plahter (1995); Pliny (1st cent AD/Rackham, 1952) XXXV, xxxvii; Ploss (1962) 124; Richter & Härlin (1974b); Riederer (1977b); Schweppe (1997); Sinclair (1995); Thompson (1935) 139; Townsend (1993b); Vitruvius (1st cent BC/Grainger, 1934) VII.ix.6

INDIGO BAGADEL

Blue

Synonym, variant or common name

A form of natural indigo, probably produced in India. For example, the MS of Alcherius (1398–1411; cf. Merrifield, 1849) remarks on 'fine indigo, which is called by the name of Bagadel'. The origin of this term appears to be that indigo from the Indian subcontinent was traded by Arabic merchants through Baghdad, from where it was distributed to the rest of Europe (Eikema Hommes, 2002; Schweppe, 1997).

See: indigo.

Eikema Hommes (2002); Merrifield (1849) 272; Schweppe (1997)

INDIGO CARMINE

Blue

Synonym, variant or common name

Two isomers occur within indigo carmine, reflecting different sulfonation points on the molecule: disodium 3,3′-dioxo-[$\mathrm{d}^{2,2'}$-biindoline]-5,5′-disulfonate and disodium 3,3′-dioxo-[$\mathrm{D}^{2,2'}$-biindoline]-5,7′-disulfonate (also given as 2-(1,3-dihydro-3-oxo-5-sulfo-2H-indol-2-ylidene)-2,3-dihydro-3-oxo-1H-indole-5-sulphonic acid disodium salt; *Merck Index*, 1992). It is prepared by treatment of indigo with sulfuric acid.

Riffault *et al.* (1874) describe this in a pigment context thus: 'Nordhausen sulfuric acid dissolves indigo almost entirely. In accordance with the proportions of acid held in it, this solution bears different names. Thus indigo purple is formed of equal equivalents of acid and indigo, and sixteen to twenty of sulfuric acid, constitute indigo carmine or sulphoindigotic acid. Generally, painters mingle these two solutions under the names of Saxony blue, blue in liquor, and composition blue.' Balfour Paul (1998) describes the result as a bright 'turquoisy' blue known to dyers as Saxon or chemic blue.

Various other names are associated with indigo carmine, such as blue carmine, blue of England, blue of Holland, indigo purple, or sulphate of indigo or extract of indigo (Balfour Paul). It is also Listed in the *Colour Index* as CI 73015 and Acid Blue 74 and Food Blue 1.

Indigoid group; Indigo; *Blue carmine*; *Blue in liquor*; *Blue of England*; *Blue of Holland*; *Composition blue*; *Indigo purple*; *Saxony blue*

Balfour Paul (1998) 116; *Colour Index* (1971) 73015; *Merck Index* (1996) 4978; Riffault *et al.* (1874) 268–269

INDIGO PURPLE

Blue-Purple
Synonym, variant or common name

Synonym for indigo carmine (*q.v.*; Riffault *et al*., 1874).

Indigo carmine
Riffault *et al*. (1874) 268

INDIGODISULFONIC ACID

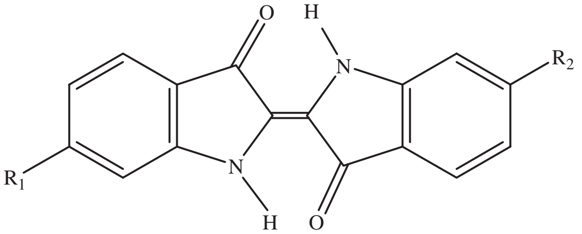
Blue
Generic compound

See: indigoid group and indigo carmine.

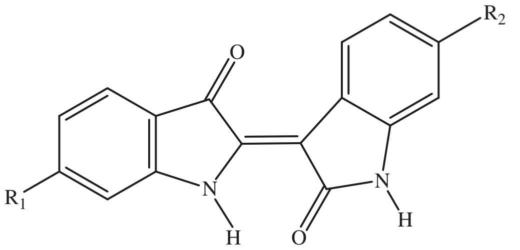
INDIGOID GROUP

Blue-Purple
Group term

Indigoid compounds are all based on the following structure, indigotin, or its isomer, indirubin:



indigotin: R_1,R_2 = H
6-bromoindigotin: R_1 = H, R_2 = Br
6,6′-dibromoindigotin: R_1,R_2 = Br



indirubin: R_1,R_2 = H
6,6′-dibromoindirubin: R_1,R_2 = Br

This is formed from two identical halves, the molecule isatin, which is water soluble but readily oxidises to form the indigo dimer, indigotin. The reduction/oxidation process is commonly known as ‘vatting’, indigo therefore being a ‘vat’ dye. An indigotin isomer, known as indirubin (*q.v.*; sometimes also called *indigo red*), can also be formed and is found to a greater or lesser extent with indigotin. Four groups of indigoid compounds can be differentiated:

Base compounds: Indigo may be derived from three broad sources: first, synthetically via a number of routes though primarily using von Heumann’s method from *N*-phenylglycine; second, from natural plant sources such as *Indigofera tinctoria* L., *Isatis tinctoria* L. (‘woad’) and others; third, recently, from genetically modified bacteria (*Pseudomonas* spp. and *Escheria coli*). Further details of sources and methods are described under the entry for *Indigo*; however, it might be noted here that in plant sources the precursor molecule varies – for example, in *Indigofera* species the precursor of indigo is *indican* (indoxyl-b-D-glucopyranoside), while in *Isatis tinctoria* it is mainly *isatan B*; extensive studies have been made, for example, into precursors in the woad plant (Kokubun *et al*., 1998; Gilbert *et al*., 2000). Indigo has been reviewed by Schweppe (1997).

Halogenated compounds: Substitution of the indigo structure by halogens are particularly notable for their relationship to shellfish purples (Tyrian purple) where one or two bromine atoms are present to form 6-bromoindigotin and 6,6′-dibromoindigotin; the equivalent 6- and 6,6′-dibromoindirubins also exist, as well as the precursor 6-bromoisatin. The chemistry has been discussed at great length by Cooksey (2001). Natural sources (mollusca) are discussed under Tyrian purple. However, as with indigo, synthetic routes have also been discovered, from as early as 1903 – prior to the analytical elucidation of the dyestuff from shellfish; an example synthesis has been discussed by Cooksey (1994). Chlorinated indigoids are discussed below as thioindigoid compounds.

Sulfonated compounds: Treatment of indigo with concentrated sulfuric acid causes sulfonation to take place, giving the material commonly known as indigo carmine (*q.v.*; usually reported as the sodium salt, such as the isomers disodium 3,3′-dioxo-[D$^{2,2'}$-biindoline]-5,5′-disulfonate and disodium 3,3′-dioxo-[D$^{2,2'}$-biindoline]-5,7′-disulfonate or equivalent).

Thioindigoid compounds: The base compound of this class, thioindigo, was discovered by Friedländer in 1905, but has been of no commercial importance in itself. However, during the 1950s several thioindigo derivatives gained commercial recognition as pigments, notably 4,4′,7,7′-tetrachlorothioindigo (CI 73312/Pigment Red 88); another derivative, 4,4′-dimethyl-6,6′-dichlorothioindigo (CI 73360/Pigment Red 181), has only very limited application (Herbst and Hunger, 1997).
See: polycyclic pigments group: thioindigoid sub-group.

Indigo; *Indigo carmine*; *Tyrian purple*; *Woad*
Colour Index (1971) 73312, 73360; Cooksey (1994); Cooksey (2001); Gilbert *et al*. (2000); Herbst & Hunger (1997) 496–502; Kokubun *et al*. (1998); Schweppe (1997)

INDIGOTIN

Blue
Generic compound

An indigoid compound that is the principal isomer present in indigo along with indirubin (*qq.v.*). A number of substituted derivatives are also of importance such as the brominated forms found in Tyrian purple (*q.v.*).
See: indigoid group.

Indigo; Indirubin; *Tyrian purple*

INDIRUBIN

Red-Purple
Generic compound

Indirubin is an isomer of the indigoid compound *indigotin* (see: indigoid group); as the term suggests, the colour is of a redder shade than indigotin. The presence of varying amounts of indirubin in commercial indigo preparations has been described by Popplewell Bloxam and Perkin (1910; cf. Wouters and Rosario-Chirinos, 1992). High indirubin amounts may be obtained by manufacturing processes that favour the oxidation of indoxyl to isatin; hence, this feature may indicate particular methods of indigo dye preparation.
See: indigoid group and indigo.

Popplewell Bloxam & Perkin (1910); Wouters & Rosario-Chirinos (1992)

INDIUM GROUP

Variable
Group term

Two indium compounds may possibly have found use as pigments – indium oxide and indium sulfide. Both are described by Salter (1869) under the term indium yellow.

Indium yellow
Salter (1869) 117–118

INDIUM OXIDE

Yellow
Generic compound

See: indium yellow.

INDIUM SULFIDE

Yellow
Generic compound

See: indium yellow.

INDIUM YELLOW

Yellow
Synonym, variant or common name

Salter (1869) gives the following description: '[indium] is chiefly interesting in an artistic sense on account of its sulphide, a fine bright yellow resembling cadmium, and best obtained by precipitating an acetic acid solution with sulphuretted hydrogen, or sulphide of ammonia. In the latter, the yellow dissolves on being heated, but deposits again on cooling of a rather paler tint.' He also mentions the yellowish indium oxide.

Indium group
Salter (1869) 117–118

INFUSORIAL EARTH

White
Synonym, variant or common name

Synonym for a diatomaceous earth (Kranich, 1973; see: silica). However, the term 'infusoria', while originally referring to an assemblage of minute, usually microscopic, organisms of many diverse kinds, is now restricted to animal protozoa rather than vegetable diatomaceae (*OED*, 2002).

Silica
Kranich (1973a); *OED* (2002) 'Infusoria'

INSECT-BASED REDS GROUP

Red
Group term

The taxonomy of the red dye producing scale insects is very complex and has long been subject to change. Many of the species are poorly researched and it is not known if there are other insects which produce dyes. The following list contains the current taxonomy (Cardon, 1990; Ben-Dov, 2003):

COCHINEAL
  Dactylopiidae
    D. coccus Costa; *D. confusus* (Cockerell); *D. ceylonicus* (Green); *D. tomentosus* (Lamark).
    (NB: *D. coccus* Costa was formerly known as *Coccus cacti* L. or *C. cacti coccinelliferi*.)
  Margerodidae
    Porphyrophora spp.
    P. polonica (L.1758); *P. hameli* (Brandt, 1853); *P. hirsutissima* (Hall, 1924).
    (Some sources give, incorrectly, *Porphyrophorus*.)
KERMES
  Kermesidae spp.
    K. vermilio (Planchon, 1864).
  Kermococcus spp.
    K. illicis L.
LAC
  Kerriidae spp.
    Kerria (*Kerria*) *lacca lacca* (Kerr) (formerly known as *Coccus laccae* and *Kerria lacca* Kerr); *Kerria* (*kerria*) *chinensis chinensis* (Mahdihassan).

The following scale insects are also given in the literature, but their status as dye sources is questionable:

Lecanium Coccus guerinii (Signoret) formerly *Coccus uvae-ursi* and *C. fragariae* are said to have been collected in Russia (Born, 1936; cf. Schweppe and Roosen-Runge, 1986).
Coccus arabae is said to have been used in France (Pubetz, 1872; cf. Schweppe and Roosen-Runge, 1986); this may be a misspelling.

Cochineal; Kermes; Lac
Ben-Dov (2003); Born (1936); Cardon (1990); Pubetz (1872); Schweppe & Roosen-Runge (1986)

INTENSE BLUE

Blue
Synonym, variant or common name

The second edition of Field's *Chromatography* (1841) describes this as indigo 'refined by solution and precipitation'. Salter (1869) provides information under this heading on how to purify indigo by sublimation: 'The best mode of subliming this substance is to mix one part indigo with two parts plaster of Paris, make the whole into a paste with water, spread it upon an iron plate, and, when quite dry, heat it by a spirit lamp. The volatilization of the indigo is aided by the vapour of water disengaged from the gypsum, and the surface of the mass becomes covered with beautiful crystals of pure indigo, which may be readily removed by a thin spatula. At a higher temperature, charring and decomposition take place.' Heaton (1928) lists intense blue as a then-current synonym for a 'purified indigo'. Mayer (1991) says that it is a variety of 'indigo lake' and has also been applied to phthalocyanine blue (*q.v.*).

Indigo
Field (1841); Heaton (1928) 382; Mayer (1991) 47; Salter (1869) 202–203

INTENSE BROWN

Brown
Synonym, variant or common name

Intense brown (or intense madder brown) is a synonym for brown madder, a calcined form of madder lake (Field, 1835).

Brown madder
Field (1835)

IODIDE OF LEAD

Yellow
Synonym, variant or common name

See: lead iodide.

IODIDE OF MERCURY

Red
Synonym, variant or common name

See: mercury iodide.

IODINE BLUE

Blue
Synonym, variant or common name

According to Salter (1869), 'When a solution of iodine in aqueous soda (carbonate of soda is not so good) is added to nitrate or acetate of lead-oxide, a transient violet-red precipitate falls, which decomposes spontaneously under water, yielding iodine and a beautiful blue powder.' The resulting compound was, apparently, rather unstable. Iodine will, of course, form a deep blue complex with starch; Standage, discussing adulteration of Prussian blue, mentions that sometimes starch coloured blue with iodine was used (Standage, 1887; cf. Carlyle, 2001).

Prussian blue
Carlyle (2001) 474, 477; Salter (1869) 231–232; Standage (1887) 29

IODINE PINK

Pink
Synonym, variant or common name

According to Salter (1869), 'There may be obtained from iodine and mercury a very pretty pink colour, analogous in composition to pure scarlet.' He includes no further details regarding preparation, though states that it alters to the scarlet form (mercury iodide, *q.v.*).

Mercury iodide
Salter (1869) 166

IODINE SCARLET

Red
Synonym, variant or common name

See: mercury iodide.

IODINE YELLOW

Yellow
Synonym, variant or common name

Term used by Salter (1869) for lead iodide (*q.v.*). He is quite scathing about its qualities as a pigment: 'iodide of lead … is one of those compounds whose presence on the palette should never have been allowed. Exceedingly brilliant, it is also utterly fugitive … One of the most unstable of substances, being slowly volatile even at common temperatures.'

Lead halides group; Lead iodide
Salter (1869) 118

IRIDIUM BLUE

Blue
Synonym, variant or common name

Probably one of Salter's speculative pigments given in his 1869 edition of Field's *Chromatography*. He states that 'The rare metal iridium affords a blue which is a mixture of the oxide and the sesquioxide; it might also perhaps be iridium oxide, Ir_2O_3, which is a blue-black powder.'

Salter (1869) 232

IRIS BLUE

Blue
Synonym, variant or common name

Clarke (2001) lists three mediaeval manuscripts which mention this colour. Thompson (1935), however, states that 'some way of making an iris blue may have … been known; … it was not generally practised'. He cites a Florentine manuscript (Ashburnhamiana MS 349; Clarke MS 630) which indicates that the secret is to 'take the yellow things out of the flowers', presumably the pollen. The *Compendium* of 1808 also lists 'iris blue'. Iris flowers were also used to make the important mediaeval colour known as iris green (*q.v.*) or lily green. Additionally, Field (1835) used the term iris blue as a synonym for 'blue bice', which was in turn mainly used for azurite but that could also be applied to blue verditer (a blue copper carbonate hydroxide).

Blue bice
Clarke (2001) 131; *Compendium* (1808); Field (1835); Thompson (1935) 424, n.4

IRIS GREEN

Green
Synonym, variant or common name

The 'juice' from petals of various plants are mentioned in mediaeval manuscripts as a source for green, sometimes confusingly called sap green (*q.v.*; where this term is usually used to denote green from unripe berries of *Rhamnus* plants). According to Thompson (1956) Iris green was sometimes prepared for use as a clothlet (*pezzette* in Italian) by dipping pieces of linen into the juice of the plants and then preserving them to dry (see the entries for turnsole and cimatura for a description of this process), or by simply squeezing the flowers and mixing with an aluminium hydroxide (alum) base. Schweppe (1992) lists the plant *Iris germanica* as a specific dye source; this contains the flavonoid compound mangiferin.

Other flower petals may have also been used in the same way. Merrifield (1849) cites the term Lily green or *verde giglio*; in Italian, however, is clear from recipes that lilies, in this context, probably refer to iris given that they are described as purple, for example the Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849) provides a recipe: '86. To make the lily green Take the purple lilies, pick off the most highly coloured lilies, pick off the most highly coloured petals, and leave them to ferment for a day; then pound them in a mortar, put the juice in a cup, then tie up some quicklime and alum in a piece of linen rag, put it into the juice, stirring it about until the green colour is developed; then keep it dry in paper, and let it be made in fine weather.' 'Flowre de luce' is mentioned in MS Sloane 6284 while the term 'lily green' is used in *The Art of Painting in Miniature* of 1730 (Harley, 1982) and Hilliard (1624) describes a 'pansy green'. Harley (1982) also cites a recipe from British Library MS Additional 23080 for making pansy green from violet petals.

Thompson states that the principal colouring matter of all of these pigments is likely to be chlorophyll (*q.v.*). Other plants producing green are also mentioned in mediaeval manuscripts such as rue, parsley and columbine (Aquilegia), honeysuckle and nightshade. Merrifield cautions against confusing the latter, in Italian, *herba morella*, with the French *maurelle* which is turnsole or *Chrozophoria tinctoria*. Thompson gives a further description of these latter plant sources, *Solanum* (nightshade) being certainly used in the thirteenth century and the honeysuckle green having been an Arabic colour, as it was sometimes described as 'Saracenic', and the recipes referring to honeysuckle in distorted arabic. This was, in Latin, *caprifolium* and hence, rarely, 'goat tree' in English. The seventeenth century writer Nunes gives a recipe for lily green called, in Portuguese, *catasol* (*q.v.*). Merrifield further states 'green pigments were also prepared from rue, parsley, columbine, and from the black nightshade. The juice of these plants was incorporated with green earth.' The term persists into the nineteenth century and Salter's edition of *Field's Chromatography* (1869) mentions 'blue flowers of iris' being added to sap green.

The classical author Pliny (77 AD) describes a green earth from Rome which he calls *Appianum*, or Appian green. Rackham (1952) has suggested that *appianum* might be an emendation of *apiacum* or *apianum*, which means 'parsley', however, iris green may also apparently refer to the mineral malachite (Gettens and FitzHugh, 1993b).

According to Thompson this colour was as important to illuminators as sap green in the fourteenth and fifteenth centuries, and may have preceded sap green in use. Clarke (2001) lists four medieaval manuscripts which refer to this colour (Clarke MSS 360; 1000; 1770 (the so-called *Venetian Manuscript*); 2470).

Majolino *et al.* (1998) have identified 'iris juice' combined with potassium aluminium sulphate ('rock alum') in a group of ninth to fifteenth century Gospel books.
See also: iris yellow and iris blue.

Chlorophyll; Malachite; Mangiferin; *Appian green*; *Catasol*; *Sap green*
Art of Painting (1730); Clarke (2001) 131; Gettens & FitzHugh (1993b); Harley (1982) 86; Hilliard (1624/Thornton & Cain, 1981) 94; Majolino *et al.* (1998); Merrifield (1849) ccxix; MS Sloane 6284 (nd); Nunes (1615) 64ff; Pliny (1st cent AD/Rackham, 1952) XXXV.xxxix; Salter (1869) 282; Schweppe (1992); Thompson (1956) 171–173

IRON ALUMINIUM OXIDE, HERCYNITE TYPE

Black
Generic compound

See: hercynite.

IRON BLACK

Black
Synonym, variant or common name

According to the *Colour Index* (CI 77050), this is precipitated metallic antimony, prepared by treating an acid solution of an antimony salt to precipitate a fine black powder known as antimony black or iron black. It is said to be used to 'impart the appearance of polished steel to papier mâché and plaster of Paris'. Terry (1893) lists iron black as 'ground black sulphide of iron'.
See also: iron oxide black.

Antimony group; Iron sulfides group; Antimony; *Antimony black*
Colour Index (1971) 77050; Terry (1893) 26

IRON BLUE

Blue
Synonym, variant or common name

Iron blue has become a widely applied synonym for Prussian blue (various blue hexacyanoferrate compounds), replacing the large number of common terms used and felt to be causing confusion (Berrie, 1997; Buxbaum, 1998). The term 'Prussian blue' has largely been retained here in the context of historical sources as it is well established and the synonyms less likely to cause confusion. The group of related pigments are dealt with as hexacyanoferrate compounds since some of them are not blue, notably the copper-substituted forms which are red, brown and black.

However, we should additionally note that Rose (1916) states that *Eisenblau* ('iron blue') and *Blaueisenerde* ('blue iron earth') were terms for the iron phosphate vivianite (*q.v.*).

Hexacyanoferrate group; Vivianite; *Prussian blue*
Berrie (1997) 191; Buxbaum (1998) 131; Rose (1916) 223

IRON BROWN

Brown
Synonym, variant or common name

Synonym for Prussian brown, a form of calcined Prussian blue (Mayer, 1991).

Prussian brown
Mayer (1991) 47

IRON CARBONATES GROUP

Yellow
Group term

Only one iron carbonate appears to be of relevance as a pigment, the mineral siderite ($FeCO_3$). It has limited importance, but may be found as a component of some ochres.

Ochre; Siderite

IRON CHROMATE HYDROXIDE

Brown
Generic compound

According to the *Colour Index* (1971), iron(III) chromate hydroxide, $Fe(OH)CrO_4$, is listed as one of the formulations of CI Pigment Yellow 45 (CI 77505), with others given as iron(III) dichromate(VI), $Fe_2(Cr_2O_7)_3$ and iron(III) chromate (*qq.v.*), $Fe_2(CrO_4)_3$. Preparation is commonly by fusing sodium dichromate with iron(II) sulfate and sodium carbonate. According to Kühn and Curran (1986), 'basic iron chromate', formed from a similar synthesis route (with potassium chromate used instead) has been used as a dark brown pigment as both oil and watercolour. This is presumably iron chromate hydroxide.

Iron chromates group; Iron dichromate
Colour Index (1971) 77505; Kühn & Curran (1986)

IRON CHROMATES GROUP

Yellow-Orange
Group term

According to the chemical literature, there are a number of iron chromates of varying composition listed as CI Pigment Yellow 45 (CI 77505). The main compounds are iron(III) chromate hydroxide, $Fe(OH)CrO_4$, iron(III) dichromate(VI), $Fe_2(Cr_2O_7)_3$, and iron(III) chromate, $Fe_2(CrO_4)_3$. Kletzinsky (1872) is associated with the early manufacture of iron chromate in the late nineteenth century and the synthesis routes for the three main compounds are precipitation by: fusing sodium dichromate with iron(II) sulfate and sodium carbonate; heating aqueous chromic acid with hydrous iron(III) hydroxide; and boiling aqueous iron(III) chloride with potassium dichromate.

According to Zerr and Rübencamp (1908) and MacIntyre (1992), iron(III) chromate of composition $Fe_2(CrO_4)_3$ is the yellow pigment known as siderin yellow (or *Sideringelb* by Kletzinsky), precipitated from a mixture of ferric chloride and potassium or sodium chromate. The same synthesis route is given by Kühn and Curran (1986) for siderin yellow, although a precise composition for the iron chromate is not listed. Kühn and Curran (1986) further mention a basic iron chromate (presumably iron chromate hydroxide), formed from neutral potassium chromate and iron sulfate and used as a dark brown pigment in both oil and watercolour applications.

Buxbaum (1998), citing a BASF patent (DE-OS 2 517 713, 1975), mentions modern pigments of composition $(Fe,Cr)_2O_3$.

Chromates group; Iron group; *Siderin yellow*
Buxbaum (1998) 87; *Colour Index* (1971) 77505; Kletzinsky (1872); Kühn & Curran (1986); MacIntyre (1992) 3090; Zerr & Rübencamp (1906/1908) 126, 154

IRON DICHROMATE

Yellow
Generic compound

According to the chemical literature, iron(III) dichromate(VI), $Fe_2(Cr_2O_7)_3$, is used as a water-soluble pigment and is obtained by heating aqueous chromic acid with hydrous iron(III) oxide (*Colour Index*, 1971; MacIntyre, 1992). Related compounds also used as pigments are iron chromate, $Fe_2(CrO_4)_3$, and iron chromate hydroxide, $Fe(OH)CrO_4$ (*qq.v.*).

Iron chromates group; Iron chromate hydroxide
Colour Index (1971) 77505; MacIntyre (1992) 3092

IRON GROUP

Variable
Group term

Iron is the most stable of all elements and forms a huge variety of compounds, many of which are used as pigments. Particularly abundant are the iron oxide, hydroxide and sulfate compounds present in ochres and other earth pigments. The main classes of compounds are listed below. More complete discussions are available under the relevant group entries.

Oxide and hydroxide minerals and synthetic analogues: goethite (α-FeOOH); lepidocrocite (γ-FeOOH); hematite (α-Fe_2O_3); maghemite (γ-Fe_2O_3); magnetite (Fe_3O_4); jacobsite ($MnFe_2O_4$); ilmenite ($FeTiO_3$); iron zinc oxide ($ZnFe_2O_4$).
Phosphates: vivianite and iron phosphate hydrate; iron manganese phosphate hydrate ($2(Fe,Mn)PO_4.H_2O$).
Sulfates: melanterite ($FeSO_4.7H_2O$); hydronium-jarosite ($Fe_3(SO_4)_2(OH)_5.2H_2O$; 'carphosiderite'); jarosite ($KFe_3(SO_4)_2(OH)_6$); natrojarosite ($NaFe_3(SO_4)_2(OH)_6$).
Sulfides: pyrite (FeS_2); marcasite (FeS_2).
Organo-iron compounds: include iron(II) oxalate; humboldtine ($Fe^{2+}C_2O_4.2H_2O$); the porphyrin hemoglobin (blood).

Earth pigments group; Iron oxides and hydroxides group; Iron phosphates group; Iron sulfates group; Iron sulfides group; Organo-iron group; Goethite; Hematite; Hemoglobin; Humboldtine; Hydronium-jarosite; Ilmenite; Iron manganese phosphate hydrate; Iron phosphate hydrate; Iron titanate; Iron zinc oxide; Iron(II) oxalate; Jacobsite; Jarosite; Lepi-docrocite; Maghemite; Magnetite; Marcasite; Melanterite; Natrojarosite; Ochre; Pyrite; Sienna; Umber; Vivianite; *Mars pigments*

IRON HYDROXIDE, LEPIDOCROCITE TYPE

Yellow-Orange
Generic compound

See: lepidocrocite.

IRON MAGNESIUM OXIDE

Brown
Generic compound

According to the *Colour Index* (1971; CI 77495/Pigment Brown 11) 'magnesium ferrite', iron magnesium oxide, has a composition of 79% Fe_2O_3 and 19% MgO. It is prepared by heating a stoichiometric mixture of iron(III) and magnesium oxides at 1000°C.

Iron zinc oxide
Colour Index (1971) 77495

IRON MANGANESE OXIDE, JACOBSITE TYPE

Black
Generic compound

See: jacobsite.

IRON MINIUM

Red
Synonym, variant or common name

Malevanny (1968; cf. FitzHugh, 1986) has noted that in France and Russia iron minium ('*minium de fer*') is in fact an ochre.

Iron oxides and hydroxides group; Lead(II,IV) oxide; Minium; *Red ochre*
FitzHugh (1986); Malevanny (1968)

IRON OXIDES AND HYDROXIDES GROUP

Variable
Group term

There is a large group of naturally occurring and synthetically produced pigments based on iron oxides and hydroxides. All of these contain one or more of a relatively small group of compounds – oxides and oxide hydroxides of iron – which are found widely in the geological environment or can be manufactured via different routes, or formed by modification of another by a treatment such as calcination.

There are 15 iron oxides, oxide hydroxides and hydroxides known to date. The most important are the oxides ferrihydrite ($Fe_5HO_8.4H_2O$), hematite (α-Fe_2O_3), maghemite (γ-Fe_2O_3) and magnetite (Fe_3O_4), and oxyhydroxides goethite (α-FeOOH), akaganeite (β-FeOOH), lepidocrocite (γ-FeOOH) and feroxyhyte (δ'-FeOOH). In addition there is $Fe(OH)_2$, FeO (wüstite), a β-Fe_2O_3, a ε-Fe_2O_3, a high-pressure FeOOH, a ferrimagnetic δ-FeOOH and a crystalline $Fe(OH)_3$ (bernalite). There is also a group of Fe^{III}-oxy-hydroxy salts which are closely related to the oxides, including the oxy-hydroxy sulfate schwertmannite and an oxy-hydroxy nitrate (Schwertmann and Cornell, 2000).

Of the mineral forms, only hematite appears to have been mined and used in its massive form; these compounds otherwise occur as greater or lesser components in secondary pigments such as the ochres, umbers and siennas (*qq.v.*), either in the natural state or from calcination. Akaganeite, lepidocrocite and maghemite (with pyrolusite) have been identified by Zolensky (1982) in prehistoric pictographs in Seminole Canyon, USA.

A number of traditonal terms have been used for synthetic members of this group, of which we note '*caput mortuum*' and the 'Mars' pigments (*qq.v.*).

Fuller (1973a) describes a number of processes that result in synthetic iron oxides and hydroxides. For red iron oxides he details calcination of iron(II) sulfate hydrate (copperas reds), calcination of synthetic yellow iron oxides (ferrite reds), aqueous precipitation from iron(III) hydroxide nucleation in solutions of iron(II) salts and calcination of magnetite at about 370°C. For yellow iron oxides Fuller describes the so-called Penniman–Zoph process (US Patent 1,327,061 granted in 1920) where hydrated iron(II) oxide is used as nucleating particles in a solution of iron(II) sulfate containing 'selected grades of scrap iron'; heat and compressed air are then introduced, causing the product to form on the nucleating particles.

So-called magnesium and zinc ferrites (MgO.Fe_2O_3 and ZnO.Fe_2O_3) have also been used as pigments (*Colour Index*, 1971: CI 77495/Pigment Brown 11 and Pigment Yellow 119; Fuller).

For fuller discussions of specific compounds, see the individual entries.

Iron group; Akaganéite; Bernalite; Feroxyhyte; Ferrihydrite; Goethite; Hematite; Iron magnesium oxide; Lepidocrocite; Limonite; Maghemite; Magnetite; Ochre; Schwertmannite; Sienna; Umber; Wüstite; *Bole*; *Burnt ochre*; *Caput mortuum*; *Copperas*; *Ferrite red*; *Mars pigments*
Colour Index (1971) 77495; Fuller (1973a); Schwertmann & Cornell (2000); Zolensky (1982)

IRON OXIDE BLACK

Black
Synonym, variant or common name

Schweppe (1992) describes iron oxide black as a very deep colour of black produced, in ancient Mesopotamia and Minoan Crete, by heating iron oxide derived from clays and ochres to 800–1100°C. It is unclear as to whether this was used in this context as anything other than a fired glaze on ceramics. According to Mayer (1991), black oxide of iron is a synonym for a black synthetic iron oxide pigment; if so, then probably this would be magnetite. An 'iron black' is also referred to by the *Colour Index* (1971); however, this is described in that source as being a form of precipitated antimony.
See: magnetite.

Antimony Magnetite; *Mars pigments*
Colour Index (1971); Mayer (1991) 39; Schweppe (1992) 33

IRON(III) OXIDE, HEMATITE TYPE

Red
Generic compound

This is the synthetic equivalent of the naturally occurring mineral, hematite (*q.v.*), α-Fe_2O_3, which produces a bright red pigment. Being a stable compound, it may be produced by many methods. These are described in Cornell and Schwertmann (1996) and may be summarised as follows:

1. Modern methods of producing hematite are based upon various wet chemical methods to produce bright red, rhombohedral crystals. These include the addition of hot (98°C) hydrochloric acid to $Fe(NO_3)_3.9H_2O$. This temperature is maintained for seven days while the hematite precipitate forms. Alternatively iron chelates will decompose to hematite in solutions with pH >12. Heating $Fe(NO_3)_3$ with ethylene glycol in air at 300°C will also produce hematite.
2. Heating hydrous iron sulfate with calcium oxide (lime), or heating hydrous iron sulfate alone produces a bright red residue of iron(III) oxide. Iron sulfate was traditionally called copperas or green vitriol and copperas-based red were the traditional chemically manufactured synthetic iron(III) oxide reds.
3. Various methods of iron(III) oxide production are based on the dehydration of goethite or other iron oxide hydroxides by heating to temperatures exceeding c. 280°C in an oxidising environment. This is the way burnt ochres and siennas are prepared from yellow ochre. De Mayerne (BL MS Sloane 2052; cf. Harley, 1982) writes it was manufactured by 'placing yellow ochre in a crucible on a fierce fire for at least two hours'. For pre-industrial societies, manufacture of synthetic red iron(III) oxide is primarily from the heating of naturally occurring goethite-rich compounds. Minimum temperatures of 230–280°C are required for goethite to transform to 'disordered hematite'. A disordered structure results from the positioning of cations into interstitial spaces within the transitional goethite-hematite structure. Ordered or well-crystallised iron(III) oxide forms only after temperatures exceeding 900°C during which cations migrate into their normal lattice sites. This compound is analogous to naturally occurring mineral hematite (Helwig, 1995; Brindley and Brown, 1980). Therefore it can be said that disordered hematite is diagnostic of the low temperature conversion of goethite to iron(III) oxide and by analogy to the manufacture of this compound by pre-industrial societies. Temperatures exceeding 900°C are very difficult to maintain without fossil fuels.
4. The oxidation of magnetite at temperatures exceeding 400°C.
5. The oxidation of iron film in air at 1027°C (maintained for 10 hours).

Other methods are employed for producing thin films of hematite for coating electrodes, etc., but do not currently appear to be relevant to pigment manufacture.

There is a long history of the production of synthetic hematite in the form of red burnt ochres. Pomiès *et al.* (1999a,b) suggest that the technology was understood from the Palaeolithic (observed at Troubat, French Pyrenées), in which case it represents the earliest form of pyrotechnology. The Roman author Pliny (77 AD) also mentions the use of burnt ochres, especially adulterated with red led, a mixture he calls *sandyx.* Light red, Brown red and English red are terms used to refer to these compounds (Harley, 1982). Bristow (1996b) lists a 'common brown oker', synonymous with 'Bristol oker' made in the early nineteenth century. 'Light red' is commonly applied to burnt yellow ochres (Field, 1835; Heaton, 1928).

Chemical processes of manufacturing red α-Fe_2O_3 have the benefit of being able to produce finer grains than those occurring naturally. This produces paints with greater transparency than the naturally occurring materials; however, the technology has only been available since the seventeenth century. Venetian red (*q.v.*), introduced in the eighteenth century, was the first synthetic iron oxide to be produced by methods other than roasting of yellow ochres. It is reputed to be manufactured in several ways but the most accepted method is by calcining copperas or 'green vitriol' ($FeSO_4.7H_2O$) with lime. Copperas red (*q.v.*) was later prepared by calcining pure copperas.

The Mars colours (*q.v.*) are a series of synthetic iron oxide pigments ranging in shades from yellow through oranges, reds, purples to blacks. Martel (1860) states: 'The *mars* pigments are prepared by precipitating certain soluble salts of iron by means of the alkalies, or alkaline earths, such as potash, soda, lime and alumina … By calcining Mars Yellow we obtain (according to the degree of heat applied, and by other means kept secret by the manufacturers) *orange*, *brown*, *red* and *violet* mars.'

Chemically synthesised iron oxides are known from many works of art worldwide, including those by the Impressionist School (Roy, 1985) and Burgio and Clark (2000) have identified it on modern Egyptian papyri (but *not* on ancient ones). Burnt ochres and similar materials have been used since the Palaeolithic (Pomiès *et al.*, 1999a,b). Béarat and Pradell (1997) have detected ‘disordered’ hematite in several examples of Roman wall paintings.

The terminology defining naturally occurring and synthetic red iron(III) oxide pigments is extremely confusing with many terms being indiscriminately applied to both varieties, or transferred to a synthetic variety when naturally occurring varieties were exhausted. Terms are most frequently related to the shade produced. Venetian red, for example, was reputed to have originally applied to a naturally occurring source (now exhausted) of red ochre from Venice (or Verona according to Merrifield, 1849) and was subsequently applied to the synthetic pigment because the colour was reproduced (Harley, 1982).

The series of colours variably called Venetian red, Indian red, Tuscan red, Pompeiian red, light red, *rouge*, *Terra Pozzuoli*, *Crocus* (*martis*), colcothar and *caput mortuum* are all terms generally applied to synthetic reds (although sources citing eastern Mediterranean and Byzantine art use *caput mortuum* to refer to naturally occurring hematite; see Sr. Daniila *et al.*, 2002). Artificial Indian red was recommended by Church (1901) to produce ‘the lilac greys of stormy clouds’ by the English Water Colour School, mixed with ultramarine, Prussian blue, indigo or indigo and yellow ochre. Weber (1923) notes that the synthetic iron oxide pigments were purer than the natural iron oxides and were very permanent. He also says that the varieties known as Tuscan red and Pompeiian red were adulterated with alizarin madder.

Iron group; Iron oxides and hydroxides group; Goethite; Hematite; Magnetite; Ochre; *Burnt ochre*; *Caput mortuum*; *Colcothar*; *Copperas*; *English red*; *Indian red*; *Mars pigments*; *Mars red*; *Mars yellow*; *Venetian red*; *Yellow ochre*

Béarat & Pradell (1997); Brindley & Brown (1980) 372–375; Bristow (1996b); Burgio & Clark (2000); Church (1901) 179–180; Cornell & Schwertmann (1996); Daniila *et al.* (2002); Field (1835) 108–110; Harley (1982) 122; Heaton (1928) 116; Helwig (1995); Martel (1860) 23; Merrifield (1849); Pliny (1st cent AD/Rackham, 1952) XXXV.xxiii; Pomiès *et al.* (1999a,b); Roy (1985); Weber (1923) 64–66

IRON OXIDE HYDRATE, FERRIHYDRITE TYPE

Red-Brown
Generic compound

See: ferrihydrite.

IRON OXIDE HYDROXIDE, AKAGANÉITE TYPE

Yellow-Brown
Generic compound

See: akaganéite.

IRON OXIDE HYDROXIDE, FEROXYHYTE TYPE

Red-Brown
Generic compound

See: feroxyhyte.

IRON OXIDE HYDROXIDE, GOETHITE TYPE

Yellow-Brown
Generic compound

See: goethite.

IRON OXIDE, MAGHEMITE TYPE

Brown
Generic compound

See: maghemite.

IRON OXIDE, MAGNETITE TYPE

Black
Generic compound

See: magnetite.

IRON OXIDE RED

Red
Synonym, variant or common name

See: hematite and iron(III) oxide, hematite type.

IRON OXIDE YELLOW

Yellow
Synonym, variant or common name

See: goethite and iron oxide hydroxide, goethite type.

IRON PHOSPHATE

Purple
Generic compound

See: vivianite.

IRON PHOSPHATE HYDRATE, VIVIANITE TYPE

Purple
Generic compound

See: vivianite.

IRON PHOSPHATES GROUP

Blue
Group term

The only important iron phosphates used in a pigment context are the naturally occurring iron phosphate hydrates, vivianite, $Fe_3(PO_4)_2.8H_2O$, and metavivianite, $Fe_{4-x}(PO_4)_2(OH)_x.(8-x)(H_2O)$. See the individual entries for further discussion.

Iron group; Metavivianite; Vivianite

IRON SULFATE HYDRATE

Green
Generic compound

Melanterite is the naturally occurring iron(II) sulphate hydrate ($FeSO_4.7H_2O$). The synthetic equivalent is more commonly known as copperas or green vitriol. This is an important raw material in the manufacture of iron oxide pigments.

Hydronium jarosite (‘carphosiderite’, $Fe_3[SO_4]_2[OH]_5.2H_2O$) is also a hydrous iron sulfate.

Iron sulfates group; Hydronium-jarosite; Jarosite; *Copperas*

IRON SULFATES GROUP

Variable
Group term

Four iron sulfates are of interest as pigments: Iron(II) sulfate hydrate (melanterite; $FeSO_4.7H_2O$); Hydronium-jarosite (‘carphosiderite’; $Fe_3(SO_4)_2(OH)_5.2H_2O$); Jarosite ($KFe_3(SO_4)_2.(OH)_6$); Natrojarosite ($NaFe_3(SO_4)_2(OH)_6$).

Iron(II) sulfate hydrate (and its mineral analogue melanterite) does not appear to have been used directly as a pigment, but found widespread employment historically as a precursor compound; calcination of so-called copperas leads to a loss of water and sulfur trioxide – that is, sulfuric acid – to give synthetic iron oxide compounds.

Iron group; Hydronium-jarosite; Jarosite; Natrojarosite; *Copperas*

Iron sulfides group

Variable
Group term

The main iron sulfides are the naturally occurring minerals pyrite and its pseudomorph marcasite. The formula of the closely related pyrrhotite is variable; pyrrhotite is an uncommon phase naturally, but is known as a corrosion product on bronze (Scott, 2002). In addition, MacIntyre (1992) lists a number of compounds related to pyrrhotite that may be encountered in the natural environment. However, the following may be included within this group: Pyrite (FeS_2); Marcasite (FeS_2); Pyrrhotite ($Fe_{0.8-1.0}S$); Iron(II) sulfide (Fe_3S_4, Fe_7S_8, etc.); Iron(II) sulfide (FeS); Iron(III) sulfide (Fe_2S_3).

Iron(II) sulfide, FeS, is the mineral troilite, known only to occur naturally in meteoritic (that is, extraterrestrial) iron. On the other hand, pyrite is a very common phase occurring in a wide variety of rocks and is an essential component of the rock type lapis lazuli, from which natural ultramarine (Lazurite) is extracted. Copperas, an important raw material used in the manufacture of synthetic iron oxide red pigments, forms from the breakdown of pyrite.

Pyrite has been detected as an admixture to Egyptian blue (*q.v.*) in 5th dynasty Egyptian tomb paintings (Scott, 2002). Terry (1893) describes an iron black as a ground iron sulfide pigment. According to Pliny (77 AD) the 'misy' of the ancients was either iron or copper pyrites (chalcopyrites, $CuFeS_2$). Marcasite is also a misnomer for bismuth.

Iron group; Marcasite; Pyrite; *Copperas*; *Egyptian blue*; *Lapis lazuli*; *Misy*
MacIntyre (1992) 18964, 18969, 19013; Pliny (1st cent AD/Rackham, 1952) XXXIV.c.31; Scott (2002) 229, 260; Terry (1893) 26

Iron titanate

Black
Generic compound

Iron titanate, $FeTiO_3$, occurs naturally as ilmenite (*q.v.*) or titaniferous iron ore. The *Colour Index* (1971) lists this as CI 77543/Pigment Black 12.

Iron group; Iron oxides and hydroxides group; Ilmenite
Colour Index (1971) 77543

Iron yellow

Yellow
Synonym, variant or common name

Salter (1869) gives this as an 'oxalate of protoxide of iron'. It was a bright pale yellow, perhaps the synthetic equivalent of the mineral humboldtine (*q.v.*). Carlyle (2001) points out that the term 'iron yellow' should not be confused with *jaune de fer*, a synonym for mars yellow (*q.v.*).

Organo-iron group; Humboldtine; Iron(II) oxalate; *Jaune de fer*; *Mars yellow*
Carlyle (2001) 528; Salter (1869) 118

Iron zinc oxide

Yellow-Brown
Generic compound

According to Fuller (1973) 'zinc ferrite', iron zinc oxide, $ZnO.Fe_2O_3$, was produced as a tan-coloured pigment and for which a patent (USP 2,904,395) was issued to Downs and Martin of the Columbian Carbon Company in 1959. It was prepared by calcining a mixture of iron oxide and zinc oxide. Also given as zinc iron yellow in the *Colour Index* (1971), CI Pigment Yellow 119. An equivalent iron magnesium oxide also exists.

Iron magnesium oxide
Colour Index (1971) Pigment Yellow 119; Fuller (1973)

Iron(II) oxalate

Yellow
Generic compound

Salter (1869) describes iron yellow (*q.v.*) as an 'oxalate of protoxide of iron'. This is perhaps the synthetic equivalent of the mineral humboldtine (*q.v.*).

Organo-iron group; Humboldtine
Salter (1869) 118

Iron(III) chromate

Yellow-Brown
Generic compound

See: iron chromates group.

Iron(III) chromate hydroxide

Yellow-Brown
Generic compound

See: iron chromates group.

Iron(III) dichromate

Yellow-Brown
Generic compound

See: iron chromates group.

Iron(III) tannate

Black
Generic compound

Solutions of iron(III) sulfate will readily react with tannins to form dark brown-black compounds, a process which underlies the use of so-called iron-gall inks.

Iron tannate is also known to form on artefacts where iron oxides are applied to substrates rich in tannins. For example, Hill (2001) describes the decoration of objects in Papua New Guinea where such alterations take place.

Iron group; Organo-iron group
Hill (2001)

Isatis

Blue
Synonym, variant or common name

A term for woad found in classical texts, the colour being derived from the plant *Isatis tinctoria*. *Isatis* is mentioned by Vitruvius (first century BC).
See: indigo.

Indigo; *Woad*
Vitruvius (1st cent BC/Grainger, 1934) VII.xiv.2

Isoindoline pigments

Red-Orange-Yellow
Synonym, variant or common name

See: azo pigments group: isoindolinone/isoindoline sub-group.

Isoindoline yellow

Yellow
Synonym, variant or common name

See: azo pigments group: isoindolinone/isoindoline sub-group.

ISOINDOLINONE PIGMENTS

Red-Orange-Yellow

Synonym, variant or common name

See: azo pigments group: isoindolinone/isoindoline sub-group.

ISOINDOLINONE YELLOW

Yellow

Synonym, variant or common name

See: azo pigments group: isoindolinone/isoindoline sub-group.

ISOMORELLIC ACID

Yellow

Generic compound

See: gambogic acid.

ISOVIOLANTHRONE VIOLET

Purple

Synonym, variant or common name

See: polycyclic pigments group: isoviolanthrone sub-group.

ITALIAN BLUE

Blue

Synonym, variant or common name

Mayer (1991) lists this as both a synonym for Egyptian blue (calcium copper silicate, *qq.v.*) and a term applied to 'imitations made from lakes or for special shades of Bremen blue'.

Bremen blue; *Egyptian blue*
Mayer (1991) 47

ITALIAN EARTH

Red-Orange-Yellow

Synonym, variant or common name

Watin (1785) mentions Italian earth ('*terre d'Italie*') which resembles 'ochre de ru' (see: *Oker de rouse*) but that it is more lively and more beautiful. He recommends choosing the strongest colour, with brown in it, to paint beautiful washes and glazes.

According to Mayer (1991), this is a synonym for a sienna-type pigment.

Sienna; *Oker de rouse*
Mayer (1991) 47; Watin (1773/edition of 1785) 33

ITALIAN PINK

Yellow

Synonym, variant or common name

This is a yellow lake generally made from buckthorn berries (various berries of the *Rhamnus* species, probably *R. cathartica* L.), called *spincervino* in Italian; however, the source could also be dyer's broom (*Genista tinctoria*) or weld (*Reseda luteola*) (Merrifield, 1849). Salter (1869) states that Italian pink is 'Also called English and Dutch pink', adding that it is 'an absurd name for a stronger and richer kind of yellow lake'. Heaton (1928) lists Italian pink as an obsolete or rarely used term for a 'pure quercitron lake'.

See: *Rhamnus giallo santo* and also: Dutch pink and English pink.

Quercitron; Rhamnus; Weld; *Dutch pink*; *English pink*; *Giallo santo*
Heaton (1928) 382; Merrifield (1849) clxiv; Salter (1869) 100

IVORY

White

Common generic composite

See: ivory black.

IVORY BLACK

Black

Synonym, variant or common name

Essentially a coke, properly of ivory, but may also refer to blacks derived from other bone types. Ivory is composed of a mixture of inorganic and organic materials. The inorganic phase (about 60% of the whole) consists of phosphorus, calcium and magnesium with a small amount of carbonate, while the organic matrix is primarily collagen and small amounts of lipid (Fischer and Bohn, 1955; Matienzo and Snow, 1986). For a general discussion on the blacks made of bone materials see: carbon-based blacks group: cokes sub-group.

Studies have shown that the inorganic phase in ivory is not hydroxylapatite as often stated, it being found that biological phosphates contain up to 5% carbonate. Moreover, structural studies (by XRD and IR spectroscopy) indicate that a more correct composition of the inorganic material is given by the mineral dahllite (*q.v.*), the CO_3^{2-} ions being substituted into the crystal lattice rather than residing as admixtures of carbonate phases on grain surfaces (LeGeros *et al.*, 1960; McDonnell, 1965).

For a discussion of the composition and structure of bone, see the related entry under that term.

Pliny (77 AD) states that Apelles invented the method for making black from burnt ivory, the Greek name for which is *elephantinon.* Genuine ivory black was made from ivory pieces or shavings baked in a closed container in a potter's kiln. Hilliard (1624) and de Mayerne (MS Sloane 2052, cf. Harley, 1982) both give instructions for the production of ivory black that involve additions of salt.

Some sources specified that the pieces first be soaked in linseed oil. However, ivory black was often substituted or adulterated with bone black (Carlyle, 2001).

Toch (1916) states that 'Ivory black is still used to some extent for very intense coach colors, and there is also a very fine species of carbon black on the market known as the "Extract of Ivory Black," which is made by digesting charred ivory chips in hydrochloric acid until nearly all of the calcium phosphate is dissolved.'

Carbon-based blacks group: Cokes sub-group; Bone
Carlyle (2001) 184, 467–468; Fischer & Bohn (1955); Harley (1982) 159; Hilliard (1624/Thornton & Cain, 1981) 90; LeGeros *et al.* (1960); Matienzo & Snow (1986); McDonnell (1965); MS Sloane 2052 (nd); Pliny (1st cent AD/Rackham, 1952) XXXV.xxv.43; Toch (1916) 106

J

JACARANTA BROWN
Brown
Synonym, variant or common name

Listed by Mayer (1991) as a synonym for burnt umber (*q.v.*).

Burnt umber
Mayer (1991) 48

JACOBSITE
Black
Generic compound

Jacobsite is a manganese iron oxide mineral with ideal composition $MnFe_2^{3+}O_4$. It is a member of the magnetite series of minerals, which all have the formula $X^{2+}Fe_2^{3+}O_4$, and include franklinite and magnetite (*qq.v.*) itself. It therefore has very similar properties to these other members as it is cubic, magnetic and black in colour with metallic lustre; it forms as octahedral crystals but is most commonly found as granular or as small disseminated particles. Jacobsite occurs in metamorphic rocks, particularly in metasomatised manganese deposits and is named after its type locality of Jakobsberg, Sweden (Rutley, 1988).

The synthetic analogue has been identified as an Etruscan pigment (Schweizer and Rinuy, 1982) in combination with hematite and bixbyite (Mn_2O_3; *qq.v.*); formation of this compound requires heating manganese- and iron-rich clays under oxidising conditions to around 950°–1100°C.

Iron group; Iron oxides and hydroxides group; Bixbyite; Franklinite; Hematite; Magnetite
Rutley (1988) 282; Schweizer & Rinuy (1982)

JALDE
Yellow
Synonym, variant or common name

Term used in Spain and Portugal for orpiment (*q.v.*), though it could also refer to the particular colour (Veliz, 1986).

Orpiment
Veliz (1986) 193, n.5

JALDE QUEMADO
Red
Synonym, variant or common name

Quemado means 'burnt' and refers to artificially produced realgar (*q.v.*). The term is to be found in seventeenth century Spanish treatises (see Veliz, 1986).

Realgar
Veliz (1986) 123, 126

JAPAN EARTH
Brown
Synonym, variant or common name

Harley (1982) notes that a few of the English texts of the second half of the eighteenth century she examined mentioned *terra japonica*, or Japan earth. It was, apparently, sometimes known as pale catechu or white catechu, being supposedly an extract of East Indian plants of the genus *Uncaria*. According to the *British Pharmaceutical Codex* of 1911 this is in fact an extract prepared from the leaves and young shoots of *Uncaria gambier* (Hunt.) Roxb. (Rubiaceae; also sometimes given as *U. gambir*), a climbing shrub indigenous to the Malay Archipelago, and cultivated in many of the surrounding islands; it is known for medicinal use and betel chewing as well as for tanning and dyeing. To prepare, the leaves and twigs are boiled with water, the resulting decoction evaporated to a syrupy consistency in copper pans and cooled, crystallisation being induced by agitation. The mass is then drained and cut into small cubes, less frequently into strips or buttons, and dried. The cubes measure about 25 mm each way, are very light, fairly regular in shape, dark red-brown externally, pale cinnamon-brown internally, porous and friable. Catechu is said to consist chiefly of catechin (7 to 33%), and catechu-tannic acid (22 to 50%). In addition to these, quercetin, wax, oil, catechu red and a fluorescent body, named gambier-fluorescein, occur in small quantities. Schweppe (1992) lists *U. gambier* (Hunt.) Roxb. as a notable source of condensed tannins.

We should note that it was the unrelated plant *Acacia catechu*, not *U. gambier*, which gave catechu brown (*q.v.*; Salter, 1869).

Tannins group; *Catechu brown*
British Pharmaceutical Codex (1911) 'Catechu BP'; Harley (1982) 156; Salter (1869); Schweppe (1992) 503–506

JAROSITE
Yellow
Generic compound

Jarosite is a yellow potassium- and iron(III)-bearing sulfate mineral with chemical composition $KFe_3(SO_4)_2(OH)_6$. It occurs in a variety of habits most commonly as euhedral crystals, although fibrous, encrusting and spherulitic forms are also found. It is usually yellow but yellow-brown or brown varieties are often observed. Jarosite is named after its type locality at the Jaroso Ravine, Sierra Almagrera, Spain and is also known as utahite. It is found worldwide at localities in Australia, Mexico, Canada, Russia and throughout Europe, although it occurs in small amounts. Jarosite forms in a variety of settings: as a secondary mineral under arid conditions often as an alteration product of pyrite or members of the feldspar group (*qq.v.*); in sulfidic marine sediments and soils (Obron and Berggren, 1995), where pyrite may also be present; or on rock surfaces in sulfuric acid spingwater pools through bacterially induced mineralisation (Kawano and Tomita, 2001). In these environments, jarosite is commonly found in association with gypsum, pyrite, galena and hematite (*qq.v.*).

The potassium in jarosite may be replaced by sodium, producing natrojarosite (*q.v.*) from which it is indistinguishable optically. Jarosite is also closely related in chemistry to hydronium-jarosite (*q.v.*), also known as carphosiderite, which has the chemical formula $(H_2O)Fe_3(SO_4)_2\{(OH_5)H_2O\}$ (Moss, 1957). The particle morphology of hydronium-jarosite and jarosite are so similar that they may be confused if optical mineralogy is used alone for identification.

Early use of jarosite as a mineral has been described by Dutrizac *et al.* (1983). El Goresy *et al.* (1986) have identified jarosite as a pigment in Egyptian wall paintings. Colinart (1998, 2001) identified jarosite or natrojarosite or a mixture of both, with Al also present, on stone artefacts from ancient Egypt. Le Fur (1994) also identified jarosite pigments from Middle Kingdom wall paintings from temples at Karnak. Wallert (1995a) has identified its presence on Greek artefacts. However, Schiegl *et al.* (1992) consider that occurrences of jarosite and natrojarosite on Egyptian monuments are explained as a result of an advanced decomposition of an iron-bearing glass pigment with potassium and sulfur, a view rejected by others on the basis of the absence of the supposed precursor pigment and the general context. Hydronium-jarosite has been identified by the authors among pigments excavated at Pompeii (Walsh *et al.*, 2004).

Feldspar group; Iron sulfates group; Galena; Gypsum; Hematite; Hydronium-jarosite; Natrojarosite; Pyrite; *Carphosiderite*
Colinart (1998); Colinart (2001); Dutrizac *et al.* (1983); El Goresy *et al.* (1986); Fur (1994); Kawano & Tomita (2001); Moss (1957); Obron & Berggren (1995); Schiegl *et al.* (1992); Wallert (1995a); Walsh *et al.* (2004)

JASMINE GREEN

Green
Synonym, variant or common name

This is listed by Mierzinski (1881) and Fiedler and Bayard (1997) as one of the names applied to either Scheele's green and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997); Mierzinski (1881) 281

JASNIGER GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

JATROPHA

Purple
Common generic composite

Wallert describes an indigenous purple colourant made from the shrub *Jatropha curcas* L. (Euphorbiaceae), which is common to tropical areas of the Americas (Wallert, 1995c, 1997b). The colourant is obtained from the seeds of the plant and was called *cuauhy-ohuachtli* by the Aztecs, who used it as a dye and a paint (Standley, 1967; cf. Haude, 1998). The seeds of *Jatropha curcas* are a noted source of oil. Another species, *J. spathulata* (Ortega) Muell. Arg., is also known as a red dye in Mexico (Mabberley, 1998).

Haude (1998); Mabberley (1998) 371; Standley (1967); Wallert (1995c); Wallert (1997b)

JAUNE BRILLIANT

Yellow
Synonym, variant or common name

According to a *Composition of Pigments* list given in a Winsor & Newton catalogue of 1896, this was 'a variety of Naples Yellow prepared from Chrome Yellow and White Lead' (cf. Carlyle, 2001). Heaton (1928) lists this as a then-current term for an 'imitation Naples yellow' compounded of 'cadmium and white lead'. Doerner (1935) describes brilliant yellow as 'a very light mixture of cadmium yellow and either Cremnitz or zinc white'. Fiedler and Bayard (1986), in their modern review of cadmium yellow pigments, state that the composition was of cadmium yellow and lead white, adding that vermilion (*qq.v.*) was also sometimes included in the formulation.

Cadmium yellow; *Chrome yellow*; *Cremnitz white*; *Lead white*; *Naples yellow*; *Vermilion*; *Zinc white*
Carlyle (2001) 526; Doerner (1935) 65; Fiedler & Bayard (1986); Heaton (1928) 382

JAUNE DE CHRÔME MALTERVE

Yellow
Synonym, variant or common name

Listed by Kühn and Curran (1986) as a synonym for zinc yellow (*q.v.*).

Zinc yellow
Kühn & Curran (1986)

JAUNE DE COBALT

Yellow
Synonym, variant or common name

See: cobalt yellow.

JAUNE DE FER

Yellow
Synonym, variant or common name

Synonym for mars yellow. Carlyle (2001) points out that this term should not be confused with iron yellow (*q.v.*), an iron(II) oxalate.

Iron yellow; *Mars yellow*
Carlyle (2001)

JAUNE MINÉRAL(E)

Yellow
Synonym, variant or common name

A variety of different pigments have been given as *jaune minéral*(*e*):

1. Mercury sulfate oxide ($HgSO_4.2HgO$);
2. Tungsten yellow ('*giallo di Tungsteno*' and '*Wolframgelb*'; Mierzinski, 1881);
3. According to Salter (1869), jaune minérale was 'prepared in Paris, and differs in no essential particular from ordinary chromate of lead, except in the paleness of its colour', adding that jaune minérale was 'another lead yellow, not a chromate';

4. A term for Naples yellow (Ure, 1875–78; Wainwright *et al.*, 1986);
5. André Beguin, in the *Dictionnaire technique de la peinture*, mentions a '*jaune paille minéral*' obtained from litharge and basic lead sulfate.

Litharge; *Naples yellow*; *Tungsten yellow*
Beguin (1978–84); Mierzinski (1881) I, 426–427; Salter (1869) 94–95; Ure (1875–78); Wainwright *et al.* (1986)

JAUNE ROYAL

Yellow
Synonym, variant or common name

See: orpiment.

JONQUILLE CHROME YELLOW

Yellow
Synonym, variant or common name

Listed by Kühn and Curran (1986) as a synonym for chrome yellow (*q.v.*); also known as *jaune de chrôme janquille*.

Lead chromates group; *Chrome yellow*
Kühn & Curran (1986)

JUGLONE

Orange
Generic compound

Juglone, 5-hydroxy-1,4-naphthoquinone, is the principal colouring matter found in shells of various Juglandaceae (walnut), principally *Juglans nigra* L. and *Juglans regia* L. (*Merck Index*, 1996; Schweppe, 1992). It is listed in the *Colour Index* as CI 75500/Natural Brown 7.
See: walnut and naphthoquinones group.

Colour Index (1971) 75500; *Merck Index* (1996) 5282; Schweppe (1992) 191–194

JUSTICIA

Blue
Common generic composite

Two species of *Jacobinia* (*J. mohintli* and *J. umbrosa*) are listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica (however, *J. mohintli* is now known as *Justicia spicigera* Schlec., while *J. umbrosa* is *Justicia aurea* Schlec.). The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *mohuitli*.

Wallert (1995c)

K

KAEMPFEROL

Yellow
Generic compound

Kaempferol, 3,4′,5,7-tetrahydroxyflavone is a flavonoid (flavonol) dye compound extracted from *Reseda luteola* L. and *Sophora japonica* L. as well as being a minor component of *Juglans nigra* L. (Schweppe, 1992).
See: weld, safflower, sophora yellow and walnut.

Flavonoids group
Schweppe (1992) 328

KAISER GREEN

Green
Synonym, variant or common name

Kaiser green is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*). Mierzinski (1881) describes Kaiser green – with neuwied, Braunschweig, berg, copper and mountain greens – as a copper acetate arsenite (that is, emerald green) lime green that contains calcium or barium sulfate.

Emerald green; *Scheele's green*
Fiedler & Bayard (1997); Mierzinski (1881)

KAISERBLAU

Blue
Synonym, variant or common name

See: *Königsblau* and smalt.

KAISERGELB

Yellow
Synonym, variant or common name

Rose (1916) gives *Kaisergelb* ('Kaiser yellow' or 'Emperor yellow') as a synonym for a cadmium sulfide pigment.
See: cadmium yellow.

Cadmium yellow
Rose (1916) 107

KALKBLAU

Blue
Synonym, variant or common name

This term was apparently equivalent to so-called neuwied(er) blue (*q.v.*), a copper-based pigment prepared by precipitating copper sulfate with calcium hydroxide (Gentele, 1860).

Neuwied blue
Gentele (1860) 207–209

KAOLIN

White
Synonym, variant or common name

Kaolin is the common name used for kaolinite (*q.v.*), a white clay mineral of composition $Al_4[Si_4O_{10}](OH)_8$ derived from the weathering of feldspars. Correctly, kaolin consists of both crystalline and amorphous material, whereas kaolinite is completely crystalline. Particle size is normally extremely fine, though typically it appears as a highly laminated agglomerate of platelets (one author graphically describes it as a 'booklet'). Calcium, magnesium and potassium are also commonly associated with kaolin as trace elements.

Kaolin is found relatively pure and therefore typically requires little processing for use as a pigment. It is also reportedly the only white mineral pigment available in commercial quantities where a substantial proportion of the whole is of a very fine particle size (<2 μm). According to Brooks and Morris (1973), kaolin would be extracted from the earth by strip mining, then either dried for sale as 'air floated clay' or else 'water classified', where the kaolin is dispersed in water to its natural particle size and grit removed by sedimentation, screening and centrifuging. The purified kaolin would then be fractionated into ultra-fine, fine and coarse grades. Pigment grades can be grouped into three major classifications: water washed china clay, calcined clay ('dehydroxylated') and delaminated clay. Calcination effectively changes the kaolin(ite) into aluminium silicate, fusing particles in the process to give a coarser product. Delamination involves mechanical grinding to separate out the agglomerated kaolin into thin platelets measuring about 0.25 μm thick and up to 10 μm in diameter.

There are numerous locations at which kaolin occurs; deep kaolinisation of granites caused by weathering having taken place in many parts of the world during the Jurassic and Cretaceous periods. Current commercial production is primarily situated in the US (Georgia) and the UK (Cornwall and Devon) where there are vast deposits, but Malaysia, Germany, the Czech Republic, France, Brazil and South Africa are also suppliers. The US and the UK were also historically the most important sources from the eighteenth century onwards, the formations in Cornwall being discovered in the 1740s.

Specific identifications of kaolinite in painted artefacts are discussed in the relevant entry, though the presence of this mineral is a likely indicator for the use of kaolin. However, kaolin itself is specifically mentioned in various recent studies of artefacts. For example, Banik and Stachelberger (1984) record having observed kaolin on an Egyptian Fayum portrait;

Orna *et al.* (1989) have identified kaolin in Byzantine manuscripts; Agrawal and Bisht (1966) state that kaolin was used for polychromy on Indian carvings as well as finding kaolin used as a ground in a painting of the late eighteenth century Jaipur School; Butzer *et al.* (1979) note kaolin as being used in South African rock art; Coremans and Thissen (1964) found kaolin in the ground of a painting attributed to Rembrandt (the so-called '*Stuttgart Self-portrait*'); Yanagisawa and Miya (1959) found kaolin used as a ground in wall paintings at the Daigo-ji pagoda, Kyoto, Japan (built 952 AD). Among documentary sources, Zerr and Rübencamp (1906) mention kaolin as being mixed with chrome yellow (*q.v.*) pigments.

Kaolin has also been used as part of the production of other pigments such as ultramarine (*q.v.*), which is an aluminium silicate in its own right (*Colour Index*, 1971). Modern commercial use is generally for ceramics, paper and pulp industries and rubber goods, but it has also been found suitable for use with titanium dioxide white (*q.v.*) pigments as an extender.

Kaolin, as with the mineral kaolinite, was named from the original locality – Kao-Ling ('high ridge'), in Jiangxi Province, south-eastern China. The term kaolin is often also used synonymously with China clay (*q.v.*), the latter commonly being stated as having derived from the use of the material in China for porcelain production. Other associated terms are pipe clay (although this term should refer to sepiolite, *q.v.*) and white bole, while Heaton (1928) also refers to Devonshire clay. A degree of confusion exists among these terms since there is a related material known as 'ball clay'. Ball clay is a sedimentary clay formed by rivers and streams washing away the decomposed granite, mixing it with other clay minerals, sands, gravels and vegetation as they flowed down from the uplands to form the deposits of ball clay in low lying basins. In ball clays, there are usually three dominant minerals: 20–80% kaolinite; 10–25% mica and 6–65% quartz. In addition, there are other 'accessory' minerals and some carbonaceous material (derived from ancient plants). The wide variation in minerals make-up, and in the sizes of the clay particles, result in different characteristics for individual ball clay seams. The name ball clay dates back to the early methods of mining, when clay was dug using specialised hand tools, which extracted the clay in rough cube shapes of about 25 cm each side; as the corners were knocked through handling and storage, the clay cubes became rounded and 'ball' shaped. Both are employed in ceramics, but it is apparently the ball clay which was used to produce pipes for smoking tobacco – hence 'pipe clay'. Although deposits of kaolin occur in Devon (Dartmoor) this area was also noted for ball clays, with material being exploited since Roman times and commercialisation from the late seventeenth century. It is unclear whether ball clays have also found use as pigments. It is sometimes also associated synonymously with *fuller's earth* (*q.v.*), although the two really have quite distinct meanings.

Finally, kaolin can be referred to as 'hydrated' (or 'hydrous') aluminium silicate. It is listed by the *Colour Index* (1971) as CI 77005/Pigment White 19. Use of kaolin as a pigment has been reviewed by Brooks and Morris (1973).

Clay minerals group; Silicates group; Kaolinite; Ultramarine; *China clay*; *Chrome yellow*; *Fuller's earth*; *Pipe clay*; *Titanium dioxide white*

Agrawal (1971); Agrawal & Bisht (1966); Banik & Stachelberger (1984); Brooks & Morris (1973); Butzer *et al.* (1979); *Colour Index* (1971) 77005; Coremans & Thissen (1964); Heaton (1928) 381; Orna *et al.* (1989); Yanagisawa & Miya (1959); Zerr & Rübencamp (1906/1908) 149

KAOLINITE

White

Generic compound

Kaolinite is an aluminium silicate hydroxide mineral with composition $Al_4[Si_4O_{10}](OH)_8$. It is the most common member of the kaolinite group, a subdivision of the clay minerals group (*q.v.*), and as such is a sheet silicate formed of layers of SiO_4 tetrahedra connected by AlO_6 octahedra. It is polymorphous with fellow group members nacrite and dickite (*qq.v.*), and transforms to metakaolinite upon heating to 650°C due to dehydration. Kaolinite is named after the original type locality of Kao-Ling, China and occurs most commonly as compact earthy masses of microscopic crystals or as larger pseudohexagonal tabular crystals. Pure forms of the mineral are white, although the presence of impurities (such as iron and magnesium) may colour it grey or yellow. Kaolinite is common worldwide and forms as secondary deposits usually from the decomposition of feldspar group minerals due to weathering or pneumatolytic action of gases; it also forms as the final alteration product after illite and montmorillonite (*qq.v.*) if sufficient water is present. Kaolinite is a principal component of china clay, which includes amorphous and crystalline components of the kaolinite and smectite group clays; together with the hydrated kaolinite group clay halloysite (*q.v.*), kaolinite is also a major constituent of lithomarge, a white, red or yellow variety of clay deposit (Deer *et al.*, 1992; Newman and Brown, 1987; Rutley, 1988).

Kaolinite is used in the manufacture of china, porcelain, paper and paint, and modern uses of kaolinite group clays have been discussed by Brooks and Morris (1973) and Huxtable and Pickering (1979). Using IR spectroscopy, Edwards *et al.* (2002) identified kaolinite admixed with '*caput mortuum*' (*q.v.*; however, probably an earth pigment) in wall paintings from the Rushton Roman villa site near Kettering, England; the addition of kaolinite was considered to have increased the adhesive properties of the pigments to the underlying substrate. Kaolinite has been found in rock paintings with muscovite and illite, and as a constituent in mineralogical crusts obscuring rock art at archaeological sites in Australia (Watchman *et al.*, 1993, 2001). Kaolinite has also been reported as a minor component with illite and montmorillonite in green earth pigments, which are dominated by the clay minerals glauconite or celadonite (*qq.v.*; Grissom, 1986). Stos-Fertner *et al.* (1979) have reported metakaolinite as present in pigments on Minoan pottery.

Aluminium group; Clay minerals group; Clay minerals group: Kaolinite sub-group; Clay minerals group: Smectite sub-group; Feldspar group; Sheet silicates group; Silicates group; Celadonite; Dickite; Glauconite; Green earth; Halloysite; Illite; Montmorillonite; Muscovite; Nacrite; *China clay*; *Kaolin*; *Pipe clay*; *White bole*

Brooks & Morris (1973); Deer *et al.* (1992) 354–362; Edwards *et al.* (2002); Grissom (1986); Huxtable & Pickering (1979); Newman & Brown (1987) 80; Rutley (1988) 410–412; Stos-Fertner *et al.* (1979); Watchman *et al.* (1993); Watchman *et al.* (2001)

KARMESIN LAKE

Red

Synonym, variant or common name

Listed as a term in the *Colour Index* under CI Natural Red 4 and said to be a cochineal lake, from the German *karmesin*.

Cochineal

Colour Index (1971)

Kassel earth

Brown
Synonym, variant or common name

See: cassel earth.

Kassel green

Green
Synonym, variant or common name

See: cassel green.

Kassler yellow

Yellow
Synonym, variant or common name

According to Heaton (1928) Kassler yellow was then an obsolete or rarely used pigment equivalent to Turner's yellow (given by Heaton in turn as 'basic lead chloride', that is, lead chloride oxide).

Lead halides group; Lead chloride oxide; *Turner's yellow*
Heaton (1928) 382

Kermes

Red
Generic compound

Kermes is a red dyestuff principally derived from various species of Coccoidea (scale insects) belonging to Kermesidae. Of these insects perhaps *Kermes vermilio* Planchon is the most important, though the related *K. ballotae* has also been mentioned in the literature (see below). The insects of *K. vermilio* live on the kermes or scarlet oak, *Quercus coccifera* L.; this is indigenous to the Mediterranean region, notably Spain, southern France and Italy as well as Crete. The extracted dye consists principally of kermesic acid, with flavokermesic acid usually also present to the level of about 10–25% (*qq.v.*); Wouters and Verhecken (1991) have found that dye from the albino *K. ballotae* primarily contains flavokermesic acid with about 20% kermesic acid. This insect is found with *K. vermilio* and may become mixed in dyestuffs, adversely affecting the colour (cf. Kirby and White, 1996). Furthermore, some confusion in the identification of pigments on works of art may have occurred in the past due to the fact that Old World Cochineal, *Porphyrophora polonica* L. also contains kermesic and flavokermesic acids (Kirby and White). This insect is also sometimes called Polish kermes, however it is actually a cochineal (*q.v.*).

Kermococcus illicis L. (formerly *Coccus illicis* L.), which is found on the oak *Quercus ilex* L. in the Mediterranean region, is mentioned in the historical literature as a source of kermes; however, it appears that it is not possible to derive a dyestuff from this insect (Schweppe, 1992) and Cardon (1990) postulates that this may have been used as a substitution product, as she indicated that it produces a poor dye of brown-red colour.

Preparation of kermes was, historically, similar or identical to other scale insect dyes, by precipitation of the extract of the insect with iron-free alum. The colour was also extracted from previously dyed material. Le Begue, for example, gives the following methodology: 'To make fine lake. – Take ashes of oak, and make a ley, and boil in it clipping of fine scarlet rubea de grana until the colour is extracted from the clippings, and then strain the ley with the colour through a linen cloth. Afterwards take some more ley ... and heat it, and put some finely powdered roche alum, and let it stand until the alum is dissolved. Then strain it through the strainer with the other liquor or ley in which the clippings were put, and immediately the ley will be coagulated, and make a lump or mass, which you must stir well. Remove it afterwards from the vase, and lay it on a new hollow brick, which will absorb the ley, and the lake will be left to dry. You must afterwards take it off the brick and keep it for use' (Clarke MS 2790; cf. and tr., Merrifield, 1849). The resultant colour is often referred to by terms relating to the fact that textile shards were used, thus giving *cimatura* and *vloken* or *bourre.* (see: *cimatura*). This method of production could explain why mixtures of dyestuffs have been found in pigments, given that variously dyed cuttings of material might have been used.

Documentary evidence indicates that kermes was an important dye from at least the second millennium BC (Schweppe and Roosen-Runge, 1986) and its use declined in Europe as the New World cochineal became available from the 1540s. This decline continued until the use of kermes became negligible in the eighteenth century, however the production of kermes lakes appears not to have ceased altogether. Kirby and White have identified a kermes lake in an area of a painting retouched sometime shortly before 1854. Identifications as a pigment on artefacts are relatively rare, probably as a result of the analytical complexities required to identify it definitively. However, Kirby and White list a number of paintings from the period 1400–1550 that contain kermes, while Sanyova and Wouters (1994) have identified dyestuff from both *Kermes vermilio* and (probably) *K. ballotae* on a group of late fifteenth and sixteenth century polychrome altarpieces from Antwerp. Analysis of some crimson colours in manuscript illuminations from the second half of the fifteenth century by Wallert (1991) found that the kermes insect was used, however Polish cochineal (*Porphyrophora polonica* L.) was found as well as brazilwood. It is possible that identifications of this sort have come about as the old world cochineal, as well as containing carminic acid, also has lesser components which are those produced by the kermes insects (flavokermesic and kermesic acids). He further found that lead white had been used in combination with these colourants.

Early classical terminology for what may reasonably be assumed to be kermes (on the basis of its distribution) is closely related to views on the nature of the source material. The insect cases and larvae, along with an exudiate were collected with the twig on which they had clustered. This material was so dense as to obscure the insect origin of the material and led to the belief that it was derived from the plant from which the twig came. It was, in several MSS, said to come from the leaves of trees, so that we find Jehan Le Begue (1431; Clarke MS 2790; cf. Merrifield, 1849) writing '*Vermiculus color rubeus est, qui fit ex frondibus silvestribus, ut dicit Catholicon, et Grece ipsum dicunt coctum; nos vero rubeum vel vermiletum*' (the colour vermiculus is scarlet and is made from the leaves of trees). Names referring to berries or grain were also applied to the material which highlights the confusion as to the source, for example. Theophrastus (c. 315 BC) and Dioscorides refer to *coccus* ('κοκκος'), which means 'berry'. Schweppe and Roosen-Runge cite Saint Jerome (c. 348–420 AD) as using *baca* (berry), and *granum* (grain), but also *vermiculus* ('small worm') – '*pro cocco iuxta Latinum eloquium apud Hebraeos tholath, id est vermiculus scrbitur*' ('for coccum in the Latin tongue, the Hebrews write tholath [worm], that is vermiculum [small worm]'); as well as Isidore of Seville (c. 570–636 AD), who recorded that *coccus* was also called *vermiculum* or *rubrum.* This laid a foundation for later confusion, not only through the free interchange of related terms, but also through similarity of words such as *vermiculum* (kemes) and *vermilion* (the mercury sulfide pigment). From the root *vermiculum*, the French *vermillion* and *vermeil*, as well as the English *vermilion*, are derived; however, the meaning is often clear in context and manuscripts may use both vermiculum and coccus terms together. Vermiculum continues to be used as late as the fifteenth century, the Bolognese MS (Clarke MS 160) advising that 'you may make lake ... from various stones and of various kinds, namely, from that form which the crimson colour is made, from dragon's blood, from *grana*, from *vermiculis*…' (tr. Merrifield, 1849).

Schweppe and Roosen-Runge usefully define two further groups of related terms which they call *Coccarin-Coccus* and *Granum-Lacca.* Examples of the former can be found in the so-called 'Lucca MS.' *Compositiones ad tigenda musiva* (Lucca: Bibl. Capitolare Feliniana MS. Codex 490; Clarke MS 2020; said to be Greco-Byzantine, sixth to eight century AD) and the derivative *Mappae Clavicula* (fourteenth century). The latter seemingly stem from authors such as Pliny (77 AD); the Lucca MS, for example, uses *crana* and *grana* (*q.v.*) and these can be reasonably associated with kermes (though Kirby and White say that this could also be Old World cochineals depending on the date). Numerous grades of *grana* were traded – the Florentine merchant Pegolotti, writing around 1339–40, for example lists seven different types among these, *grana di schiavona*, while a fourteenth or early fifteenth century manual on silk mentions *grana di cintri, Spagnuola, le barbaresche, la Valenza* and *la Provenza.* A further list includes *grana di Armenia*, however this last may refer to Armenian cochineal (Kirby and White, 1996).

The etymology for the term kermes itself is considered to be from the Sanskrit *kirmidja*, 'engendered by a worm', and the Persian *krim*, 'worm', in reference to the supposed origin mentioned above. From this root it appears to have been incorporated into numerous languages, giving rise to terms such as *cramoisi* (French), *karmin, karmoisin* and *karmesin* (German) and the English *crimson* and related E. forms such as *cremoysin* and *cramoisy* (see: *OED*, 2002, 'Crimson'). Contextual usage indicates these terms to be mediaeval in origin. (Kirby and White however suggest that *chermisi* might refer to the bluer crimson or pink produced by cochineal.) In seventeenth century Spain, *carmin* identified a red lake pigment made from kermes (Veliz, 1986).
See: cochineal, lac and grana.

Anthraquinones group; Insect-based reds group; Carminic acid; Kermes; Lac; *Carmine*; *Chinese lake*; *Cimatura*; *Crimson lake*; *Florentine lake*; *Grana*; *Hamburgh lake*; *Purple lake*; *Roman lake*; *Scarlet lake*; *Venetian lake*
Bersch (1901) 362; Cardon (1990); Kirby & White (1996); Merrifield (1849); *OED* (2002); Sanyova & Wouters (1994); Schweppe (1992); Schweppe & Roosen-Runge (1986); Wallert (1991); Wouters & Verhecken (1991)

KERMESIC ACID

Red
Generic compound

Kermesic acid is 9,10-dihydro-3,5,6,8-tetrahydroxy-1-methyl-9,10-dioxo-2-anthracenecarboxylic acid; the structure has been determined by Gadgil *et al*. (1968). It is the principal compound found in dye extracted from the kermes insect *Kermes vermilio* Planchon and also, to a lesser extent, the so-called 'Polish' cochineal insect *Porphyrophora polonica* L. and to an even lesser extent the 'Armenian' cochineal *Porphyrophora hamelii* Brandt. This consists principally of kermesic acid, although the related compound flavokermesic acid is usually present to the level of about 10–25% (Schweppe, 1992; Schweppe and Roosen-Runge, 1986). Wouters and Verhecken (1991a) have on the other hand found that dye from another kermes insect, *K. ballotae*, primarily contains flavokermesic acid, with about 20% kermesic acid.

Flavokermesic acid, a minor dye constituent isolated from Kermes insects, has been identified as 1-methyl-3,6,8-trihydroxy-9,10-anthracene dione-2-carboxylic acid (synonym for laccaic acid D or xanthokermesic acid; Wouters and Verhecken, 1987).

Listed by the *Colour Index* as CI 75460/Natural Red 3.
See: kermes and anthraquinones group.

Anthraquinones group; Kermes
Colour Index (1971) 75460; Gadgil *et al*. (1968); Schweppe & Roosen-Runge (1986); Schweppe (1992) 646; Wouters & Verhecken (1987); Wouters & Verhecken (1991a)

KERMESITE

Red
Generic compound

Kermesite is an antimony oxide sulfide mineral of red colour. Gross morphology is of acicular or fibrous crystals which radiate out from a centre. The name derives from kermes (*q.v.*; a term more recently reserved for the insect red dye derived from *Kermococcus illicis*), which in turn comes from the Persian *qurmizq* – 'crimson'. In older chemistry this referred to red amorphous antimony trisulfide, often mixed with antimony trioxide.

Antimony sulfides group; Antimony oxide sulfide; Kermes

KERNEL BLACK

Black
Synonym, variant or common name

Although Mayer (1991) describes this as being synonymous with vine black it is more probably a char based on fruitstones.

Peach black
Mayer (1991) 48

KIESELGUHR

White
Synonym, variant or common name

See: silica.

KING GREEN

Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997)

KING'S BLUE

Blue
Synonym, variant or common name

Bersch (1901) lists King's blue among terms for cobalt blue, made in a similar manner to Rinmann's green (*q.v.*). The *Colour Index* (1971; CI 77346) lists both smalt and cobalt blue as synonymous with this term, while Doerner (1935) indicates that it is cobalt blue or synthetic ultramarine with cremnitz white.

Smalt; Ultramarine; *Cobalt blue*; *Cremnitz white*
Bersch (1901) 230; *Colour Index* (1971) 77346; Doerner (1935) 80

KING'S YELLOW

Yellow

Synonym, variant or common name

Term formerly applied to orpiment-based pigments, the name King's yellow being mainly applied during the eighteenth century (Dossie, 1764; de Massoul, 1797) where the usage is thought to have derived from Arabic alchemical texts describing orpiment and realgar as the 'two kings' (Crosland, 1962; Harley, 1982). Weber (1923) also mentions King's yellow and *Koenigsgelb* as synonyms for orpiment, and mentions that it 'is found native … or can be made artificially by precipitation or sublimation'.

King's yellow is probably more readily applied to the synthetic varieties of orpiment due to the alchemical connections, however. For example, Carlyle (2001) identifies this as a synthetic analogue of the mineral orpiment, though she also notes its later substitution by combinations such as chrome yellow and zinc white. King's yellow is listed by Kühn and Curran (1986) as having been used as a synonym for chrome yellow (*q.v.*), recording that it may refer to a variety extended with a white material.

Arsenic sulfide, orpiment type; Orpiment; *Cadmium yellow*; *Chrome yellow*; *Zinc white*

Carlyle (2001) 529–530; *Colour Index* (1971); Crosland (1962) 36; Dossie (1764) I-97; FitzHugh (1997); Harley (1982) 93–94; Kühn & Curran (1986); Massoul (1797); Weber (1923) 96, 104

KIRCHBERG GREEN

Green

Synonym, variant or common name

Kirchberg(er) green was a term associated with emerald green (*q.v.*). According to Zerr and Rübencamp (1906) it was a mixture of 40–50 parts imperial green and 50–60 parts baryte, imperial green being in turn another emerald green-derived compound.

Baryte; *Emerald green*; *Imperial green*

Zerr & Rübencamp (1906/1908) 222

KLAGENFURT WHITE

White

Synonym, variant or common name

Klagenfurt white is listed by Doerner (1935) as being lead white.

Lead white

Doerner (1935) 53

KOBALTGELB

Yellow

Synonym, variant or common name

See: cobalt yellow.

KÖCHLIN'S GREEN

Green

Synonym, variant or common name

Seemingly a copper-arsenic green (*q.v.*). Terry (1893) describes the process as involving the preparation of copper arsenite from copper sulfate and sodium arsenite ('arsenite of soda'). The precipitate is then treated with acetic acid or, interestingly, formic acid; the former would result in the usual copper acetate arsenite, the latter in copper formate arsenite. Terry comments: 'The pigment thus produced is of good colour, but its superiority would not seem to justify the use of such an expensive article as pure formic acid, nor the minute adjustment of the proportions of the ingredients, in an operation to be conducted on a commercial scale.'

Although not generally identified to date on artefacts, two samples labelled *minraalgroen* ('mineral green') and another labelled *papegaaigroen* ('parrot green') are to be found in the nineteenth century Dutch Hafkenscheid Collection. Analysis of these has shown that they consist of artificial copper-arsenic compounds, tentatively identified as a 'copper formo-arsenite' (that is, copper formate arsenite).

Terry (1893) 123

KÖNIGSBLAU

Blue

Synonym, variant or common name

Nineteenth century German authors such as Gentele (1860) and Mierzinski (1881) use the term *Königsblau* for cobalt-based blues in general, rather than a specific form such as one or all of the cobalt aluminates, or smalt. *Königsblau* is also given as a synonym for smalt by Mühlethaler and Thissen (1993), however. What appears to be an Anglicisation, King's blue, also occurs in the literature with a broadly similar range of meaning (Bersch, 1901; Doerner, 1935; *Colour Index*, 1971).

Smalt; *Kaiserblau*; *King's blue*

Bersch (1901) 230; *Colour Index* (1971); Doerner (1935) 80; Gentele (1860) 227; Mierzinski (1881); Mühlethaler & Thissen (1993)

KÖNIGSGELB

Yellow

Synonym, variant or common name

See: orpiment.

KRAPPCARMIN

Red

Synonym, variant or common name

See: cochineal.

KREMS WHITE

White

Synonym, variant or common name

Generally taken as synonymous with Cremnitz white, a form of lead white (normally lead carbonate hydroxide, *qq.v.*). According to Osborn (1845), '*Krems, or Silver White.* The Finest preparation of the oxyd or subcarbonate of lead … We class the *Krems* and *Silver White* as one, because the latter name is merely significative of the brilliant and pure whiteness of the preparation; and the designation, at first confined to a French manufacture (*Blanc d'argent*), is now applied to all white leads of equal quality, without regard to their place of origin.' Osborn also adds that Krems white was received directly from Vienna (giving rise to another alternate name, 'Vienna white') and apparently imported as 'small cubical masses'.

Cremnitz white; *Flake white*; *Lead white*; *Silver white*; *Vienna white*

Osborn (1845) 1–2

KREMSER WHITE

White

Synonym, variant or common name

Despite the obvious philological similarity with Cremnitz (or Kremnitz, Crems or Krems) white and although also listed as a form of lead white, this was still differentiated in documentary sources such as Salter (1869), who – while stating Kremser white was unadulterated – places it with 'other white leads, generally foreign, cheaper, and adulterated'.

Cremnitz white; *Lead white*
Salter (1869) 75

KUGEL LAKE

Red
Synonym, variant or common name

Kugel lake is considered by Schweppe and Roosen-Runge (1986) to be a cochineal lake prepared by extraction of the dye with alum solution followed by precipitation with soda. The term probably derives from the Middle High German word *kugel* or *kugele*, meaning a ball or globe; it may therefore be in reference to the physical form of the pigment (like 'drop' lake) and related to terms such as globe lake.

Cochineal
Schweppe & Roosen-Runge (1986)

KUHLMANN'S BLUE

Blue
Synonym, variant or common name

Terry (1893) describes a form of manganese blue attributed to Kuhlmann, discovered accidentally as part of the manufacture of calcium chloride. It appears to be a calcium manganate.

Calcium maganate; *Manganese blue*
Terry (1893) 49

KUHLMANN'S GREEN

Green
Synonym, variant or common name

According to Bersch (1901), Kuhlmann's green was prepared by heating lime with excess copper chloride.

Calcium copper chloride
Bersch (1901) 294

KURRERS GREEN

Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997)

KYANOS

Blue
Synonym, variant or common name

In classical texts, blue was referred to generically as κυανος (kyanos) by Theophrastus (c. 315 BC) and *caeruleum* by Pliny (77 AD). Theophrastus states that there are natural and synthetic forms of kyanos; the synthetic are Egyptian Blue and Scythian blue (from Phoenicia). Both were made by combining sand, flowers of soda and copper fillings to create the artificial copper silicate analogue of cuprorivaite. Vitruvius (first century BC) uses the term *caeruleum* to refer to Egyptian blue alone. By his time of writing, a factory to manufacture cuprorivaite had been set up by one G. Vestorius in Puteoli (modern Pozzuoli). Pliny repeats Theophrastus by naming Egyptian and Scythian blue. He also refers to the home grown cuprorivaite as *Vestorianum* and also as *Puteolanum*. Again, with typical allegiance to Theophrastus, Pliny says these blues may collectively be referred to as *kyanon*.

Egyptian blue
Pliny (1st cent AD/Rackham, 1952) XXXV.45–47; Theophrastus (c. 315 BC/ Caley & Richards, 1956) 55

L

LABRADORITE

White
Generic compound

Labradorite is an aluminosilicate mineral which is a member of the feldspar group, belonging to the plagioclase feldspar series. It has a composition $Ca_{0.5–0.7}Na_{0.5–0.3}(Al,Si)AlSi_2O_8$ and lies halfway along the albite-anorthite (*qq.v.*) compositional join. Plagioclase feldspars are common minerals in all rock types, and labradorite is most common in basic igneous rocks and high-grade metamorphic rocks, as well as sedimentary rocks derived from these (Rutley, 1988; Deer *et al.*, 1992). The mineral is named after its type locality of Labrador Peninsula, Canada.

The use of labradorite as a paint extender has been discussed by Schroeder (1954).

Feldspar group; Silicates group; Albite; Anorthite
Deer *et al.* (1992) 451–453; Rutley (1988) 417, 425; Schroeder (1954)

LAC

Red
Generic compound

Lac is a red dyestuff principally derived from various species of Coccoidea (scale insects) belonging to *Tachardiidae* species, *Kerria (Kerria) lacca lacca* (Kerr) (formerly *Laccifer lacca* Kerr or *Coccus lacca*) and *Kerria (kerria) chinensis chinensis* (Mahdihassan). These are indigenous to India, the Muluccas, China, Cambodia, Thailand and Sumatra. The principal colouring matter is composed of the various laccaic acids (*q.v.*) A–F as well as erythrolaccin, isoerythrolaccin and deoxyerythrolaccin (White and Kirby, 2001). The quality of the colourant depends on the various host plants, mostly of the *Croton* and *Ficus* species (Schweppe, 1992). The clustered female insects and their larvae, along with a hard brown red exudation, are collected from various trees, principally figs, indigenous to Asia and India. This exudation was principally used to make shellac and gum; however, the red colour of this material also provided an important dye and lake pigment. The insect origin of this material was difficult to detect, the exudation of *K. chinensis* coming away from the host plant in lumps which were thought to be a gum or mineral (Li Shih-Chen, cf. Cardon, 1990), and that from other species such as the *K. lacca* remaining attached to the twig so that the twig was harvested along with the substance therefore being called *stick lac*. No early sources give any indication of the insect origin whatsoever, for instance, it is listed in the *Table of Synonymes* (c. 1431; Clarke MS 2790; cf. Merrifield, 1849) as a red producing substance as well as a gum; '*Lacca est gumma quedam*, *facta de liquore rubeo, qui exit de liquore edere, arboribus herente et repente, si rami ipsius in mense Marcii aculeo ferreo perforentur*' (Lac is a kind of gum made from the reddish fluid that issues from the sap of the ivy clinging to and creeping up trees, if twigs are pierced with an iron pin in the month of March).

Cardon (2003) indicates that there is a description of lac as a dye as early as c. 1500 BC in the Atharvaveda, an Indian Sacred text. Documentary evidence for this as a pigment indicates that it was probably the primary red lake used for easel painting in fifteenth century Italy. It appears to have been first imported into Europe as a dyestuff by the Catelans and Provençals about 1220 and a recipe for its use as a pigment is given in *De Diversis Coloribus.* (Archerius; Clarke MS 2790; cf. Merrifield, 1849).

A typical recipe for extraction of the colour from gum lac is given in the Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849), 'pulverise the gum and put it into a ley [*alkaline solution*] of rosewood or vinewood, which will extract its colour; you must then separate the water from the gum [*by evaporation*] … You must then take it from the fire, and stir it with a silver spoon, and let it settle till the morning.' Lac was also prepared as a pigment by extraction of the dyestuff from previously dyed textiles, the resultant product being termed *Lacca di cimatura.* For a fuller explanation of this method see: cimatura.

A study of red lakes on paintings in the National Gallery, London, found lac in paintings by Lippi (c. 1475), Ghirlandaio (c. 1480), Michelangelo (c. 1479), Tintoretto (c. 1575), Holbein (1533) and de Champaigne (c. 1637) (Kirby and White, 1996).

The terms surrounding the various insect-based red colours have often been applied indiscriminately, see cochineal and kermes. Common terms for lac-based colours include *Indian lake*, this refering to the source of the insects (Harley, 1982).

Insect-based reds group; Cochineal; Kermes; Laccaic acid; *Cimatura*; *Grana*; *Indian lake*
Cardon (1990); Cardon (2003) 513; Harley (1982) 131–133; Kirby & White (1996); Merrifield (1849) clxxvii, 30, 686; Schweppe (1992) 272; White & Kirby (2001)

LACA DI FRANCIA

Red
Synonym, variant or common name

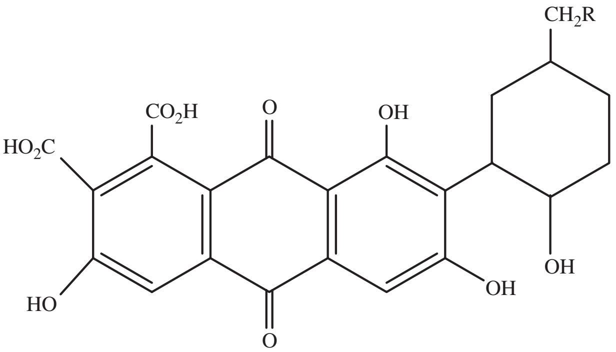
Palomino, in his *El museo pictórico y la escala óptica* (1715), mentions a pigment 'called laca di Francia in Spain, although it is called carmine [*q.v.*] in France, where likewise they call carmine laca' (cf. & tr. Veliz, 1986). Veliz considers the meaning to be a red lake based on madder (*q.v.*; dye derived from *Rubia* spp.).

Madder; *Carmine*
Palomino (1715–24); Veliz (1986) 214, n.21

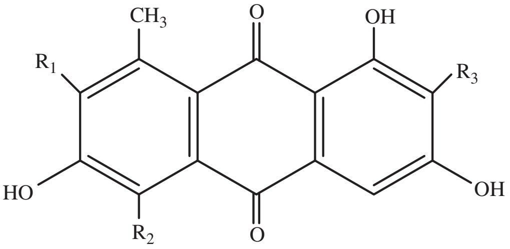
LACCAIC ACID
Red
Generic compound

Laccaic acid refers to a group of closely related anthraquinone compounds known as laccaic acids A–F (although only types A to D are commonly reported). Erythrolaccin, isoerythrolaccin and deoxyerythrolaccin are also discussed here since they are very similar structurally and occur in the same source material.

The base structures concerned are:



Structure I



Structure II

The relevant substitutions for each compound are:

Structure I:
Laccaic acid A: $R = CH_2NHCOCH_3$
Laccaic acid B: $R = CH_2OH$
Laccaic acid C: $R = CH(NH_2)CO_2H$
Laccaic acid E: $R = CH_2NH_2$
Laccaic acid F: $R = CH_2OCOCH_3$
Structure II:
Laccaic acid D: $R_1 = CO_2H$; $R_2 = H$; $R_3 = H$
Erythrolaccin: $R_1 = H$; $R_2 = OH$; $R_3 = H$
Isoerythrolaccin: $R_1 = H$; $R_2 = H$; $R_3 = OH$
Deoxyerythrolaccin: $R_1 = H$; $R_2 = H$; $R_3 = H$

Laccaic acid D is also called flavokermesic or xanthokermesic acid, and closely resembles kermesic acid (*q.v.*) in structure. Laccaic acid F has so far only been found in Thai stick lac (Hu *et al.*, 1997; cf. White and Kirby, 2001).

Principal occurrence in pigments is in dyestuffs derived from the 'lac' insects *Kerria (kerria) lacca lacca* (Kerr) and *Kerria (kerria) chinensis chinensis* (Mahdihassan).
See: lac and anthraquinones group.

Kermesic acid
Hu *et al.* (1997); White & Kirby (2001)

LACQUER BLUE
Blue
Synonym, variant or common name

Listed by Berrie (1997) as a term associated with Prussian blue (*q.v.*).

Prussian blue
Berrie (1997)

LACQUER GREEN
Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

LAKE PIGMENTS
Variable
Group term

Field (1835) states that 'lake' is 'A name derived from the *Lac* or *Lacca* of India, [and] is the cognomen of a variety of transparent red and other pigments of great beauty, prepared for the most part by precipitating coloured tinctures of dyeing drugs upon alumine and other earths.'

Watin (1785) distinguishes between true lakes laid on alum or 'a white chemical body', and false lakes laid on starch or chalk. He goes on to say that Venice and Florence lakes are red lakes laid on alum and that the name refers to place of manufacture.

The *Oxford English Dictionary* (2002) further broadens the definition of a lake, calling it 'A pigment obtained by the combination of animal, vegetable, or coal-tar colouring matter with some metallic oxide or earth. Often preceded by some qualifying word, as crimson, Florence, green, madder, yellow, etc. lake.' However, although the term 'lake' was historically used to refer to dyes which were adsorbed onto substrates as described above, modern usage of the term differs from this and may specifically imply the production of insoluble metal salt pigments. In Europe these pigments are also known as 'toners', although this is a term with other meanings as well. Examples are the monoazo pigment lakes based on a pyrazolone sulfonic acid derivative as a coupling component, such as the aluminium tartrazine lake CI 19140:1/Pigment Yellow 100 (Herbst and Hunger, 1997).

Other historic terms derived from the Hindustani *lakh* and the Sanskrit *laksha* (also *raksh*) (*OED*), and the Latin *lacca* include the French *laque*, Spanish *laca*, Italian *lacca* or *lacha* and the German *lack or lach.* These terms all apply to red lakes, whereas the English lake also refers to yellows.

For a discussion on various lake pigments see the entries relevant to the dyestuff. Source: brazilwood; cochineal; kermes; madder; rhamnus; saffron.

Brazilwood; Carmine lake; Cochineal; Kermes; Madder; Rhamnus; Saffron
Colour Index (1971) 19140; Field (1835) 97; Herbst & Hunger (1997); *OED* (2002) 'Lake'; Watin (1773/edition of 1785) 24

LAKE WHITE
White
Synonym, variant or common name

Patton (1973i) equates *lake white* with *light alumina hydrate*. This latter term refers to a 'basic aluminium sulfate prepared as a precipitate from solutions of aluminium sulfate and sodium carbonate'; because it has been commonly used as a substrate for the preparation of lake pigments, it is sometimes called lake white.

Aluminium sulfates group
Patton (1973i)

Lamorinière green

Green
Synonym, variant or common name

Apparently named after the Belgian artist Jean Pierre François Lamorinière (1828–1911), *Lamorinière green* was a specialty of the colourmen Jacques Blockx Fils SA. According to a notebook recipe in that company's possession, it was made by mixing 1000 gr of potassium bichromate with 250 gr of potato starch flakes, then calcining and washing it thoroughly. The pigment has not been produced by Blockx since the 1940s; they have substituted CI Pigment Green 17 (chromium oxide, *q.v.*) in modern samples under this name (pers. comm., 2003). It is also said to be a combination of chromium and aluminium hydroxides (*q.v.*; Montagna, 1993).

Aluminium oxides and hydroxides group; Chromium oxide
Colour Index (1971); Montagna (1993) 141

Lamp black

Black
Synonym, variant or common name

A form of flame carbon or carbon black prepared by burning oils, resins and, more specifically, rosin and pitch, the soot being collected on a cooler surface arranged such as to allow the particles to be caught up on it. As such, lamp black must represent one of the most ancient pigments (Lucas, 1962) and is described as a 'beautiful black' (Tingry, 1804). Numerous descriptions of preparation exist, such as Peacham (1612): 'The making of ordinary lamp blacke. Take a torch or linke, and hold it vnder the bottome of a latten basen, and as it groweth to be furd and blacke within, strike it with a feather into some shell or other, and grind it with gumme water.' According to Watin (1785) the best lamp black is made by putting pitch into an iron pot and placing this into a completely closed room entirely hung with sheepskin or cloth and burning the pitch; the resultant smoke condenses in a black soot attached to the cloth or sheepskin, which can then be collected. Eighteenth century French sources also distinguish two other sorts of lamp black: *noir de fumée* ('smoke black') from combustion of pitch and tar and *noir de bougie* from candle wax. Mérimée (1830) also describes a black made by collecting the soot from burning coal; however, he states that this is heavier and coarser as well as containing a large quantity of ammonia. Schweppe (1992) mentions that the Mayans and the Aztecs made a black called *Tliliocatl* which appears to be a lamp black carbon from torches.

Perhaps the highest degree of sophistication in historical production techniques was achieved in the manufacture of pigments for so-called 'Chinese ink'. This is well described by Li Ch'iao-p'ing (1948): 'The lampblack was made either by burning pine wood or vegetable oils. The process of making lampblack from pine wood was carried out by using a vertical kiln, more than ten feet high, having a wide belly and a small mouth. Instead of the chimney, at its top there was a jar of a capacity of fifty liters, on which five others were put one upon another. They were of different sizes, each having a hole at its bottom. The diameter of the holes varied according to the size of the jar. The spaces between these jars were closely sealed with mud. When the lampblack produced in the jars gradually became thick, the fire was stopped and the lampblack was swept out by means of a feather brush. Two, three, or five varieties of the product might be classified but that collected in the first vessel was not suitable for use.' Li Ch'iao-p'ing goes on to describe a horizontal kiln 'used in later years'; this was some 125 feet long in which three to five branches of pine wood were slowly burnt.

Production has continued in one form or another into recent times. Toch (1916), for example, states that 'Lampblack is the condensed smoke of a carbonaceous flame, and at present is made from a hydrocarbon oil of the type of dead oil, or it may be made from a number of distillates which on burning give a condensed black soot. Lampblack is still made from resinous woods, tar and pitch where the dead oil is not obtainable.' The lamp black process is still used to a limited extent; Buxbaum (1998) describes the use of oil with a high aromatic hydrocarbon content being burnt in large flat steel vessels, the off-gas containing the carbon black being sucked up into a conical exhaust pipe.

Winter (1983) has proposed differentiating lamp black from soot. The former term would on his basis cover products made by burning oil at a wick (that is, in lamps) as opposed to carbon made by burning wood; by extension soot would refer to any traditional flame carbon made otherwise than in an oil lamp. However, since soot is commonly defined as 'A black carbonaceous substance or deposit consisting of fine particles formed by the combustion of coal, wood, oil, or other fuel' (*OED*, 2002), this seems a difficult distinction to maintain.

Flame carbons may be found in contexts worldwide from ancient times to the present day. Examples of identifications include Bugini and Folli (1997), who found lamp black on first century BC Roman wall paintings in Brescia, Italy. Okada *et al.* (1994a,b) describe finding lamp black or pine soot in urushi on early Heian period (eighth to twelfth century) Japanese *maki-e* lacquerware. Capitán-Vallvey *et al.* (1994) report finding lamp black in decorative wall paintings in the Corral del Carbón, in Granada, Spain (Nasrid period, fourteenth century AD). Brabec and Zelinger (1991) identified lamp black in mediaeval mural paintings at the Jindrichuv Hradec castle, Czech Republic. Gettens and Turner (1951) note lamp black among pigments used on some early nineteenth century religious paintings of New Mexico.

The term may also be spelled lamp-black and lampblack.
See additionally: carbon-based blacks group: flame carbons sub-group.

Carbon-based blacks group: Flame carbons sub-group; *Carbon black*; *Furnace black*
Brabec & Zelinger (1991); Bugini & Folli (1997); Buxbaum (1998) 158; Capitán-Vallvey *et al.* (1994); Gettens & Turner (1951); Li Ch'iao-p'ing (1948) 123–124; Lucas (1962) 339; Mérimée (1830/trans. Taylor, 1839) 189; *OED* (2002) 'Soot'; Okada *et al.* (1994a); Okada *et al.* (1994b); Peacham (1612) 76; Schweppe (1992) 42; Tingry (1804) 348; Toch (1916) 98; Watin (1773/edition of 1785) 35; Winter (1983)

Lamptschen endich

Blue
Synonym, variant or common name

According to Borradaile and Borradaile, in their translation of the *Strasburg MS* (15th cent; Clarke MS 2000) where the term appears, *Lamptschen endich* could literally be translated 'London indigo'. On that basis they argue that the term probably refers to a blue made from woad (*Isatis tinctoria*) rather than indigo from one of the *Indigofera* species. However, van Eikema Hommes (2002) has recently pointed out that lumps of indigo imported

into Europe from India via Italy (and sometimes called *endich* (Boltz, 1549) or *endicho* in other sources) are also referred to as 'Lombardian' indigo in certain German treatises and the translation of this term as London indigo is probably incorrect. The *Illuminierbuch* of Boltz von Ruffach gives particular praise to *Lampartischen endich*. In consequence it seems more likely that *Lamptschen/Lampartischen endich* is Lombardian, rather than London indigo, and the product of *Indigofera* spp. rather than *Isatis tinctoria*.
See: indigo and woad.

Boltz von Ruffach (1549/Benziger, 1913) 81; Eikema Hommes (2002) 115–116; *Strasburg MS* (15th cent/ tr. Borradaile, 1966) 99

LANARKITE

White
Generic compound

First described by Beudant in 1832 and named after Lanarkshire (Scotland) where it was initially identified, lanarkite is a white lead sulfate mineral with composition $PbO.PbSO_4$. It occurs as soft acicular crystals or masses of crystals, which may be pale yellow, green or grey when impurities are present. Lanarkite is closely related to anglesite (*q.v.*) and forms as a secondary mineral from the weathering of lead ore deposits worldwide (Dana, 1932).

Ponsot *et al.* (1998) have shown that lanarkite forms, after anglesite, during the thermal oxidation of galena (*q.v.*) between 400 and 600°C, causing an iridescent blue sheen to form on the galena surface (above 600°C, the lead sulfates decompose to compounds richer in PbO with an associated loss of SO_2). Ponsot *et al.* quoting Dairi (1991) and Lucas (1962), report the use of galena in traditional North African recipes for cosmetics (such as those used in ancient Egypt) and indicate that the galena was processed, often by heating, prior to application. The work by Ponsot *et al.* suggests that lanarkite may be encountered in such materials or in other processed forms of galena. Specific occurrences of lanarkite as a pigment are otherwise unknown although other synthetic forms of lead sulfate are known to have been used.
See: lead sulfates group.

Anglesite; Galena
Dairi (1991); Dana (1932) 756; Lucas (1962); Ponsot *et al.* (1998)

LANGITE

Blue-Green
Generic compound

Langite is a hydrated copper sulfate mineral that forms in oxidised copper veins (gossans; Rutley, 1988). It has chemical composition $Cu_4(SO_4)(OH)_4.H_2O$ and forms as blue-green or blue crystals with massive or fibrous form, or as concretions. It is chemically similar to other copper sulfate minerals such as antlerite, bonattite, brochantite, chalcanthite and posnjakite (*qq.v.*) that form in similar environments. The type locality for langite is St. Blazey (Cornwall, England) where it was identified by Maskelyne in 1864 and named after the Austrian physicist V. von Lang (1838–1921). It is common worldwide around copper ore deposits and is found at localities such as Broken Hill (Australia), Salzburg (Austria), Saxony (Germany), Attica (Greece) and Sardinia.

Pigmentary langite has been noted by Banik (1989) in manuscripts and Naumova *et al.* (1990) in sixteenth century Russian frescos.

Copper sulfates group; Antlerite; Bonattite; Brochantite; Chalcanthite; Posnjakite
Banik (1989); Naumova *et al.* (1990); Rutley (1988) 326

LANSFORDITE

White
Generic variety

First described by Genthe in 1888 and named after Lansford (Pennsylvania, USA), lansfordite is a magnesium carbonate hydrate mineral with composition $MgCO_3.5H_2O$ (Dana, 1932; Liu *et al.*, 1990). It occurs as relatively soft prismatic white crystals and crusts, and forms as a weathering product of magnesium-rich minerals such as forsterite and anthophyllite (*qq.v.*). It is a metastable mineral, usually transforming to hydromagnesite (*q.v.*) with which it is commonly found; artinite (*q.v.*), dypingite, barringtonite and nesquehonite are related hydrous magnesium carbonate minerals with which lansfordite may also be associated (Bruni *et al.*, 1998).

Although lansfordite has not been encountered as a pigment, its close association with hydromagnesite and magnesite (*q.v.*) suggests that positive identifications may be recorded in the future.

Magnesium carbonates group; Anthophyllite; Artinite; Forsterite; Hydromagnesite; Magnesite
Bruni *et al.* (1998); Dana (1932) 531; Liu *et al.* (1990); Ming & Franklin (1985)

LAPIS ARMENIUS

Blue
Synonym, variant or common name

Term associated with azurite (*q.v.*; Gettens and FitzHugh, 1993a).

Azurite
Gettens & FitzHugh (1993a)

LAPIS BONONIENSIS

White
Synonym, variant or common name

Term associated with baryte (*q.v.*; Feller, 1986).

Baryte
Feller (1986)

LAPIS FISSUS

Brown
Synonym, variant or common name

See: brunus.

LAPIS LAZULI

Blue
Synonym, variant or common name

Lapis lazuli, or simply *lapis*, is a rock composed of a mixture of minerals, usually calcite, pyrite and lazurite (*qq.v.*), with the latter being the dominant constituent. Occurrence is as a blue rock containing brassy yellow crystals (pyrite) with white streaks due to calcite. It is formed from the metamorphism of limestones by an alkaline igneous intrusion (Deer *et al.*, 1992; Rutley, 1988). Other silicate minerals such as haüyne, sodalite, diopside, forsterite, muscovite and wollastonite (*qq.v.*) may also be present. The term is often used incorrectly to refer to the mineral lazurite, which is only one of its components. Lapis lazuli is most famously known from the deposit in the Kokcha River valley, Afghanistan, where it has been mined for more than 6000 years for use in jewellery, as an ornamental stone and as a pigment. It is also known from Mt Vesuvius (Italy), Colorado and California (USA), Siberia and Chile.

The term has not, however, always been applied exclusively to this rock type. In Germany during the late fifteenth and earlier sixteenth centuries large amounts of high-quality azurite (*q.v.*) were mined, so as to almost wholly displace the use of natural lazurite; consequently the term lapis lazuli was applied to the unpurified azurite instead (Burmester and Krekel, 1998).
See: lazurite; ultramarine.

Azurite; Calcite; Diopside; Forsterite; Haüyne; Lazurite; Muscovite; Pyrite; Sodalite; Ultramarine; Wollastonite
Burmester & Krekel (1998); Deer *et al.* (1992) 502; Rutley (1988) 436

LAPIS SOLARIS

White
Synonym, variant or common name

See: baryte.

LAQUE DE GAUDE

Yellow
Synonym, variant or common name

See: weld.

LAQUE MINERAL

Orange
Synonym, variant or common name

According to Salter (1869), 'Laque mineral is a French pigment, a species of chromic orange, similar to the orange chromate of lead. This name is likewise given to orange oxide of iron.'

Chrome orange; *Mars orange*
Salter (1869) 258

LAUNDRY BLUE

Blue
Synonym, variant or common name

A term applied to generally inexpensive blue pigments used to counteract the yellowing of textiles during the washing process. For example, synthetic ultramarine has been supplied for this purpose, as has smalt (*qq.v.*).

The firm of Reckitt & Sons in England produced *Reckitt's blue* from 1852, a combination of synthetic ultramarine and sodium hydrogen carbonate (sodium bicarbonate). The use of laundry blue was effectively superseded, however, by the introduction of fluorescent optical brighteners.

The use of laundry blue in painting ethnographic artefacts has been reviewed by Odegaard and Crawford (1996). Moffatt *et al.* (1997) have noted its use on American Naskapi artefacts from the early twentieth century onwards. Hill (2001) has remarked on the use of laundry blueing in the earlier twentieth century in Papua New Guinea. Finally, 'blue' rock-art paintings in Kakadu National Park in Australia are also based on laundry blue as a pigment source (Chippindale and Taçon, 1998).

Smalt; Ultramarine
Chippindale & Taçon (1998); Hill (2001); Moffatt *et al.* (1997); Odegaard & Crawford (1996)

LAURIONITE

White
Generic compound

Laurionite is an orthorhombic lead chloride hydroxide mineral (PbCl(OH)), which forms by secondary processes as a result of smelting. It is named after its type locality at Laurion, Attica, Greece, where it was found in ancient slag heaps. It has also since been found at other locations such as Ashburton Downs (Western Australia), St Hilary (Cornwall, England), Saxony (Germany) and Loire (France) (Nickel and Gartrell, 1993). Laurionite forms as relatively large prismatic acicular crystals, often with V-shaped striations on the surface, in association with fiedlerite, cerussite and phosgenite ($Pb_2CO_3Cl_2$) (*qq.v.*). It is polymorphous with paralaurionite (*q.v.*), which precipitates in the same environment but occurs as small white or pale yellow tabular crystals.

Satoh *et al.* (1994) identified laurionite (and phosgenite) as present in a fourteenth to fifteenth century BC glass kohl bottle from Al-Tur, South Sinai, Egypt. Walter (1999) also demonstrates how laurionite and phosgenite were produced using wet chemistry to form white powders which were added to other products to make Egyptian cosmetics. The synthetic analogue of laurionite, lead chloride hydroxide, (*q.v.*) is also known in a pigment context, identified by Winter in the 'lead white' used on Japanese paintings (1981); blixite (*q.v.*), another lead chloride hydroxide mineral, was also identified in the same context.

For further discussion of the occurrence in paintings of the synthetic analogue, see the entries for lead chloride hydroxide and lead halides group.

Lead group; Lead halides group; Blixite; Cerussite; Fiedlerite; Lead chloride hydroxide; Paralaurionite; Phosgenite
Nickel & Gartrell (1993); Satoh *et al.* (1994); Walter (1999); Winter (1981)

LAWSON'S RED

Red
Synonym, variant or common name

Another of the various experimental colours discussed by Salter (1869), he describes it as follows: 'In 1861 it was stated that Professor Lawson had prepared a new dye of great richness, in the laboratory of Queen's College, Canada, from an insect, a species of coccus, found the previous summer for the first time on a tree of the common black spruce (*Abies nigra*), in the neighbourhood of Kingston … In colour it closely resembled ordinary cochineal [*q.v.*] but was rather more scarlet in hue.'

Cochineal
Salter (1869) 168

LAZULINE BLUE

Blue
Synonym, variant or common name

Mayer (1991) gives this as a synonym for the pigment derived from lapis lazuli (*q.v.*).
See: lazurite.

Lazurite; *Lapis lazuli*
Mayer (1991) 48–49

LAZUR

Blue
Synonym, variant or common name

See: azure.

LAZURITE

Blue
Generic compound

Lazurite is a cubic sodic-calcic aluminosilicate sulfate mineral with composition $(Na,Ca)_8[(Al,Si)_{12}O_{24}](S,SO_4)$. Its name refers to the distinctive blue colour of the mineral and is derived from the Persian word for blue, *lazaward*. Lazurite usually occurs as small vitreous crystals, which cluster together as granular masses and aggregates, although larger well-formed dodecahedral or cubic crystals may also be found. Lazurite is a member of the sodalite group of minerals and is often found with the other members – haüyne, sodalite (*qq.v.*) itself and nosean. The sodalite minerals are termed 'felspathoids' as they are similar in structure and chemistry to the feldspar group of minerals (*q.v.*), but their SiO_2 content is notably lower. The structure of lazurite itself is complex and several polymorphs (e.g. cubic, modulated and orthorhombic) are known; these polymorphs can be found within a single fragment of the mineral (Hassan, 2000). Lazurite forms in metamorphosed limestones and marble, associated with an alkaline igneous intrusion, where it commonly occurs with calcite and pyrite (*qq.v.*). When it is found mixed with other minerals such as these it forms as rock type known as lapis lazuli (*q.v.*), in which lazurite is the dominant component (Deer *et al.*, 1992; Rutley, 1988). Plesters (1993) has shown through analysis of X-ray diffraction data that lazurite samples may also contain diopside, forsterite, muscovite and wollastonite (*qq.v.*), deriving from the lapis lazuli matrix. Lazurite occurs at several locations worldwide and is most commonly encountered in lapis lazuli. It is best known from the Kokcha River valley (Afghanistan), mined for more than 6000 years and believed to be the source of most of the lazurite used in Europe during the Middle Ages and the early modern period. The nineteenth century British colourman Field (1835) mentions lapis lazuli from Siberia, which may mean the source known at Lake Baikal (Russia). It is also found at Mt Vesuvius (Italy), Colorado and California (USA), the Chilean Andes, Argentina, Burma and Canada.

As Plesters has noted, unless the lapis lazuli from which the pigment is prepared is of exceptional quality, simple grinding and washing produces only a greyish blue powder. However, it appears that at some point soon after about 1200 AD an improved method of extraction was developed that preferentially released the lazurite, thus allowing higher yields. Lapis lazuli is relatively hard and difficult to grind and so there was often an initial stage of heating and rapid quenching, followed by the grinding; Thompson (1935), for example, quotes Bibl. Casanatense MS 2265 (Clarke MS 3060) as stating '*Se li peçi sono grandi, meteli tra li carboni*' (If the pieces are large, put them among the coals), going on to list a number of other fifteenth century MSS describing calcination as a remedy. The resulting powder was then kneaded in a paste of molten wax, resins and oil under water or lye (an alkaline solution of potassium carbonate formed by aqueous extraction of beechwood ashes), the blue lazurite particles being preferentially washed out and collected, the unwanted minerals largely remaining behind. Different stages would thus give grades of variable quality, ending with the poorest, which have come to be generally known as ultramarine ashes. Documentary descriptions of these methods of preparation may be found in sources such as Cennini's early fifteenth century *Il Libro dell'Arte* (c. 1400, Clarke MS 590) and Merrifield (1849); Kurella and Strauss (1983) also provide a useful modern summary. De Mayerne (BL MS Sloane 2052), writing in the early seventeenth century, again provides this basic recipe while mentioning another, quicker, method involving crushing of the lapis lazuli, pouring vinegar onto it and heating; the blue is then reputedly drawn out into the liquid.

Although lazurite has been described by the classical authors Pliny (77 AD) and Theophrastus (c. 315 BC), there is no evidence that it was used ground as a pigment in dynastic Egypt, or in the Greek or Roman periods, though it was used as a stone for carving into jewellery (Aston *et al.*, 2000). The earliest identification of lazurite in a pigment context is that by Gettens (1938a) on sixth to seventh century AD cave temple wall paintings at Bâmiyân, Afghanistan. Laurie (1914) apparently found lazurite on Byzantine MSS of the sixth to twelfth centuries (cf. Plesters, 1993); Laurie also apparently found high levels of associated minerals, supposing this to indicate that the pigment was not subject to the extraction process described above. Lazurite has also been found by Paramasivan (1937–38) on eleventh to twelfth century Indian mural paintings at Brihadisvara Temple at Tanjor, and by Gettens (1950) on a twelfth century Armenian manuscript. In European paintings, lazurite is most extensively used in the fourteenth and fifteenth centuries for illuminated manuscripts and Italian panel paintings; it has also been identified by De Wild in fifteenth to nineteenth century Netherlandish, Flemish and Dutch easel paintings. Plesters provides an extensive list of identifications in her review of ultramarine pigments.

Lazurite was an expensive pigment, so that it was often underpainted with other, less costly, blue pigments such as azurite and indigo (*qq.v.*); the seventeenth century Portuguese writer Nunes (1615), for example, states that 'Because it is so costly, ultramarine blue is not much used, and for that reason how to work it well is not widely known. He who cares to use it first must work the draperies as he wishes, either with blues of Castile [*azurite*], ashes and after it dries, he has to paint it over with the ultramarine' (tr. Veliz, 1986). It was also often reserved for iconographically important elements of a painting for seemingly similar reasons.

Terminology associated with lazurite and pigment derived from lapis lazuli can be broadly segmented into two groups, the 'azur' forms and the 'ultramarine' forms. Numerous variations of the former exist, Plesters, for example, listing *az(z)ur(r)um ultramarinum*, *a. transmarinum*, *az(z)ur(r)o oltramarino*, *azur d'Acre* and *pierre d'azur*. (Plesters also lists *lazurstein*, though this may (also) be azurite – for a fuller discussion of the complexities of this term see: *azure*.) Harley (1982) adds that in some sixteenth century English sources the pigment is simply referred to as *azure*. Merrifield claims that the term 'ultramarine' must have been common in Italy by the beginning of the fifteenth century since it occurs in two MSS of that period, those by Johannes de Modena and Alcherius (Archerius; Clarke MS 2790). Hilliard (1624) uses the term ultermaryn of Venice, which reflects the pivotal position that city had in the trade at that time; when Norgate (cf. Harley) was writing not much later, he remarks that the pigment was obtainable from Aleppo. From this point on use of ultramarine as the primary term appears to be both consistent and continuous.

Early understanding of the chemical nature of lazurite is due to Désormes and Clément (1806), which laid aspects of the groundwork for the subsequent artificial preparation of the compound. The synthetic form of lazurite, called in this text ultramarine, was first manufactured and introduced by Guimet in France (1826–28) and Gmelin in Germany (1827), and has been used extensively as a pigment since that time. A fuller discussion of the artificially prepared forms may be found under the entry: ultramarine.

Aluminium group; Calcium group; Feldspar group; Silicates group; Azurite; Calcite; Diopside; Forsterite; Haüyne; Indigo; Muscovite; Pyrite; Quartz; Sodalite; Ultramarine; *Azure Bleu de garance*; *Lapis lazuli*

Aston *et al.* (2000) 39–40; Cennini (c. 1400/Thompson, 1960) 37–38; Clarke (2001) 2790; Deer *et al.* (1992) 500; Désormes & Clément

(1806); Field (1835); Gettens (1938a); Gettens (1950); Harley (1982) 43; Hassan (2000); Hilliard (1624/Thornton & Cain, 1981) 92; Kurella & Strauss (1983); Laurie (1914) 63–70; Merrifield (1849); MS Sloane 2052 (nd) 70; Norgate (early 17th c/Thornton & Cain, 1981); Nunes (1615) 59; Paramasivan (1937–38); Plesters (1993); Pliny (1st cent AD/Rackham, 59 1952) XXXV, xxviii, 47; Rutley (1988) 436; Theophrastus (c. 315 BC/Caley & Richards, 1956) 51; Thompson (1935) 429; Veliz (1986) 6; Wild (1929) 18

LAZURSTEIN
Blue
Synonym, variant or common name

See: *azure*.

LEAD
Metal
Generic compound

Metallic lead (Pb) may be encountered as an unintentional component of certain pigments as a result of unsatisfactory processing techniques. However, Dunn (1975), for example, describes the use of flake metallic lead as an anticorrosive paint. Metallic lead is also known to occur as a phase with lead(II) oxides in products such as those known as ashes of lead or grey oxide (*qq.v.*; Bristow, 1996b; Martin, 1813, cf. Bristow; Tingry, 1804).

Lead group; Lead(II) oxide; Metal pigments; *Ashes of lead*; *Grey oxide*
Bristow (1996b) 60–61; Dunn (1975) 362; Martin (1813) 460; Tingry (1804) 343–344

LEAD ACETATES GROUP
White
Group term

A variety of lead acetate compounds are known to exist. For example, the following were found during studies on acetic acid corrosion of lead (Tétreault *et al.*, 1998): $Pb_3(CH_3CO_2)_6$ $PbO.H_2O$, $Pb(CH_3CO_2)_2.2PbO.H_2O$ and $Pb(CH_3CO_2)_2.3H_2O$.

Lead group
Tétreault *et al.* (1998)

LEAD(II) ACETATE TRIHYDRATE
White
Generic compound

See: lead acetates group.

LEAD ALUMINATE
White
Synonym, variant or common name

See: lead aluminium oxide.

LEAD ALUMINIUM OXIDE
White
Generic compound

Pigment of stated composition $PbO.Al_2O_3$ said to be prepared from 'litharge and alumina' by the *Colour Index* (1971) under CI 77585.

Aluminium group; Lead group; Litharge
Colour Index (1971) 77585

LEAD ANTIMONATE
Yellow
Synonym, variant or common name

See: lead antimony oxide.

LEAD ANTIMONIATE
White
Generic compound

Riffault *et al.* (1874) describe a white 'antimoniate of lead', the preparation being to mix one part antimony sulfide (stibnite, *q.v.*) with five parts potassium nitrate, this being heated to red hot; the product is dissolved in water and a neutral lead acetate solution added. Essentially the same recipe occurs in the text by Bersch (1901), who describes this and lead antimonite as 'heavy, white powder… dearer than white lead [*q.v.*], to which [it] is inferior in covering power, and which [it does] not exceed in permanence'. The precise chemical composition seems to be currently unknown. See also: lead antimonite.

Antimony group; Lead group; Lead antimonite; Stibnite; *Lead white*
Bersch (1901) 115; Riffault *et al.* (1874) 160

LEAD ANTIMONITE
White
Generic compound

Riffault *et al.* (1874) describe the preparation of 'Antimonite of lead' as follows: boil 50 parts metallic antimony with 20 parts of concentrated sulfuric acid to give antimony sulfate. Heat this until there are no more acid fumes. Calcine the result with 21 parts dry sodium carbonate. Finally boil the fused product with water and add neutral lead acetate. The result is lead antimonite. Bersch (1901) also provides essentially the same recipe, though giving only five parts of antimony; he also describes it (and 'lead antimoniate') as a 'heavy, white powder… dearer than white lead [*q.v.*] to which [it] is inferior in covering power, and which [it does] not exceed in permanence'.

Antimony group; Lead group; *Lead white*
Bersch (1901) 115; Riffault *et al.* (1874) 161

LEAD ANTIMONY OXIDE
Yellow
Generic compound

Two lead antimony oxides, plus tertiary oxides formed with tin and, to a lesser extent, bismuth and zinc, are of interest as pigments. Of these the synthetic analogue of the mineral bindheimite, $Pb_2Sb_2O_6(O,OH)$, widely known under the name Naples yellow (*qq.v.*; *giallo di Napoli*, *jaune de Naples*) and with a history stretching from dynastic Egypt to the present day, is the most significant. The second type, the synthetic analogue of the rare mineral rosiaite (*q.v.*), $PbSb_2O_6$, is significant in the context of the tertiary pyrochlore formed with tin. Seemingly occurring within paintings almost exclusively in Italy (and principally in Rome) in the seventeenth century, this compound has only recently become known, both mineralogically and as a pigmentary phase. The more complex tertiary compounds, lead antimony (bismuth, tin, zinc) oxides isostructural with the bindheimite type, have an overlapping history with the rosiaite type.

Although the composition of the principal form of lead antimony oxide is now generally given as $Pb_2Sb_2O_7$, historically a number of other formulae have been given including $Pb_3(SbO_4)_2$, $Pb(SbO_3)_2$, $Pb_8(SbO_4)_2$, $Pb(SbO_4)_2$ and $PbSb_2O_4$; all of these latter forms should be considered as superseded (Wainwright *et al.*, 1986). Bindheimite, its analogue and the tertiary forms in fact belong to the cubic pyrochlore group of structures that take an idealised form of $A_2B_2O_7$ when stoichiometric. The structure is, however, very accommodating and a variety of other metals may substitute into the A and B positions – for example, large low oxidation state cations such as Pb(II), Sn(II) and Bi(II) in the A position and almost any metal that can take octahedral coordination, including Pb, Sb, Sn, Bi and Zn, in the B position. To complicate matters further, so-called 'defect' pyrochlores exist, where one of the oxygens can be wholly or partially missing, giving formulae such as $Pb_{2.5}Sb_{1.5}O_{6.75}$ and $Pb_2SnSbO_{6.5}$. However, studies on the formation of lead antimony tin oxides have shown that unless the ratio of antimony to tin is 1:1, when just the mixed pyrochlore will form, a proportion of $PbSb_2O_6$ will also be present, this seemingly being the origin of the compound in pigments (Cascales *et al.*, 1986; Roy and Berrie, 1998). Other discussion of the structure of this latter compound is given in Magnéli (1941) and Coffeen (1956) while the mineral analogue rosiaite has been described by Basso *et al.* (1996) and Ryback and Francis (2001).

The bindheimite structure can be simply prepared by calcining lead and antimony oxides at suitable temperatures; the PbO-Sb_2O_5 phase diagram shows that on heating a finely ground Pb-rich mixture of PbO and Sb_2O_5, it will begin to melt at a temperature of 820°C (Levin *et al.*, 1964). However, the lead compound in historical recipes might also have been derived from metallic lead, litharge, lead(II,IV) oxide and lead white, while the antimony could come from the metal, antimony oxide or sulfide (the mineral stibnite), potassium antimonate or 'tartar emetic' (antimony potassium tartrate). Brunner (1837) also records the use of printers' type, a lead antimony alloy, as the starting point for a low-grade form. Other ingredients were also frequently added, including wine lees ('tartar'), alum, common salt, ammonium chloride and potassium nitrate; the intended function of these would seem to have been comparable to the flux used in glass and ceramics to lower formation temperature; lead antimony oxide has a history intimately connected with both of these industries, perhaps making similarities in processing unsurprising. The *Colour Index* (1971) also gives an aqueous method where antimony trisulfide is fused with sodium nitrate at red heat, the product being boiled with water and precipitated with lead acetate.

Historical recipes are clearly varied and not necessarily accurate. As Wainwright *et al.* (1986) comment: 'Many of the early lead antimonate recipes … are vague with respect to the temperature at which the pigment is to be prepared and the length of time the ingredients are to be roasted. Indeed, some of them will not yield lead antimonate yellow at all'; from a close reading of various eighteenth and earlier nineteenth century recipes, they conclude that a heterogeneous mixture of lead and antimony oxides, chlorides and oxychlorides would probably form. (However, as indicated above, the presence of other components may affect the temperature at which the compound can be formed.) The earliest recipe generally cited is that by Piccolpasso, dated to the late 1550s, in the context of colouring ceramic glazes. A wide range of other recipes has been reviewed and summarised by Wainwright *et al.*; Laurenze and Riederer (1982) have discussed variant recipes from the mid-eighteenth century.

Formation of the rosiaite structure has been alluded to above; if lead, antimony and tin oxides are mixed and calcined in the temperature range 680–1000°C, if the molar proportions of tin to antimony are around 0.5, then significant amounts of $PbSb_2O_6$ will be formed (Cascales *et al.*).

A number of lead antimony zinc yellow recipes are given in Wainwright *et al.* 1986; this area has additionally been reviewed by Buzzegoli *et al.* (2000). Seventeenth century Italian examples are to be found in an unpublished manuscript from Palatina Library in Florence (MS 1024), the Muranese glassmaker's MS by Giovanni Darduin (recipe LXXV), an unpublished MS by the son of Salvator Rosa and a limning treatise by Valerio Mariani da Pesaro (Hermens, 2002). Riffault *et al.* (1874) mention an English patent by G. Hallett and J. Stenhouse in 1861 for pigments with an antimony base that includes a Naples yellow formed with zinc. As a further example, the *Colour Index* (1971) records a pigment compounded of 'lead antimonate with zinc and bismuth oxides', which they claim to have been used in Babylon c. 600 BC (unconfirmed by the present authors); their modern bismuthian formulation uses three parts bismuth fused with 24 of antimony sulfide and 64 of potassium nitrate; one part of the ground product is then fused with eight of ammonium chloride and 128 parts litharge (*q.v.*).

There are numerous identifications of lead antimony oxides in paintings and other objects. The earliest occurrences are as opacifiers and colourants in glass from the Egyptian mid-XVIIIth dynasty (1550–1295 BC) and apparently coinciding with the development of glass itself (Turner and Rooksby, 1959; Caley, 1962; Kaczmarczyk and Hedges, 1983; Shortland *et al.*, 2000; Shortland, 2002). However, as a paint pigment the earliest examples are much later and appear to be those documented by Santamaria *et al.* (1998) from the early sixteenth century. Further, extensive, listings may be found in Wainwright *et al.* who concluded that the primary distribution of use commences in the second quarter of the seventeenth century, peaking around 1750–1850, after which it was gradually replaced by lead chromate and cadmium sulfide pigments.

Ternary oxides of lead, antimony and tin are also of significance, forming compounds as described above. According to Santamaria *et al.* (1998), the earliest currently known identifications of lead antimony tin oxide in paintings are the frescos by the school of Raphael at the Loggia di Psiche, Villa Farnesina, Rome, which were executed in the late 1510s; lead antimony and lead tin oxides (*q.v.*) were also found alongside. However, incidences of these lead antimony tin pigments are most strongly associated with Roman seventeenth century artists such as Poussin, Pietro da Cortona, Salvator Rosa, Sassoferrato, Gentileschi and Lanfranco, the earliest painting datable to c. 1610, the latest of around 1660–85 (Roy and Berrie). It should though be added that mixed (solid-solution) phases between lead antimony oxide and lead tin oxide have been noted by Turner and Rooksby in an eleventh century glass mosaic tessera from a Byzantine church in Novgorod and a fourteenth century enamelled bottle from Syria.

Terminology surrounding these yellows is complex and intimately entwined with those for the lead oxides and lead tin oxides. For discussion of the issues, see the entries for massicot and giallolino.

Bindheimite; Lead tin oxide; Litharge; Massicot; Rosiaite; *Giallolino*; *Naples yellow*

Basso *et al.* (1996); Brunner (1837); Buzzegoli *et al.* (2000); Caley (1962); Cascales *et al.* (1986); Coffeen (1956); *Colour Index* (1971); Darduin MS (1644) 147; Hermens (2002); Kaczmarczyk & Hedges (1983); Laurenze & Riederer (1982); Levin *et al.* (1964); Magnéli (1941); Piccolpasso (1556–59/edition of 1934); Piccolpasso (1556–59/edition of 1974); Riffault *et al.* (1874) 161; Roy & Berrie (1998); Ryback & Francis (2001); Santamaria *et al.* (1998); Shortland (2002); Shortland *et al.* (2000); Turner & Rooksby (1959); Wainwright *et al.* (1986)

LEAD ANTIMONY OXIDE, BINDHEIMITE TYPE

Yellow
Generic compound

The most common form of lead antimony oxide (lead antimonate(IV)), $Pb_2Sb_2O_7$, takes the same composition and crystal structure as the mineral bindheimite (*q.v.*). For a fuller discussion, see: lead antimony oxide.

Lead oxides and hydroxides group; Bindheimite; Lead antimony oxide

LEAD ANTIMONY OXIDE, ROSIAITE TYPE
Yellow
Generic compound

The crystal structure of rosiaite, $PbSb_2O_6$, has been discussed by Magnéli (1941) and Coffeen (1956). For a fuller discussion, see: lead antimony oxide and rosiaite.

Lead oxides and hydroxides group; Lead-based yellow group; Lead antimony oxide; Rosiaite
Coffeen (1956); Magnéli (1941)

LEAD ANTIMONY TIN OXIDE
Yellow
Generic compound

See: lead antimony oxide.

LEAD ANTIMONY ZINC OXIDE
Yellow
Generic compound

Recipes for lead antimony zinc oxide yellow pigments have been noted in a text *Della Miniatura* by Valerio Mariani da Pesaro, with identifications in miniatures by that artist (Buzzegoli *et al*., 2000; Hermens, 2002).
See: lead antimony oxide.

Lead antimony oxide
Buzzegoli *et al*. (2000); Hermens (2002)

LEAD ARSENATE
Yellow
Generic compound

Salter (1869) describes *arsenic yellow*, stating that it is 'Called also Mineral Yellow, [and] has improperly been classed as an orpiment, from which it differs in not being a sulphide, and in containing lead. It is prepared from arsenic fluxed with litharge [*qq.v.*] and reduced to a powder.' From the chemical literature, several lead arsenates exist, such as $Pb_3As_4O_2$ and Pb_2AsO_7. Additionally there are two lead arsenic minerals, schultenite ($PbHAsO_4$) and mimetite (*q.v.*; $Pb_5(AsO_4)_3Cl$). The latter of these has been identified by Rouveret and Walter (1998) in a pigmentary context, found during analysis on 22 Greek stèles in the Louvre.

Meggiolaro *et al*. (1997) have also identified a yellow lead-based compound, which they describe as a 'Pb, Fe(Sb,Zn) arsenate', among pigments found in Corinth (mid-first century AD). This was found as part of a red underlayer in a fresco, the pigment being encapsulated by hematite (*q.v.*) particles. The homogeneous compound has a 'honey-yellow' colour and was found to be composed of primarily lead (28%), iron (19%) and arsenic (14%) with minor amounts of antimony, sulfur and zinc (0.8–2.6%). The authors speculate that it was an unintentional by-product that developed during the manufacture of some other pigment. However, an alternative explanation might be that it is related to the lead arsenate mineral mimetite which, as reported above, has been found by Rouveret and Walter in a Hellenistic context. Iron is known to diffuse into adjacent paint layers over time (see, for example, Burns and Wilson-Yang, 1991) and the presence of the surrounding hematite particles could have provided such a diffusion source adjacent to an original mimetite phase.

Lead group; Hematite; Litharge; Mimetite; Orpiment
Burns & Wilson-Yang (1991); Meggiolaro *et al*. (1997); Rouveret & Walter (1998); Salter (1869) 116

LEAD ARSENITE
Yellow
Generic compound

According to Riffault *et al*. (1874), this is produced by mixing ten parts arsenious acid with seven parts litharge (*q.v.*; lead(II) oxide) and bringing it to a red heat in a crucible. Little is known of the exact composition or use.

Litharge
Riffault *et al*. (1874) 409

LEAD BLACK
Black
Synonym, variant or common name

According to Terry (1893), lead black is prepared by 'boiling lead fume in sulphide of soda solution'. Presumably this would form a lead sulfide. Terry also comments that he thought it would be unstable and prone to oxidation.

Lead sulfides group
Terry (1893) 26

LEAD CARBONATE
White
Generic compound

Lead carbonate ('neutral lead carbonate', $PbCO_3$) is one of the compounds which may fall under the common name of lead white (*q.v.*). It is the synthetic analogue of the mineral cerussite (*q.v.*), a term sometimes extended to this compound. While processes such as the 'stack' method of manufacturing lead white tends to form the more commonly encountered lead carbonate hydroxide (*q.v.*), some circumstances favour lead carbonate. For example, Heaton (1928) records that the 'Kremnitz' process, which uses a paste of litharge and acetic acid or lead acetate (*qq.v.*) exposed to carbon dioxide, may produce neutral lead carbonate.

Lead acetates group; **Lead carbonates group**; Cerussite; Lead carbonate hydroxide; Litharge; *Lead white*
Heaton (1928) 65–81

LEAD CARBONATE HYDROXIDE
White
Generic compound

Lead carbonate hydroxide (basic lead carbonate, $2PbCO_3.Pb(OH)_2$) is the most widely encountered pigment to fall under the common name lead white (*q.v.*). It is the synthetic analogue of the mineral hydrocerussite (*q.v.*), a term sometimes inaccurately extended to this compound since there is little evidence that the mineral was ever used as a pigment except perhaps in antiquity. Two other lead carbonate hydroxides are known to exist and occur in a pigment context, that given a tentative formula of $3PbCO_3.Pb(OH)_2$ and a lead carbonate hydroxide oxide of formula $4PbCO_3.2Pb(OH)_2.PbO$ known as 'pearlescent' lead white. The compound $3PbCO_3.Pb(OH)_2$, though only published in 1957 (Mauch and Brunold, 1957), is known to exist as a component in historical pigments (Keisch, 1972); $4PbCO_3.2Pb(OH)_2.PbO$ was the subject of a US patent issued in 1940 (Thompson and Stewart, 1940) and manufactured by the National Lead Company from that time. A related lead carbonate hydroxide oxide mineral, plumbonacrite (*q.v.*; $Pb_{10}(CO_3)_6O(OH)_6$), also exists. Laboratory synthesis of the compound $2PbCO_3.Pb(OH)_2$ by a hydrothermal process is given by Katz and Lefker (1957). Mauch and Brunold describe the preparation of $3PbCO_3.Pb(OH)_2$ by bubbling air containing CO_2 through a solution of lead acetate and sodium hydroxide. Production of $4PbCO_3.2Pb(OH)_2.PbO$ involves addition of CO_2 to a slurry of litharge (*q.v.*) or metallic lead in acetic acid under controlled pH, the process being terminated when the pH drops from about 9.5 to 7.5 (Thompson and Stewart 1940; Stewart, 1950).

Lead acetates group; Lead group; Lead oxides and hydroxides group; Cerussite; Hydrocerussite; Litharge; Plumbonacrite; *Lead white*
Katz & Lefker (1957) 65–81; Keisch (1972); Mauch & Brunold (1957); Stewart (1950); Thompson & Stewart (1940)

LEAD CARBONATE HYDROXIDE OXIDE

White
Generic compound

Known commercially as 'pearlescent lead white', this is a compound of general formula $4PbCO_3.2Pb(OH)_2.PbO$. For more information, see the discussion under lead carbonates group.

Lead carbonates group

LEAD CARBONATES GROUP

White
Group term

Four lead carbonates and three related minerals may be considered to fall within the lead carbonates group (Dunn, 1975). First, lead carbonate ('neutral lead carbonate', $PbCO_3$) is the synthetic analogue of the mineral cerussite (*q.v.*), a term sometimes also extended to this compound. Second, lead carbonate hydroxide ('basic lead carbonate') – $2PbCO_3.Pb(OH)_2$ – is the most widely encountered pigment to fall under the common name lead white (*q.v.*). It is the synthetic analogue of the mineral hydrocerussite (*q.v.*), a term sometimes inaccurately extended to this compound since there is little evidence the mineral was ever used as a pigment except perhaps in antiquity. Two other lead carbonate hydroxides are known to exist and occur in a pigment context, that given a tentative formula of $3PbCO_3.Pb(OH)_2$ and a lead carbonate hydroxide oxide of formula $4PbCO_3.2Pb(OH)_2.PbO$ known as 'pearlescent' lead white. The compound $3PbCO_3.Pb(OH)_2$, though only published in 1957 (Mauch and Brunold, 1957), is known to exist as a component in historical pigments (Keisch, 1972); $4PbCO_3.2Pb(OH)_2.PbO$ was the subject of a US patent issued in 1940 (Thompson and Stewart, 1940) and manufactured by the National Lead Company from that time. A related lead carbonate hydroxide oxide mineral, plumbonacrite ($Pb_{10}(CO_3)_6O(OH)_6$), also exists; the synthetic analogue of this material, listed here as lead oxide carbonate hydroxide, has been as a lead corrosion product (Tétreault *et al.*, 1998).

Studies of the occurrence of the various lead carbonate and carbonate hydroxide compounds in western historical pigments have been published by Keisch, who found that most of the material he studied was $2PbCO_3.Pb(OH)_2$, typically with low and variable amounts of the other carbonate and carbonate hydroxides present.

Lead carbonate hydroxide has been made since antiquity using close variants of the process known as the 'stack' or 'Dutch' process whereby lead is exposed to acetic acid vapours in the presence of moisture and carbon dioxide; the latter is generally provided by fermenting matter (horse manure; waste grape skins; tan bark), which also provides a constant raised temperature for the reaction. Control was difficult; overheating was said to cause higher proportions of the 'neutral' lead carbonate to form, or for it to decompose into the lead(II) oxide litharge (*q.v.*), both of which could clearly occur in historical material for just this reason. A modification of this method – generally known as the 'chamber' process – seems to derive from a patent owing to Sir James Creed in 1749 (Heaton, 1928); however, the necessary controls over temperature and atmosphere were difficult to achieve and not satisfactorily resolved until the later nineteenth century. The chamber process seems to produce a finer, more uniform particle size.

A second group of methods is typified by the Carter process where granular lead is used in a rotating drum into which acetic acid is sprayed along with a current of hot carbon dioxide and air; this method is said to produce an exceptionally uniform texture to the product.

While these methods involved direct conversion of metallic lead, there were also innumerable variations on the aqueous conversion of an oxide or soluble lead salt. For example, the 'Thénard' or 'French' process involved boiling lead acetate with litharge to produce an acetate hydroxide which could then be precipitated with CO_2, as well as related processes such as the 'Rowe' process, the 'Kremnitz' process (using a paste of litharge and acetic acid or lead acetate; this, again, reputedly gave a product relatively rich in lead carbonate), the 'Rowley' process and so forth. Finally, a number of electrolytic methods (such as the 'Sperry' process) also exist.

Lead group; Cerussite; Hydrocerussite; Litharge; *Lead white*
Dunn (1975); Heaton (1928) 71; Keisch (1972); Mauch & Brunold (1957); Tétreault *et al.* (1998); Thompson & Stewart (1940)

LEAD CHLORIDE, BASIC

White
Generic compound

See: lead chloride hydroxide.

LEAD CHLORIDE HYDROXIDE

White
Generic compound

Various lead chloride hydroxides exist and have been observed in a paint context, notably $Pb(OH)_2.PbCl_2$ (or Pb(OH)Cl) and $Pb_2Cl(O,OH)_{2-x}$ (where x is about 0.325), synthetic analogues to the orthorhombic minerals laurionite and blixite (*qq.v.*), respectively. A monoclinic form of laurionite, paralaurionite, also exists and fiedlerite, an associated mineral, is also a lead chloride hydroxide ($Pb_3Cl_4F(OH).H_2O$). Lead chloride hydroxide is synonymous with 'basic lead chloride'.

Lead chloride hydroxide might be encountered in a number of contexts. First, Winter (1981) has shown that 'lead white' in Japanese painting is frequently (though not invariably) composed of this, reporting finding both the blixite and laurionite forms of lead chloride hydroxide. (The laurionite form was also found in studies of lead corrosion in acetic acid environments; see: Tétreault *et al.*, 1998.) Naruse (1996) has also identified blixite and laurionite forms on Japanese *Shoso-in* objects; he notes that the former always occurs with a proportion of a hydrocerrusite phase, attributable to alteration on exposure to air. A recipe given in Dioscorides' De Materia Medica (1st cent. AD) also appears to form laurionite: 'Then having mixed to a pound of Lithargyrum 5 dragms of Sal Fossile, and pouring on warm water, beat it three times a day, straining out the old, and mixing new water. But whether it is become white, pouring on warm water, do the same until it have a show of no saltness.'

Second, investigations of translucent particles in the structure of certain western European easel paintings – notably the '*Anatomy Lesson of Dr Nicolaes Tulp*' by Rembrandt (Mauritshuis, Den Haag) – has indicated that lead chloride hydroxide is present (Noble and Wadum, 1998). In that case it was proposed that the occurrence could be explained as a reaction product caused by purifying the oil medium with salt water and adding a drier based on lead(II,IV) oxide (red lead, *qq.v.*); a description of such a process is given in the roughly contemporary de Mayerne MS (c. 1620, BL MS Sloane 2052). However, there currently seems to be insufficient research on this subject to assess whether this can reasonably explain all instances of such translucent particles.

Finally, nineteenth century European sources – such as Riffault *et al.* (1874) – mention its use, describing the preparation of 'basic lead chloride' for use as a pigment from a solution of neutral lead acetate precipitated with hydrochloric acid, then treated with basic lead acetate until it 'has become basic'. The precipitated pigment was then washed and dried.

Not to be confused with *lead chloride oxide* (Turner's yellow or Patent yellow).

Lead halides group; Blixite; Fiedlerite; Laurionite; Lead chloride oxide; Lead(II, IV) oxide; Paralaurionite; *Lead white*; *Red lead*
Dioscorides (1st cent. AD/Osbaldeston & Wood, 2000) 5, 102; MS Sloane 2052 (nd); Naruse (1996); Noble & Wadum (1998); Riffault *et al.* (1874) 158–159; Tétreault *et al.* (1998); Winter (1981)

LEAD CHLORIDE HYDROXIDE, BLIXITE TYPE

White
Generic compound

Given as $Pb_2Cl(O,OH)_2$ or $Pb(O,OH)_3Cl$.
See: lead chloride hydroxide and blixite.

LEAD CHLORIDE HYDROXIDE, FIEDLERITE TYPE

White
Generic compound

$Pb_3Cl_4F(OH).H_2O$.
See: lead chloride hydroxide and fiedlerite.

LEAD CHLORIDE HYDROXIDE, LAURIONITE TYPE

White
Generic compound

PbCl(OH).
See: lead chloride hydroxide and laurionite.

LEAD CHLORIDE OXIDE

Yellow
Generic compound

Lead chloride oxide (lead oxychloride) has a typical composition of $PbCl_{2.5–7}PbO$ and varies in hue from lemon to dull sulfur yellow depending on the lead oxide content. The *Colour Index* (1971, CI 77592/CI Pigment Yellow 30) states that it can be prepared either by fusing lead oxide with ammonium chloride or by stirring litharge (*q.v.*) with 20% brine for 24 hours, then igniting.

Lead chloride oxide was patented as a pigment by James Turner in 1781 (hence the name Turner's yellow and patent yellow), this was made by combining and calcining a lead oxide and sodium chloride (Harley, 1982). A number of other synonyms have been recorded such as Cassel yellow, English yellow, *jaune minérale*, Montpellier yellow *(qq.v.)* and Verona (or Veronese) yellow; however, Mérimée (1830) gives three recipes (two distinct from that above) for the partial synonym mineral yellow (*q.v.*). Recipes for the pigment can be found up to and including early twentieth century sources such as Bersch (1901), who gives recipes for Cassel and Montpellier yellows (#113) and Turner's or English yellow (#149); Zerr and Rübencamp (1906) also describe Cassel and Turner's yellows, differentiating them on the basis of the manufacturing route. By 1928 Heaton comments that lead chloride oxide is practically obsolete as a pigment and that patent yellow was an obsolete or rarely used term.

A lead oxychloride mineral exists, mendipite (*q.v.*), which occurs in the Mendip Hills, Somerset, UK and near Brilon in Westphalia; the formula is currently given as $Pb_3Cl_2O_2$. Matlockite, from Cromford, near Matlock in Derbyshire, UK, used to be considered a lead chloride oxide, but is now given as PbFCl. Neither mineral is known to have been used as a pigment. Lead chloride hydroxide compounds should not be confused with this pigment; they are in any case white and discussed under lead chloride hydroxide.

Lead group; Lead chloride hydroxide; Litharge; Mendipite; *Jaune minérale*; *Lead oxychloride*; *Mineral yellow*; *Montpellier yellow*
Bersch (1901) 113–114; *Colour Index* (1971) 77592; Harley (1982) 99–100; Heaton (1928) 143; Mérimée (1830/trans. Taylor, 1839) 96–97; Zerr & Rübencamp (1906/1908) 153–154

LEAD CHLOROSULFITE

White
Synonym, variant or common name

Heaton (1928) lists 'lead chloro-sulphite' as an obsolete or rarely used pigment under the name Caledonian white (*q.v.*).

Caledonian white
Heaton (1928) 380

LEAD CHROMATE HYDROXIDE

Yellow
Generic compound

The basic lead chromate, $PbCrO_4.Pb(OH)_2$, is commonly listed in the literature (for example, Gettens and Stout, 1966; MacIntyre, 1992) as one of the compositions of chrome red and chrome orange pigments, in addition to basic lead chromate(VI) oxide (*qq.v.*), $PbCrO_4.PbO$. However, Kühn and Curran (1986) cite the work of Pollack and Feller (1976) who report that there is no evidence of structurally bound hydroxyl units (only hygroscopic water) in chrome orange, suggesting that the composition cannot be given as lead chromate hydroxide. The *Colour Index* (1971) also lists basic lead chromate (CI 77601) with a variable composition of $xPbCrO_4.yPb(OH)_2$ (or $xPbCrO_4.yPbO$), as giving rise to compounds designated CI Pigment Orange 21 and 21:1, CI Pigment Orange 45 and CI Pigment Red 103; commercial products are also reported to contain lead sulfate in some cases. According to Bearn (1923), lead chromate hydroxide may be synthesised by boiling lead white (*q.v.*) with a strong solution of potassium dichromate and a small amount of caustic soda.
See: lead chromates group.

Lead chromates group; Lead sulfates group; Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*; *Lead white*

Bearn (1923) 74; *Colour Index* (1971) 77601; Gettens & Stout (1966) 106; Kühn & Curran (1986); MacIntyre (1992) 3070; Pollack & Feller (1976)

LEAD CHROMATE MOLYBDATE

Red
Generic compound

According to Kühn and Curran (1986), lead chromate molybdate is more commonly known as the pigment molybdate orange, or molybdate red (*qq.v.*), with composition given as $PbCrO_4.PbMoO_4.PbSO_4$. It is also listed by the *Colour Index* (1971) as CI Pigment Red 104 (CI 77605), with a composition reported as consisting of lead chromate-lead molybdate mixed crystals often containing some sulfate. In modern applications, the lead chromate-molybdate paints are replacing the chrome orange and chrome red (*qq.v.*) pigments.

Lead chromates group; Lead sulfates group; Lead chromate(VI); *Chrome orange*; *Chrome red*; *Molybdate orange*; *Molybdate red*
Colour Index (1971) 77605; Kühn & Curran (1986)

LEAD CHROMATE(VI)

Yellow
Generic compound

Lead chromate(VI), $PbCrO_4$, also known as plumbous chromate, was first synthesised around 1800, with its potential use as a pigment first reported by Berthollet and Vauquelin in 1804. According to Vauquelin (1809), it was prepared by adding lead acetate or lead nitrate to potassium chromate, and the shade of the precipitate could be varied (from yellow to orange or red) by adjusting the acidity/alkalinity of the products. Lead chromate(VI), which occurs naturally as the rare mineral crocoite (Rutley, 1988), is known as the pigment chrome yellow (*qq.v.*). It is listed by the *Colour Index* (1971) as CI Pigment Yellow 34 (CI 77600). The commercial manufacture of the pigment was largely influenced by the availability of suitable raw materials (usually in the form of the abundant mineral chromite, $FeCr_2O_4$). The earliest record of the use of chrome yellow is in a painting by Sir Thomas Lawrence dated prior to 1810 (Kühn, 1969). Sources of the pigment are reported by Harley (1982, citing Field, 1809) to be available by 1814–15, with Bollman (1769–1821) cited as the first commercial manufacturer in England, with production beginning around 1814–16.

Lead chromate(VI) may also be mixed with lead sulfate, to form lead chromate sulfates (*qq.v.*) in which a range of shades and crystal structures (monoclinic or orthorhombic) are produced; these are also termed chrome yellow; however, they are generally the lighter shades, middle hues being neutral lead chromate and the orange hues being basic lead chromate (see: lead chromate(VI) oxide; Gettens and Stout, 1966). The chrome yellow pigments tend to discolour on exposure to light, turning green due to the formation of chromium oxide (*q.v.*), or darkening due to photochemical processes in the absence of oxygen and moisture (for example, Haug, 1951; Watson and Clay, 1955). According to Haug, the orthorhombic form shows the greater tendency to darken with age and more modern lightfast varieties are based on the monoclinic varieties, with permanency increased by several methods: the addition of stabilising agents, such as zinc salts; by precipitating the lead chromate with a lead sulfate coating; or by encapsulating the pigment with silica (Kühn and Curran, 1986; Feller, 1972). The pigment also darkens in the presence of hydrogen sulfide particularly when used in aqueous-based media and was considered unsuitable for use in fresco painting due to its reaction with alkalis.

Lead chromate(VI) is also used in the preparation of green pigments such as chrome green or green cinnabar, in which it is mixed with Prussian blue (*qq.v.*). It is also listed by the *Colour Index* as a component of Pigment Green 15.

Chromates group; Chromium oxides and hydroxides group; Hexacyanoferrate group; Lead chromates group; Lead group; Lead sulfates group; Chromium Crocoite; Lead chromate(VI) sulfate; *Chrome green*; *Chrome yellow*; *Green cinnabar*; *Prussian blue*
Berthollet & Vauquelin (1804); *Colour Index* (1971) 77600; Feller (1972); Field (1809); Gettens & Stout (1966) 106; Harley (1982) 101; Haug (1951); Kühn (1969); Kühn & Curran (1986); Rutley (1988); Vauquelin (1809); Watson & Clay (1955)

LEAD CHROMATE(VI) OXIDE

Red
Generic compound

According to the literature (for example, Heaton, 1928; Schiek, 1973; Kühn and Curran, 1986), lead chromate(VI) oxide, $PbCrO_4.PbO$ (or monobasic lead chromate) is one of the chemical formulae given for chrome orange and chrome red pigments (the other is lead chromate hydroxide (*qq.v.*), $PbCrO_4.Pb(OH)_2$). A natural mineral with the same composition is known as phoenicochroite (Williams *et al.*, 1970), which could co-occur with the lead chromate(VI) mineral crocoite (*qq.v*). The synthetic pigment can be obtained in a variety of colours ranging from orange to red, according to precipitation conditions and particle size (red varieties are coarser grained). Preparation is at high temperature by the addition of a solution of a soluble lead salt to alkali chromate (usually potassium or sodium) solution, with precipitation occurring from alkaline solutions; the colour increases in redness as the basicity of the solution increases; neutral or weakly acid solutions prepared at colder temperatures, and those with excess lead in solution, produce the pigment chrome yellow (*q.v.*). The *Colour Index* (1971) lists chrome red and chrome orange (*qq.v.*) pigments (CI 77601) with variable composition of $xPbCrO_4.yPbO$ (or $xPbCrO_4.yPb(OH)_2$), resulting in designations CI Pigments Orange 21 (yellowish orange) and 21:1 (precipitated on a silica base), CI Pigment Orange 45 (reddish orange) and Pigment Red 103; it is also reported that commercial products may contain lead sulfate (see: lead sulfates group). It is possible that such compositional variation may lead to the tetrabasic lead chromate composition $PbCrO_4.4PbO$ given by Dunn (1975).

Lead chromates and their potential use as orange and red pigments were first discussed by Berthollet and Vauquelin (1804) and Vauquelin (1809) in the early nineteenth century, although their introduction as pigments is not well known. The lightfastness of the lead chromate oxides also varies. According to Kühn and Curran, chrome red is basically lightfast, unlike chrome yellow which tends to darken on exposure to light (Brown, 1944); chrome orange has intermediate lightfastness between the two.

The popularity of lead chromate(VI) oxide as a pigment has declined in recent years due to the increased demand of the cheaper and more durable molybdate orange and red (*qq.v.*) pigments which are based on the composition $PbCrO_4.PbMo_4.PbSO_4$.

Many synonyms for lead chromate(VI) oxide may be found in the literature, in reference to chrome red and orange pigments, these include: Austrian cinnabar, Persian red (*q.v.*), basic lead chromate, red lead chromate and chromium lead oxide (*Merck Index*, 1996).

Chromates group; Lead chromates group; Lead sulfates group; Crocoite; Lead chromate hydroxide; Phoenicochroite; *Chrome orange*; *Chrome red*; *Chrome yellow*; *Molybdate orange*; *Molybdate red*; *Persian red*

Berthollet & Vauquelin (1804); Brown (1944); *Colour Index* (1971) 77601; Dunn (1975); Heaton (1928) 380; Kühn & Curran (1986); *Merck Index* (1996) 5423; Schiek (1973); Vauquelin (1809); Williams *et al.* (1970)

LEAD CHROMATE(VI) SULFATE

Orange

Generic compound

Lead chromate sulfate, $PbCrO_4.xPbSO_4$, is a solid solution series of lead chromate(VI) and lead sulfate, also known as lead sulfochromate. The relative contents of the end members can be varied which gives rise to a range of chrome yellow (*q.v.*) pigments with different properties. According to the ASTM Standard (D211-67), there are three main types of lead chromate sulfate pigments, subdivided according to their lead chromate contents: Type I ('primrose') contains $>50\%$ $PbCrO_4$; Type II ('lemon' or 'light') contains $>65\%$ $PbCrO_4$; and Type III ('medium') contains $>87\%$ $PbCrO_4$; the rest of the pigment is commonly composed of lead sulfate although other compounds such as silicates, aluminium phosphate, titanium or zirconium compounds may be used (Schiek, 1973; Kühn and Curran, 1986).

The variable contents of lead chromate and lead sulfate in solid solution cause changes in the crystal structure. Lead chromate sulfates with a $PbCrO_4$ content of >30–35% have monoclinic symmetry (as does pure lead chromate(VI), *q.v.*); a lead chromate content of $<10\%$, results in a pigment with orthorhombic symmetry (Watson and Clay, 1955), although stabilisation by additives such as lead tartrate, metal oxide or hydroxide is required to prevent conversion back to the monoclinic form (Wormald, 1975); lead chromate sulfates of intermediate composition (that is, those containing 10–30% $PbCrO_4$) result in co-precipitation of both structures (Watson and Clay). Thus, in terms of the ATSM standard, all types of lead chromate sulfate are monoclinic. However, the review by Kühn and Curran reports that some modern commercial examples of the 'primrose' type, particularly the pale varieties (which presumably contain more lead sulfate), may have a much lower lead chromate(VI) content, and can be precipitated in the orthorhombic form if the lead chromate content falls below 10% and stabilisers are used. They also state that more recent products may be stabilised in the orthorhombic form with a $PbCrO_4$ content of up to 85%.

Lead chromate sulfate is listed by the *Colour Index* (1971) as CI Pigment Yellow 34 (CI 77603) and as a component of CI Pigment Green 13, 15 and CI Pigment Orange 21 (CI 77601). Heaton (1928) also lists chrome primrose as a then-current term for a 'chromate and sulphate of lead'.

According to Haug (1951), monoclinic lead chromate shows the greater lightfastness of the chrome yellows, which tend to darken with age (for example, Haug; Watson and Clay), and as stated by Kühn and Curran, the modern lightfast pigments are commonly based on the monoclinic form, to which photochemical stabilisers are added.

Lead chromates group; Lead sulfates group; Lead chromate(VI)

Colour Index (1971) 77601, 77603; Haug (1951); Heaton (1928) 130; Kühn & Curran (1986); Schiek (1973); Watson & Clay (1955); Wormald (1975)

LEAD CHROMATE(VI) SULFATE, MONOCLINIC TYPE

Yellow

Generic compound

See: lead chromate(VI) sulfate.

LEAD CHROMATE(VI) SULFATE, ORTHORHOMBIC TYPE

Yellow

Generic compound

See: lead chromate(VI) sulfate.

LEAD CHROMATES GROUP

Red-Orange-Yellow

Group term

Lead chromates of various compositions are used as pigments that range in colour from yellow to orange and red. The situation surrounding the different compositions of lead and chromium is sufficiently complex that Dunn (1973b), writing a review paper on lead pigments, comments 'The terminology describing lead chromates is a bit confusing.' He states that there are four lead chromate compounds: lead chromate(VI), $PbCrO_4$; the monobasic lead chromate(VI) oxide, $PbCrO_4.PbO$ (*qq.v.*); basic lead chromate oxide hydrate, $2PbCrO_4.5PbO.H_2O$ and tetrabasic lead chromate oxide, $PbCrO_4.4PbO$; primarily the first two are said to be used as pigments. To these we should add: the mineral analogue of $PbCrO_4$, crocoite; lead chromate hydroxide, $PbCrO_4.Pb(OH)_2$; the two structural forms (monoclinic and orthorhombic) of lead chromate sulfate ($PbCrO_4.xPbSO_4$), and lead chromate molybdate, $PbCrO_4.PbMo_4.PbSO_4$ (*qq.v.*); a further compound, lead dichromate, $PbCr_2O_7$, is also listed in the literature as a red-brown pigment.

According to Dunn, lead chromate pigments are usually prepared by mixing solutions of alkali chromates with solutions of lead salts such as lead nitrate or lead acetate. Alternatively, and more recently, these pigments have been produced from a lead oxide/water slurry to which a solution of chromic acid is added. The yellow to yellow-orange products are termed chrome yellow (*q.v.*) with the composition usually given as $PbCrO_4$; lighter shades are often co-precipitated with lead sulfate, carbonate or phosphate and are termed lead chromate sulfates (*q.v.*), with composition given as $PbCrO_4.xPbSO_4$ (Dunn); the orange and red shades (chrome orange, chrome red, *qq.v.*) are basic lead chromates (lead chromate(VI) oxide) with composition commonly listed as $PbCrO_4.PbO$ (Kühn and Curran, 1986). Lead chromate molybdate pigments, commonly known as molybdate orange and red (*qq.v.*), are also mentioned by Kühn and Curran.

Chromates group; Lead carbonates group; Lead group; Lead phosphates group; Lead sulfates group; Crocoite; Lead chromate(VI); Lead chromate hydroxide; Lead chromate molybdate; Lead chromate(VI) oxide; Lead chromate(VI) sulfate; *Chrome orange*; *Chrome red*; *Chrome yellow*; *Molybdate orange*; *Molybdate red*

Dunn (1973b); Kühn & Curran (1986)

LEAD CHROME GREEN

Green

Synonym, variant or common name

Essentially a green pigment formulated from lead chromate and Prussian blue (*qq.v.*). Robinson (1973) lists this term among various synonyms for 'chrome green' (*q.v.*) pigments.

Hexacyanoferrate group; Lead chromates group; *Chrome green*; *Prussian blue*

Robinson (1973b)

LEAD CYANIDE

Yellow
Generic compound

The *Colour Index* (1971) lists this compound under CI 77610/Pigment Yellow 48, describing it as 'lead cyanamide', with a formula $Pb(CN)_2$. Preparation is by extracting 'commercial calcium cyanamide' with water, adding a little lead nitrate to precipitate the black sulfides, then filtering and heating the filtrate with lead nitrate and ammonia to precipitate the yellow lead cyanide. Use and other terminology is currently unknown.

Colour Index (1971) 77610

LEAD DICHROMATE

Yellow
Generic compound

Lead dichromate, $PbCr_2O_7$, is listed by the *Colour Index* (1971) as CI 77607, a reddish brown pigment used in the USA.

Lead chromates group
Colour Index (1971) 77607

LEAD DIOXIDE

Black-Brown
Synonym, variant or common name

See: plattnerite.

LEAD GROUP

Variable
Group term

In addition to metallic lead, which can occur as a component in certain lead-based pigments, the following lead compounds have been used as pigments, or are closely associated:

Carbonates: cerussite and lead carbonate ($PbCO_3$); hydrocerussite and lead carbonate hydroxide ($Pb(CO_3)_2(OH)_2$); lead carbonate hydroxide oxide ($4PbCO_3.2Pb(OH)_2.PbO$); lead oxide carbonate hydroxide and plumbonacrite ($Pb_{10}(CO_3)_6O(OH)_6$; phosgenite ($Pb_2(CO_3)Cl_2$).
Cyanides: lead cyanide ($Pb(CN)_2$).
Halides: lead chloride occurs as cotunnite ($PbCl_2$); lead chloride hydroxide has four forms – blixite, fiedlerite, laurionite and paralaurionite ($PbCl(OH)$) types; lead chloride oxide ($PbCl_{2.5–7}PbO$); lead iodide (PbI_2). Lead chlorosulfite is listed in the literature. Additonally, mendipite ($Pb_3Cl_2O_2$) occurs as a related lead halide.
Oxides and hydroxides: lead(II) oxide, litharge and massicot types and mineral analogues (PbO); lead(IV) oxide (PbO_2) and plattnerite; lead(II,IV) oxide and minium ($2PbO.PbO_2$); lead hydroxide ($Pb_3O_2(OH)_2$). The *Colour Index* (1971) also lists a Pb_2O_3.
Tertiary, quaternary and higher oxides: lead aluminium oxide; lead antimony oxide and bindheimite; lead antimony tin oxide ($Pb(Sb,Sn)O_3$); lead antimony zinc oxide; lead arsenic oxide; lead tin oxide (Pb_2SnO_4); lead silicon tin oxide ($Pb(Si,Sn)O_3$); lead antimony bismuth zinc oxide.
Phosphates: lead phosphate ($Pb_9(PO_4)_6$); lead hydroxide phosphate ($Pb_5(PO_4)_3OH$). The *Colour Index* (1971) also lists $Pb_3(PO_4)_2$.
Sulfates: lead sulfate and anglesite ($PbSO_4$); lead oxide sulfate ($PbSO_4.2PbO$); lanarkite ($PbO.PbSO_4$).
Sulfides: galena (PbS).

In addition, lead acetates may be present as residual intermediate compounds in the formation of lead carbonates; species known include lead(II) acetate trihydrate ($Pb(CH_3CO_2)_2.3H_2O$) and lead acetate oxide hydrate ($Pb(CH_3CO_2)_2.2PbO.H_2O$ and $Pb_3(CH_3CO_2)_6.PbO.H_2O$).

A lead silicate sulfate chloride has also been identified (Corbeil *et al.*, 1996). Meggiolaro *et al.* (1997) have identified a yellow lead-based compound – 'Pb,Fe(Sb,Zn) arsenate' – among pigments found in Corinth (mid-first century AD). A lead oxide hydroxide, $3PbO.H_2O$ has been identified as a lead corrosion product (Tétreault *et al.*, 1998).

Lead acetates group; Lead carbonates group; Lead chromates group; Lead halides group; Lead oxides and hydroxides group; Lead phosphates group; Lead silicates group; Lead sulfates group; Lead sulfides group; Alamosite; Anglesite; Bindheimite; Blixite; Calcium lead oxide; Cerussite; Cotunnite; Crocoite; Fiedlerite; Galena; Hydrocerussite; Lanarkite; Laurionite; Lead; Lead aluminium oxide; Lead antimoniate; Lead antimonite; Lead antimony oxide; Lead antimony oxide, bindheimite type; Lead antimony oxide, rosiaite type; Lead antimony tin oxide; Lead antimony zinc oxide; Lead arsenate; Lead arsenite; Lead carbonate; Lead carbonate hydroxide; Lead carbonate hydroxide oxide; Lead chloride hydroxide; Lead chloride oxide; Lead chromate hydroxide; Lead chromate molybdate; Lead chromate(VI); Lead chromate(VI) oxide; Lead chromate(VI) sulfate; Lead cyanide; Lead dichromate; Lead iodide; Lead molybdate; Lead oxide carbonate hydroxide; Lead oxide hydroxide; Lead oxide sulfate; Lead silicate sulfate chloride; Lead sulfite; Lead tin oxide; Lead tin silicon oxide; Lead titanate; Lead tungstate; Lead(II,IV) oxide; Litharge; Massicot; Mendipite; Mimetite; Paralaurionite; Phosgenite; Plattnerite; plumbonacrite; Pyromorphite; Raspite; Rosiaite; Stolzite; Vanadinite; Wulfenite; *Lead chlorosulfite*
Colour Index (1971); Corbeil *et al.* (1996); Meggiolaro *et al.* (1997); Tétreault *et al.* (1998)

LEAD HALIDES GROUP

Variable
Group term

A number of lead halides occur as pigments or are closely associated with ones that do. These include: lead chloride (cotunnite, $PbCl_2$; Naruse, 1996); lead chloride hydroxide, $PbCl(OH)$, which has four crystal modifications (blixite, fiedlerite, laurionite and paralaurionite types; see, for example Winter, 1981 and Noble and Wadum, 1998); and lead chloride oxide ($PbCl_{2.5–7}PbO$), which was patented as a pigment in the late eighteenth century (Harley, 1982). Yellow lead iodide (PbI_2) is also documented as a pigment from the nineteenth century (Mérimée, 1830). A lead silicate sulfate chloride has also been identified (Corbeil *et al*., 1996). 'Lead chloro-sulfite' is also listed in the literature, though little is known about it (Heaton, 1928). Additionally, mendipite ($Pb_3Cl_2O_2$) occurs as a related lead halide mineral, although it does not appear to have been employed directly as a pigment.

Lead group; Blixite; Cotunnite; Fiedlerite; Laurionite; Lead chloride oxide; Lead iodide; Mendipite; Paralaurionite; *Lead chlorosulfite*
Corbeil *et al.* (1996); Harley (1982) 99–100; Heaton (1928) 380; Mérimée (1830/trans. Taylor, 1839); Naruse (1996); Noble & Wadum (1998); Winter (1981)

LEAD HYDROXIDE

White
Generic compound

See: lead oxides and hydroxides group.

LEAD IODIDE

Yellow
Generic compound

Lead iodide – PbI_2 – is a bright yellow compound with some apparently limited use as a pigment. Mérimée (1830) describes this colour as 'not yet much known in commerce, is as bright as orpiment or chromate of lead [*qq.v.*]. It is thought to be more permanent; but time only can prove its pretension to so essential a quality. It is prepared by precipitating a solution of acetate or nitrate of lead, with hydrochlorate of potass: the nitrate produces a more brilliant yellow colour.' The *Colour Index* (1971) lists CI 77613 as 'lead di-iodide', describing it as a 'golden yellow pigment used in mosaic gold'; however, this latter term is typically reserved for a tin(IV) sulfide compound.

Lead chromates group; Lead group; Orpiment; *Mosaic gold*
Colour Index (1971) 77613; Mérimée (1830/trans. Taylor 1839) 103

LEAD MOLYBDATE

Red-Orange
Generic compound

So-called molybdate orange and molybdate red (*qq.v.*) pigments are produced by the addition of a small amount of lead molybdate, $PbMoO_4$ (and occasionally some lead sulfate) to a lead chromate pigment. These typically contain 15% molybdate and 5% sulfate. The mineral analogue, wulfenite (*q.v.*), has been found among cosmetic pigments from Ur (Bimson, 1980).

Lead chromates group; Lead group; Molybdenum group; Wulfenite; *Molybdate orange*; *Molybdate red*
Bimson (1980)

LEAD OXIDES

Red-Orange-Yellow
Group term

There are three yellow to red lead oxides that might be found in paintings: the yellow monoxides (PbO) litharge and massicot (not to be confused with the synonym for lead tin yellow) and the orange-red lead(II,IV) oxide ('lead tetroxide', 'red lead' or 'minium').

Additionally the brown lead dioxide, PbO_2, may occur (the mineral analogue is plattnerite), perhaps as an alteration product, such as described in Wang *et al.* (1993b).

Lead(II,IV) oxide; Litharge; Massicot; Minium; Plattnerite
Wang *et al.* (1993b)

LEAD OXIDE CARBONATE HYDROXIDE

Black
Generic compound

This is the synthetic analogue of plumbonacrite (*q.v.*), although the formula is given here as $6PbCO_3.3Pb(OH)_2.PbO$. It has been found in studies of lead corrosion in acetic acid environments (Tétreault *et al.*, 1998); it might occur during production of so-called 'lead white' (*q.v.*) pigments but so far has not been identified in that context.

Lead carbonates group; Lead group; Plumbonacrite; *Lead white*
Tétreault *et al.* (1998)

LEAD OXIDE HYDROXIDE

White
Generic compound

This is $3PbO.H_2O$, found in studies of lead corrosion in acetic acid environments. It might occur during production of so-called 'lead white' pigments (*q.v.*) but so far has not been identified in that context. (Tétreault *et al.*, 1998).

Lead group; Lead oxides and hydroxides group; *Lead white*
Tétreault *et al.* (1998)

LEAD OXIDE SULFATE

White
Generic compound

Lead oxide sulfate ('basic lead sulfate') is the common form of lead sulfate used as a pigment in recent times. Composition apparently varies between limits of about $PbO.2PbSO_4$ and $PbO.3PbSO_4$. Lanarkite (*q.v.*), $PbO.PbSO_4$, is a lead oxide sulfate mineral.

Salter, writing in 1869, states that 'the whites of lead are carbonates of that metal with two exceptions:- Flemish white or the sulphate, and Pattison's white or the oxychloride'. Heaton, writing in 1928, describes how the first patent was taken out on the use of lead oxide sulfate as a pigment by Bartlett in 1870 but that it was rarely used. It was originally made by roasting high-grade galena (*q.v.*) concentrates in a modified blast furnace. Volatilised lead sulphide was then oxidised by a cold air blast and collected in a cooling chamber. The product is described as an 'amorphous and exceedingly fine powder possessing considerable opacity'. Composition of manufactured material is known to vary with lead and zinc oxides (forms unknown) also being present to typical levels of 14–20% and 5–6% respectively (Heaton). Small quantities of lead sulfate may occur as an impurity in zinc oxide pigments made by the so-called 'direct' process and made up roughly 50% of 'zinc lead white' (*qq.v.*).

Sometimes known as 'sublimed white lead', there is also a 'Maxwell Lyte lead white' of this composition by a process patented in 1886. *Colour Index* (1971) designations are CI 77633/Pigment White 2.

Lead group; Lead oxides and hydroxides group; Lead sulfates group; Galena; Lanarkite; Zinc oxide; *Maxwell Lyte lead white*; *Sublimed white lead*; *Zinc lead white*
Colour Index (1971) 77633; Heaton (1928) 81–83; Salter (1869) 67–68

LEAD OXIDES AND HYDROXIDES GROUP

Variable
Group term

The lead oxides with important applications as pigments, especially associated with yellow pigments are: lead(II) oxide, litharge and massicot types and the mineral analogues (PbO); lead(IV) oxide (PbO_2), plattnerite; lead(II,IV) oxide and minium ($2PbO.PbO_2$). The *Colour Index* (1971) also lists a lead oxide (Pb_2O_3). 'Plumbic ochre' occurs as a secondary ore associated with lead-rich ore deposits; also known as brown lead(IV) oxide (PbO_2), it may be encountered as an alteration product in pigments.

Various authors in the later nineteenth century discuss the presence of lead hydroxide in lead white (*q.v.*), Scott Taylor (1885), for example, mentioning the formula should be about 25%; this in fact refers to the common composition of lead white – lead carbonate hydroxide, $2PbCO_3.Pb(OH)_2$; there are in fact other lead carbonate hydroxides, for which see: lead carbonates group.

Tertiary, quaternary and higher oxides also have important applications as yellow pigments, especially lead antimony tin-based yellows. These are: lead aluminium oxide ($PbO.Al_2O_3$); lead antimony oxide and bindheimite ($Pb_2Sb_2O_6[O,OH]$); lead antimony tin oxide ($Pb(Sb,Sn)O_3$); lead antimony zinc oxide ($Pb(Sb,Zn)O_3$); lead arsenic oxide ($Pb_3As_4O_2$, Pb_2AsO_7); lead tin oxide (Pb_2SnO_4); lead silicon tin oxide ($Pb(Si,Sn)O_3$); lead antimony bismuth zinc oxide ($Pb(Sb,Zn,Bi)O_3$); calcium lead oxide ($CaPbO_4$); lead molybdenum oxide ($PbMoO_4$); lead titanium oxide ($PbTiO_3$); lead tungsten oxide and raspite ($PbWO_4$).

Lead chromates (*q.v.*) also form an important number of pigment compounds, and these are discussed separately. Finally, a lead oxide hydroxide, $3PbO.H_2O$ has been found as a corrosion product of lead although not in a pigment context (Tétreault *et al.*, 1998).

Lead carbonates group; Lead chromates group; Lead group; Bindheimite; Calcium lead oxide; Lead aluminium oxide; Lead antimoniate; Lead antimonite; Lead antimony oxide; Lead antimony oxide, bindheimite type; Lead antimony oxide, rosiaite type; Lead antimony tin oxide; Lead antimony zinc oxide; Lead arsenate; Lead arsenite; Lead chromate hydroxide; Lead chromate molybdate; Lead chromate(VI); Lead chromate(VI) oxide; Lead dichromate; Lead molybdate; Lead oxide hydroxide; Lead tin oxide; Lead titanate; Lead tungstate; Lead(II,IV) oxide; Litharge; Massicot; Plattnerite; Raspite; Rosiaite; *Lead white*
Colour Index (1971); Scott Taylor (1885) 98; Tétreault *et al.* (1998)

Lead(II) oxide

Yellow
Generic compound

See: litharge and massicot.

Lead(II) oxide, litharge type

Yellow
Generic compound

See: litharge.

Lead(II) oxide, massicot type

Yellow
Generic compound

See: massicot.

Lead(II,IV) oxide

Red
Generic compound

Lead(II,IV) oxide, $2PbO.PbO_2$ (historically, Pb_3O_4), is thought to have been one of the earliest artificially produced pigments and one which is still in use today. More commonly known under the name 'red lead', it is the synthetic analogue of the mineral minium (*q.v.*; Dunn, 1973c).

Historically, the most widely cited technique for the production of red lead was through conversion of another lead compound, usually lead white (*q.v.*). This involved roasting the precursor compound until the required colour was achieved, sometimes the instructions include formation of the lead white in the traditional manner from lead plates and vinegar. Examples of this are given in such wide-ranging texts as those by Vitruvius (first century BC), Pliny (77 AD) and Dioscorides (first century AD), the authors of the tenth and twelfth century MS known as the *Mappae Clavicula* (Clarke MS 2260), the eleventh century treatise by Theophilus and from the chief librarian to the sixteenth century Persian emperor Shah Abbas (Welch, 1981). The second basic route was to form an intermediate oxide from lead; usually this was achieved by raking off the dross which formed on the surface of the molten metal. It seems that the explicit methodology is not found in texts earlier than the eighteenth century, but the route must have been practised much earlier than that. Temperatures for both processes in the range 300–500°C are usually given or implied, which is not surprising since above about 550°C only lead monoxide is stable. However, Toch (1916) describes the preparation of red lead by heating litharge (*q.v.*; PbO) to 600–700°C; he notes that a proportion of litharge typically remains in the product. Further, Toch also describes a preparation used by some manufacturers in the US at that time where litharge is oxidised by sodium nitrite ('nitrite of soda'); this apparently led to significant amounts of sodium hydroxide being formed *in situ*. Litharge itself was also prepared by what was known as the 'nitrate process', metallic lead being treated with sodium nitrate to give lead oxide and sodium nitrite; reportedly, red lead prepared using this litharge would normally contain small amounts of sodium hydroxide along with residual sodium nitrite.

According to Schafer (1955), the synthetic compound was known as early as the fifth century BC in China, the term *ch'ien tan* – literally, lead cinnabar – being used in the Han dynasty. The classical authors Pliny and Dioscorides also use the term 'false sandarach' for red lead, 'true' sandarch in this case being realgar (*q.v.*); Vitruvius simply uses sandarach. Other terms applied to the pigment by classical authors (or mixtures using it) include *sandyx*, a mixture of red lead and red ochre, and *syricum* (or *siricum*), which could apply to red lead or litharge, sandyx, or a mixture of sandyx and the red earth known as sinoper (*qq.v.*). In the Chinese Sung dynasty (tenth to thirteenth centuries AD) a special government factory supplied painters and decorators; Schafer suggests that the product was also exported, since at that time red lead was known as *cinapishta* – literally, 'China flour' – in India. Yü (1955) also adds the term *Zhang red*, deriving from production in Zhangzhou, Fujian Province, China; it was supposedly produced from the remains of lead white production. By the fifteenth and sixteenth centuries, however, in Europe *minium*-variant terms solely referred to lead(II,IV) oxide. For example, the fifteenth century *Strasbourg MS* (Clarke MS 2000) uses the term *minie*, while Agricola (1556) calls it *menning*.

Other terms have also been applied. Orange lead (or orange mineral) is to be found in numerous nineteenth and twentieth century sources (see: orange lead). Salter (1869) uses the term saturnine red. Toch notes several commercial varieties, including '*Dutch Boy Red Lead*' (a very pure form) and '*French Orange Mineral*'. Malevanny (1968; cf. FitzHugh (1986)) has noted though that in France and Russia iron minium ('*minium de fer*') is in fact an ochre (*q.v.*). Modern terms listed by the *Merck Index* (1996) include lead tetroxide, red lead, mineral red, lead oxide, red lead oxide, orange lead, lead tetraoxide and lead(II,III) oxide.

Salter mentions that red lead was 'frequently adulterated with earthy substances, such as brickdust, red ochre, and colcothar'. Various additives are also mentioned by Toch, including silica, lampblack, graphite (*qq.v.*) and silicate of alumina. Conversely, this compound has not infrequently been used to adulterate vermilion (*q.v.* Gettens *et al.*, 1993b).

As befits a pigment with such a long history, the known occurrences of it cover both a wide geographical range and a great variety of artistic contexts.

Lead oxides and hydroxides group; Colcothar; Graphite; Litharge; Minium; Ochre; Realgar; *Lamp black*; *Lead white*; *Orange lead*; *Red lead; Red Ochre*; *Sinoper*; *Vermilion*
Agricola (1556/trans. Hoover & Hoover 1950) 232; Dioscorides (1st cent AD/Osboldeston & Wood, 2000) 5, 103; Dunn (1973c); FitzHugh (1986); Gettens *et al.* (1993b); Malevanny (1968); *Merck Index* (1996) 5449;

Pliny (1st cent. AD/Rackham, 1952) XXXV.xxii, XXXIII.xl; Salter (1869) 151–152; Schafer (1955); Theophilus (c. 12th cent/Hawthorne & Smith 1963) I, 37; Toch (1916) 55; Vitruvius (1st cent. AD/Granger 1934) 125; Welch (1981) 268; Yü (1955/trans. Silbergold & McNair, 1988) 6; Strasburg MS (18th cent./tr. Borradaile 1966) 50

LEAD(IV) OXIDE

Brown
Generic compound

See: plattnerite.

LEAD OXYCHLORIDE

Yellow
Synonym, variant or common name

See: lead chloride oxide.

LEAD PHOSPHATE

White
Generic compound

See: lead phosphates group.

LEAD PHOSPHATES GROUP

White
Group term

A number of lead phosphates are known to exist, notably: lead phosphate, $Pb_9(PO_4)_6$; lead phosphate hydroxide, $Pb_5(PO_4)_3OH$; hydroxypyromorphite, $Pb_5(PO_4)_3OH$; pyromorphite, $Pb_5(PO_4)_3Cl$; and lead phosphate fluoride, $Pb_5(PO_4)_3F$.

Lead phosphate has been identified by Winter (1981) on a fourteenth century Kamakura panel among examples of 'lead white' (*q.v.*) on Japanese paintings. Composition is given as $Pb_9(PO_4)_6$ from coincidence of X-ray diffraction data and identification of lead(II) and phosphate ions. No wholly equivalent natural mineral exists, though pyromorphite ($Pb_5(PO_4)_3Cl$), mimetite ($Pb_5(AsO_4)_3Cl$) and oxypyromorphite ($Pb_{10}(PO_4)_6O$) are the most closely related structurally.

Dunn (1973a) also lists a 'dibasic lead phosphite' (lead oxide phosphite hydrate, $2PbO.PbHPO_3.0.5H_2O$) that was patented in 1949 and used commercially from soon after. Preparation was by adding small amounts (0.1%) of acetic acid to a litharge (*q.v.*) slurry, heating to 38°C and then adding phosphoric acid. A pigmentary form of this compound was marketed under the name '*Dyphos*'.

Lead group; Litharge; Mimetite; Pyromorphite; *Lead white*
Dunn (1973a) 81–83; Winter (1981)

LEAD SILICATE

White
Synonym, variant or common name

See: lead silicates group.

LEAD SILICATE SULFATE CHLORIDE

Yellow
Generic compound

Corbeil *et al.* (1996) have identified a yellow lead silicate sulfate chloride among pigments used on Abbasid qasr frescos (early eighth century AD) in Jordan.

Lead group; Silicates group
Corbeil *et al.* (1996)

LEAD SILICATES GROUP

White
Group term

There are four main lead silicate compounds (Gellner *et al.*, 1934) though Dunn (1973a) states that generally only that corresponding to close variations of $3PbO.2SiO_2.H_2O$ (rather than the '$PbSiO_3$' given by the *Colour Index*, 1971) and which he terms 'basic lead silicate' is used for pigmentation. There is also a 'mixed' lead silicate pigment with a high silica content that Dunn also states is of a distinct composition, and a 'basic lead silico sulfate' comprising a core of silica and a coating (mixture) of lead oxide silicate ($PbSiO_3.3PbO$) and lead oxide sulfate ($PbSO_4.PbO$).

Lead silicate appears to have been employed as an extender, or 'pigment builder', and Dunn has observed that there is a long history of its use in the paint industry.

Lead silicate can be prepared as a pigment in several ways, such as by treating lead sulfate in the presence of water with a silicate of an alkaline earth metal or by grinding a mixture of lead monoxide or hydroxide and silicic acid in water in the presence of an acid catalyst. Dunn describes a technique in which silica and litharge (*q.v.*) are fused directly at a temperature of about 980°C, running the melt into water to granulate it. Lead silicate also occurs naturally as the mineral alamosite (*q.v.*) from which lead silicate pigment may also have been prepared. The *Colour Index* lists this as CI 77625/Pigment White 16.

Lead group; Silicates group; Alamosite; Litharge
Colour Index (1971) 77625; Dunn (1973a) 76–80; Gellner *et al.* (1934)

LEAD SULFATES GROUP

White
Group term

According to Dunn (1973a, 1975) there are some six lead sulfates in use as pigments: $PbSO_4.4PbO$, $PbSO_4.3PbO.H_2O$, $PbSO_4.3PbO$, $PbSO_4.2PbO$, $PbSO_4.PbO$ (lanarkite) and $PbSO_4$. The latter two are used in the paint industry along with a mixed pigment containing $PbSO_4.PbO$, PbS, $PbSO_3$, ZnO and carbon (known as 'blue lead', owing to its blue-grey colour). It is generally likely to be encountered as a synthetically produced white pigment, though there is a mineral analogue, *anglesite* (*q.v.*). The authors have also identified a mixture of the lead oxide sulfate hydrate, $PbSO_4.3PbO.H_2O$, and the lead oxide sulfate $PbSO_4.PbO$ along with a lead carbonate sulfate hydroxide, the synthetic analogue of the mineral susannite, $Pb_4(CO_3)_2(SO_4)(OH)_2$, in a modern commercial lead sulfate pigment. Zhou *et al.* (1997) have found the lead carbonate sulfate mineral *leadhillite* ($PbSO_4.2PbCO_3.Pb(OH)_2$) in pigments from the Tiantishan Grottoes, China. A lead sulfite hydroxide $3PbSO_3.Pb(OH)_2$ has also been noted by Brochwicz *et al.* (1993).

Some limited use of lead sulfate as an artists' pigment is known and Winter (1981) has, for example, identified lead sulfate in thirteenth to sixteenth century Chinese paintings. Harley (1982) suggests that watercolour painters in late eigtheenth and early nineteenth century Britain were using lead sulfate prepared from a solution of a lead salt precipitated with sulfuric acid, citing instructions published in the *Practical Treatise* of 1795; it was apparently sold under the name of 'Flemish white'. 'Freeman's white' was another form including zinc white and baryte (Laurie, 1895). It is also likely to be found as a by-product; Zerr and Rübencamp (1906), for example, report that it was inevitably produced as part of the manufacturing process used for 'sulphur and pale yellow chromes'. However, most more recent occurrences are likely to be lead oxide sulfate as this has become the dominant form used in the paint industry. Dunn, for example, states that these are called 'basic lead sulfate', but that this is used as a broad term that embraces many compounds, with varying degrees of basicity above the normal (non-basic) lead sulfate.

Dunn also describes three methods of modern manufacture for lead sulfate pigments. The first was the formation of lead sulfate as a component of a mixture with zinc oxide, because in the early history of this pigment both zinc oxide and lead sulfate were made directly from the ores through sublimation using controlled atmospheres. Second, in 1935, a 'new' basic lead sulfate was made by a precipitation process that gave improved optical and physical properties as well as a higher basicity; however, it was not particularly economical to produce and was taken off the market about 1960. Third, Dunn states that the pigment currently produced when he was writing (1973) was formed by a fume process where molten lead was atomised into a jet flame in the presence of excess air and sulfur dioxide.

Lead sulfate pigments were sold under many trade names and it is not always clear whether they refer to the basic form. These include (for lead sulfate, CI Pigment White 3) *fast white, lead bottoms, milk white* and *Mulhouse white* and (for basic lead sulfate, CI Pigment White 2) *basic sulfate white lead, Lewis white lead*, *sublimated white lead* and *white lead sulfate*.

Lead group; Anglesite; *Blue lead*; *Flemish white*; *Freeman's white*; *Lead white*
Brochwicz *et al.* (1993); *Colour Index* (1971); Dunn (1973a) 73–75; Dunn (1975); Harley (1982) 172; Laurie (1895); *Practical Treatise* (1795); Winter (1981); Zerr & Rübencamp (1906/1908) 148; Zhou *et al.* (1997)

LEAD SULFIDE

Brown
Generic compound

See: galena and lead sulfides group.

LEAD SULFIDES GROUP

Variable
Group term

Galena (PbS, *q.v.*) is a naturally occurring lead sulfide mineral that has been used as a pigment (and in cosmetics) since ancient times. It is the principal ore of lead and is therefore a raw material used in the manufacture of many synthetic lead compounds.

Lead sulfides may also occur as alteration products of cadmium yellow and other cadmium sulfide-based pigments.

Cadmium sulfides and selenides group; Lead group; Galena; *Blue lead*; *Cadmium yellow*; *Lead black*

LEAD SULFITE

White
Generic compound

Lead sulfite ($PbSO_3$) has yet to be confirmed on paintings although several late nineteenth century documentary sources mention it. Riffault *et al.* (1874) describe this pigment as follows: 'Mr. Scoffern, who has proposed its employment, says that [lead sulfite] is obtained in the following manner: sulphurous acid is prepared by heating sawdust with concentrated sulphuric acid, and the gas is passed through a solution of basic acetate of lead. There is formed a precipitate of sulphite of lead, and the liquor is a solution of neutral acetate which may be rendered basic by boiling it with litharge (*q.v.*), as in the Thénard process.' Bersch (1901) essentially repeats this recipe adding that the process is 'similar to the French white lead process, with the difference that sulphur dioxide is used instead of carbon dioxide'. He also comments that it has no advantages over white lead (see: lead white) and 'has thus never found practical application'. Dunn (1975) lists lead sulfite as a component in a mixed pigment based primarily on lead sulfate and lead sulfide (see lead sulfates group for more information).

Lead group; Lead sulfates group; Litharge; *Lead white*
Bersch (1901) 114–115; Dunn (1975); Riffault *et al.* (1874) 159

LEAD SULFOCHROMATE

Yellow
Synonym, variant or common name

See: lead chromate(VI) sulfate.

LEAD TETROXIDE

Red-Orange
Synonym, variant or common name

See: lead(II,IV) oxide and minium.

LEAD TIN OXIDE

Yellow
Generic compound

Two compounds based on lead and tin are of particular interest as pigments, plus a related material which also incorporates antimony. Commonly known as lead tin yellow (*q.v.*), these found widespread use as pigments for painting in the period from about 1300 to 1750 in European painting.

The first of these compounds, sometimes referred to as lead tin yellow type I, lead tin oxide (lead stannate) has a composition Pb_2SnO_4. The crystal structure is reported as orthorhombic and is very closely related to that of lead(II,IV) oxide, Pb_3O_4 (*q.v.*); while this latter compound is tetragonal at room temperature, it undergoes a transition to the orthorhombic crystal system on being cooled to 170 K. According to Clark *et al.* (1995) both compounds may be regarded as mixed valence materials of general formula $M_2^{II}M^{IV}O_4$. Synthesis of Pb_2SnO_4 is commonly achieved by calcination of a lead oxide (usually PbO) and tin(IV) oxide (SnO_2) at appropriate temperatures. This process has been studied by a number of authors, notably Urazov *et al.* (1956) who made detailed studies of the associated phase system. They found that below 780°C the reactants PbO and SnO_2 are in the form of a mixture of the solid compounds; between 780°C and 1060°C, with mixtures of $<2:1$ PbO:SnO_2, the compound Pb_2SnO_4 coexists in solid form with free SnO_2; above 780°C, for mixtures of $>2:1$ PbO:SnO_2 the compound Pb_2SnO_4 may form eutectic mixtures with PbO, the lowest eutectic temperature being 850°C. Clearly, non-stoichiometric mixtures of the lead and tin oxides will give rise to the presence of residual phases, these not uncommonly being observed in analyses of material from paintings.

The second compound, also known by the term lead tin yellow type II, is a lead tin silicon oxide. Generally given as $Pb(Sn,Si)O_3$ (Rooksby, 1964; Kühn, 1993b), Clark *et al.* (1995) have, however, shown from diffraction studies that the tin and silicon atoms are randomly distributed over the same type of site with a tin:silicon ratio of about 3:1 (that is, $PbSn_{1-x}Si_xO_3$ where x is $\sim\frac{1}{4}$). Formation conditions for $PbSn_{1-x}Si_xO_3$ are less well defined than for Pb_2SnO_4 and research by Eastaugh (1988) suggests that a more complex process takes place, perhaps involving the formation of an intermediate lead silicate at around 690°C before the lead tin silicon compound itself forms at temperatures in the region of 750°C. The compound is also known to decompose at temperatures of about 1100°C. Additionally, it was found that at tin:silicon ratios below 1:1 a ternary mixture of Pb_2SnO_4, SnO_2 and $Pb(Sn,Si)O_3$ occurred; at ratios above 1:1 a different ternary mixture resulted consisting of $Pb(Sn,Si)O_3$, SnO_2 and a glassy phase.

A number of other lead tin oxides are also known to exist. (Lead antimony tin oxide is discussed under lead antimony oxide.) Vigouroux *et al.* (1982) have reported a compound SnPb (Pb_2O_4). Verbitskaya and Burakova (1965a,b) document the formation of an unidentified phase when sintering PbO-SnO_2 mixtures in the temperature range 1050–1250°C; it appears as yellow crystals in the form of rods a few microns long, with distinct optical properties, although its precise structure or even its exact composition have not apparently been determined. A cubic perovskite phase of $PbSnO_3$ has been formed by Sugawara *et al.* (1968). Fournier and Kohlmuller (1970) have described Pb_3SnO_4, Pb_2SnO_3, $PbSnO_2$ and $PbSn_6O_7$, but these do not appear to have any relevance as pigments, the preparation conditions required for their formation being radically different from those used in the preparation of Pb_2SnO_4.

For a discussion of terminology and use as a pigment see the entry for lead tin yellow and ensuing references.

Lead oxides and hydroxides group; Tin group; Lead antimony tin oxide; Lead(II,IV) oxide; Lead tin silicon oxide; *Lead tin yellow*
Clark *et al.* (1995); Eastaugh (1988); Fournier & Kohlmuller (1970); Kühn (1993b); Rooksby (1964); Sugawara *et al.* (1968); Urazov *et al.* (1956); Verbitskaya & Burakova (1965a); Verbitskaya & Burakova (1965b); Vigouroux *et al.* (1982)

LEAD TIN SILICON OXIDE

Yellow
Generic compound

Generally given as $Pb(Sn,Si)O_3$ (Rooksby, 1964; Kühn, 1993b). However, Clark *et al.* (1995) have shown from diffraction studies that the tin and silicon atoms are randomly distributed over the same type of site with a tin:silicon ratio of about 3:1 (that is, $PbSn_{1-x}Si_xO_3$ where x is ~¼). Also commonly known as lead tin yellow type II. For a fuller discussion, see: lead tin oxide and lead tin yellow.

Lead tin oxide; *Lead tin yellow*
Clark *et al.* (1995); Kühn (1993b); Rooksby (1964)

LEAD TIN YELLOW

Yellow
Synonym, variant or common name

Term of modern invention referring to two lead tin oxide compounds used as pigments. So-called 'type I' is a lead tin oxide of composition Pb_2SnO_4, while 'type II' contains silicon in the crystal lattice to give a compound of approximate formula $Pb(Sn_{1-x}Si_x)O_3$, where $x \sim$ ¼ (Kühn, 1993b; Clark *et al.*, 1995). The term may also encompass tertiary compounds based on lead, tin and antimony (see: lead antimony oxide).

Jacobi (1941) appears to be the earliest modern publication identifying the composition of certain yellow pigments in paintings as being based on lead and tin. According to Kühn (1993b), Jacobi, while engaged in a systematic study of samples from paintings at the Doerner Institut in Munich, noticed that in a large proportion of yellow samples he found in addition to lead high levels of tin. He was further able to show that a yellow pigment could be synthesised by heating a mixture of lead oxide (monoxide, tetroxide or dioxide) with metastannic acid at temperatures between 650°C and 800°C, and concluded that this was the pigment involved. It was also in that paper that the term '*blei-zinn-gelb*', or lead tin yellow, first appeared. Since that time numerous studies have been made on the pigments, including general reviews (Kühn; Eastaugh, 1988), structural studies (Clark *et al.* 1995) and assessments of occurrence in paintings (Martin and Duval, 1990).

Historical terminology for these compounds is complex and is not necessarily bounded by the presence of tin within the composition. However, terms with which lead tin yellow can be reasonably connected fall into the following groups: the *giallolino* group, the massicot group, the *general/genuli* group and the *plygal* group. These are largely placed in geographical/language groups, such that *giallolino* occurs in (and derives from) Italian sources, massicot is primarily northern European/English, *general* occurs in English sources and *genuli* in Spanish ones, while plygal is found primarily in German-language texts. In addition, the rarely used term machim, found, for example, in the Portuguese treatise by Nunes (1615), also appears to refer to lead tin yellow. Litharge, although referring to a lead oxide now and closely related to massicot (*qq.v.*), appears to have had a historically distinct meaning related to metallurgy. Various sources of the nineteenth and early twentieth centuries also supposed that lead-based yellow pigments were identical to so-called Naples yellow. Lastly, there are several terms of modern invention used for lead tin antimony oxides, such as Roman yellow. For a discussion of the origin and development of individual terms, see the relevant entries.

Identifications of lead tin yellow are frequently cited in the modern literature. The earliest occurrences are in the context of glass opacifiers, a topic otherwise outside the scope of this text; however, the type II compound will form and has been detected in, for example, vitreous material dated from 100 BC to 50 AD from Hengistbury Head, UK (Henderson, 1987), a late Roman shard of the fourth to fifth century AD (Lazzarini and Hreglich, 1977) and in a lead tin antimony compound by Turner and Rooksby (1959) in an eleventh century glass mosaic tessera from a Byzantine church in Novgorod and a fourteenth century enamelled bottle from Syria. In paintings the earliest examples of lead tin yellow are from Florentine works ascribed to Giotto and the di Cione workshop (Kühn; Gordon *et al*., 1985; Bomford *et al*., 1989); where known, these are type II. This pattern, whereby early works from Florence, Venice and Bohemia contain type II lead tin yellow, has been observed by Kühn and generally confirmed by Martin and Duval (1990); in the latter research it was possible to show, for example, that in Italy it appears that type I replaced type II during the second quarter of the fifteenth century. However, suggestions that type I is of Northern European origin have not thus far been confirmed (see also the discussion on this point under *giallolino*). Isolated examples of type II have also been reported in an altarpiece by Melchior Broederlam of 1396 (Kockaert, 1984) and a painting of 1627 by Ter Brugghen in the National Gallery, London (Kühn). Type I on the other hand is found widely in paintings throughout Europe until the first half of the eighteenth century. Few analytical identifications exist in works dating beyond the beginning of that century and the latest documentary reference before its rediscovery in 1941 appears to be the *Farbenlexicon* by Prange of 1782. Lead tin yellow does not appear to have been used in other places or cultures unless specific trade with Europe took place. Lead tin yellow is currently commercially available from specialist suppliers.

Lead antimony oxide; Lead antimony tin oxide; Lead tin oxide; Lead tin silicon oxide; Litharge; Massicot; *Giallolino*; *Naples yellow*; *Plygal*; *Roman yellow*

Bomford *et al.* (1989); Clark *et al.* (1995); Eastaugh (1988); Gordon *et al.* (1985); Henderson (1987); Jacobi (1941); Kockaert (1984); Kühn (1993b); Lazzarini & Hreglich (1977); Martin & Duval (1990); Nunes (1615) 60ff; Prange (1782); Turner & Rooksby (1959)

LEAD TITANATE

Yellow

Generic compound

Lead titanate, $PbTiO_3$, can be prepared by heating titanium dioxide and litharge in molar proportions; the product is said to contain lead sulfate and oxide as impurities (*Colour Index*, 1971). The *Colour Index* lists this as CI 77645/Pigment Yellow 47.

Colour Index (1971) 77645

LEAD TUNGSTATE

White

Generic compound

Lead tunstate, $PbWO_4$, appears to have had limited use in its synthetic form as a pigment. There are also two lead tungstate minerals, the tetragonal stolzite and monoclinic raspite (*qq.v.*; both $PbWO_4$); however it is not known what crystal system the synthetic pigment takes.

While the Salter (1869) edition of Field's *Chromatography* states that tungsten white was 'very recently' introduced in France by M.E. Rousseau and was being prepared on a large scale, Carlyle (2001) found little other mention of it in a survey of British nineteenth century literature. Riffault *et al.* (1874) do none-the-less describe the preparation of lead tungstate as follows: 'tungstate of soda was dissolved in the smallest possible quantity of boiling water & another hot concentrated solution of lead acetate added while a precipitate forms. The basic lead tungstate formed was then treated with nitric acid or acetic acid to make the acid tungstate.' This is also described by Bersch (1901) as tungsten white and in the *Colour Index* (1971; CI 77650), where it is described as a yellowish powder used in the USA as a pigment.

Barium tungstate; Raspite; Stolzite; *Tungsten white*

Bersch (1901) 128; Carlyle (2001) 518; *Colour Index* (1971) 77650; Riffault *et al.* (1874) 159–160; Salter (1869)

LEAD VANADATE

Red-Orange-Yellow

Generic compound

See: vanadinite.

LEAD WHITE

White

Synonym, variant or common name

'No pigment can compare with white lead' according to Terry (1893) and in fact it has been by far the most important of the white pigments used in Europe from the Roman period onwards. The term is somewhat of an umbrella, implying generally any lead-based white pigment; however, it normally refers to lead carbonate hydroxide, $2PbCO_3.Pb(OH)_2$; additionally 'lead white' may be extended to describe, for example, the lead chloride oxides, lead phosphates and particularly the lead sulfates (Dunn, 1975).

Lead carbonate hydroxide is chemically equivalent to the naturally occurring hydrocerrusite (*qq.v.*); however, the mineral equivalent is extremely rare and consequently rarely used as a pigment source. During the Roman period, Vitruvius (1st cent. BC) and Pliny (1st cent. AD) describe the synthesis of *cerussa* by steeping lead in vinegar. Both sources mention a possible natural source of the pigment on the estates of one Theodosius at Smyrna (Izmir, Turkey), although there is confusion as to whether or not this deposit is actually hydrocerussite. What is certain is that this pigment has a history of intentional manufacture. The processes used by the Romans are the basis of the mediaeval to seventeenth century technologies for lead white manufacture. The simplest (but most tedious and hazardous) methods are the 'stack process' or the very similar Dutch process. Both were commonly used up until the 1880s. These processes required a specially constructed chamber, in which were set rows of earthenware pots filled with acetic acid. These were surrounded by a fermenting substance that would not only release the necessary heat to forward the reaction but also produce carbon dioxide. Such substances were commonly dung (and lead manufactories were often associated with garrison towns with a copious supply of horse manure), spent tanner's bark or even wine lees. Lead sheets were placed above the pots, and then wooden floorboards were laid over them. Another stack of pots of acetic (ethanoic) acid was laid on the floorboards, surrounded by dung, etc. and topped with lead and so on, creating a stack to fill the chamber (in the Dutch process, coils of lead were placed inside the pots). The chamber was then left for three to four months. On opening, the lead white accumulated on the lead sheets was scraped off, washed and dried. The lead is converted, with the action of air, acetic acid and carbon dioxide via lead hydrate to lead acetate, lead acetate hydroxide to lead carbonate hydroxide. However, the reaction was often somewhat hit and miss.

Stack lead white was often slightly pinkish or yellowish in tone from impurities derived from the fermenting material. However, it was crystalline in structure, but with particles of variable size and habit from 'colloidal to 20 μm' (Heaton, 1928). Additionally, Tingry (1804) notes that it was not uncommon to find the reaction incomplete, producing a pigment still containing metallic lead that imparted a greyish hue. Remnant lead acetate ('sugar of lead') may also be present. Terry says of the stack and Dutch processes: 'It is a most tedious and uncertain operation; it is a most dangerous occupation for all concerned; it is founded on no true principles of any kind; and of science its whole course is ignorant. White lead making is ruled by the "happy-go-lucky" philosophy.' It was generally accepted (due to the lack of control during the fermentation process) that there would be a wide variation in the amount and purity of the lead carbonate hydroxide formed within the chamber. The chambers were traditionally worked by women, and the dangers of lead poisoning were well understood.

Other processes were developed working on the same principle, but forever trying to increase the speed of the process and to reduce the waste. The chamber process was patented by Sir James Creed in 1749. Lead sheets were hung 'like saddles' on wooded beams above heated gas generating rooms, negating the need for the dung or tan. The process took about eight weeks. Very similar methods developed locally were known as the

German process and Italian process (with a factory at Cogoleto which managed to reduce the reaction time down to six weeks).

The Cremnitz (or Kremnitz) process was developed in the town of Krems in Austria (according to Harley, 1982, the adoption of the name 'Kremnitz', a town in Hungary, was a mistake). Though based on a similar series of reactions a more predictable and purer pigment was produced, a 'flake white' called Cremnitz white (and variations on that name). It was described as amorphous by nineteenth century authors, but is in fact very finely crystalline. Heaton (1928) describes the Cremnitz process being carried out in a chamber with shelves holding trays containing a paste of litharge (*q.v.*) and acetic acid or lead acetate. Moist carbon dioxide was streamed into the chamber, and the lead carbonate hydroxide formed. The factory at Krems had closed down by 1839 (Harley).

The Thénard or French process was introduced in France in the early nineteenth century and was based on a similar method to the Cremnitz, with litharge as the raw material. The lead white produced was also of fine quality and called 'silver white' (a similar method was adopted in the UK, called the Rowe process).

Further technological advances came later in the nineteenth century, particularly in the USA. The Bailey process used lead fibres, which, due to increased surface area, allowed full corrosion to be completed in three days. However, this method was a commercial failure. More successful was the Matheson process wherein granulated lead (made by pouring molten lead into water) was soaked in a tank with dilute acetic acid into which air and steam were streamed. When the lead was all converted to lead acetate, carbon dioxide was streamed through to finish the reaction. The Carter process was applied 'on a considerable scale' using 'blown lead' (i.e. molten lead poured over a blast of high pressure steam) which was fed into a large wooden drum (a Carding cylinder). Acetic acid was sprayed into the drum at intervals with a hot stream of carbon dioxide and air. The lead was entirely converted to lead white over about 12–15 days. The Rowley process, using powdered lead in a slurry, produced a very fine white in two to three days.

Late nineteenth century and early twentieth century processes were based on electrolysis ('electric lead white'). The electrolytic process (patented by A.G. Brown in the USA; Heaton, 1928) was based upon electrolysis of sodium nitrate in the presence of lead. Lead nitrate and NaOH formed and these reacted to form lead hydroxide; lead carbonate was produced after treatment with sodium bicarbonate. A similar method was the Sperry process.

Production of lead sulfate white utilised the waste products from the metallic lead extraction industry from furnace slags and low grade galena (PbS; *q.v.*). The most important process was Hannay's process, developed by J.B. Hannay (Terry; Heaton). Galena was shovelled into a small coke-burning furnace at red heat and consequently oxidised. The coke was also oxidised producing carbonic oxide. Pyrite (*q.v.*) could be added if there was insufficient sulfur to form a sulfate. The gases produced passed through flues into a condenser from where the lead sulfate was pumped into a settling vat. It was then washed and filtered. The final material had a composition lying between $PbO.3PbSO_4$ and $PbO.2PbSO_4$, the precise formula varying with the temperature at which the reaction took place. The Lewis process developed by John T. Lewis of Philadelphia, with a factory at Joplin, Missouri, used low quality galena and the slag resulting from smelting lead from high quality galena. Lead sulfate was sublimed and then shaken down from tall furnaces.

Lead chloride whites were manufactured for a short time in Germany (Schmidt, 1857 cited in Gettens *et al*., 1993c). Winter (1981) reports that this compound was used as a pigment on Japanese paintings on silk and paper during the thirteenth and fourteenth centuries.

Lead white was supplied either in dried cakes or ready prepared, ground with oil. The latter was safer, considerably reducing the dispersion of poisonous dusts. The pigment is permanent, relatively stable in all media (but particularly used in oil). It was rarely used in fresco, where lime white was substituted. However, Clark and Gibbs (1997) report that severe discoloration observed on a thirteenth century Byzantine manuscript was caused by the degradation of lead white to lead(II) sulfide. Kuchitsu *et al*. (1996) similarly have noted the blackening of lead white caused by the formation of galena after exposure to hydrogen sulfide. Cooper *et al*. (2002) have discovered that laser cleaning of works of art can also cause discoloration of lead white.

Lead white was commonly adulterated with other white pigments, particularly chalk, baryte and kaolinite (*qq.v.*). Gettens *et al*. use the Dutch term *loot wit* for a lead white mixed with chalk, often used as priming layers.

The pigment has been in routine use from antiquity to the present day, and is common on western easel painting. Due to the ubiquity of the pigment, a review of notable occurrences is beyond the scope of this work. Lead white has been reviewed by Gettens *et al*., Kühn, Lancelot *et al*. and Winter (the latter in the context of Far Eastern pigments). Notably, however, Zhou *et al*. (1997) have detected lead whites based on lead sulfate and various lead carbonates ($PbCO_2.Pb(OH)_3$, $2PbCO_3.Pb(OH)_2$, $3PbCO_3.2Pb(OH)_2.H_2O$ and $PbCO_3.Pb(OH)_2.H_2O$), on paintings and sculpture in the Tiantishan Grottoes, all adulterated with combinations of gypsum, kaolinite, quartz and calcium(II) oxalate (*qq.v.*; however, the latter is probably a secondary alteration product).

Many synonyms for lead white (or white lead) or, more specifically, terms denoting variants of source, manufacturing or composition (real and supposed) are known including the following: Berlin white, *blanc d'argent* and silver white, body white, ceruse, pure ceruse, *cerussa, cerussa alba*, condy's white lead, Cremnitz (or Kremnitz), Crems (or Krems) and Kremser white, Dutch white, flake white (or snowflake white), French white, Hamburg white, London white, Nottingham white, Pattison's white, Roman white, Slate white, Venetian white and Vienna white, although this last term was also used for lime white (Watin, 1773; Harley, 1982; Terry, 1893; Scott Taylor, 1885; Weber, 1923). Merrifield (1849) adds from her survey of historical (mainly Italian) sources the terms *albus, blacha* or *bracha, blanchet, biacca* and *ceruse*, and that it was called *albayalde* by the Spanish. Some of these terms are also of multiple or uncertain meaning. Paste white lead was white lead ground with linseed oil and sold ready prepared and reduced white lead and Hamburg white were adulterated with baryte (Heaton, 1928).

Names for lead sulfate-based whites were Flemish white, Mühlhausen white, sublimed white lead and Bartlett lead. Others played on the relative safety of this pigment such as non-poisonous lead white. A trade name, '*Freeman's Non-Poisonous White Lead*' was a mixture of lead sulfate, zinc white, magnesium carbonate and artificial baryte (barium sulfate, *qq.v.*; Zerr and Rübencamp, 1908). However, Heaton notes that at the time he was writing it was illegal to sell a pigment as lead white unless it contained 67–80% lead carbonate and 20–33% lead hydroxide chemically combined (British Engineering Standards Association 'standard specifications for Paints, Varnishes and Paint Ingredients'; Specification 239, issued March 1926). Zinc lead white was a mixture of zinc oxide and lead sulfate (Weber, 1923). Lead chloride white was also called *bleiweiss* (Gettens *et al*., 1993c).

Lead carbonates group; Lead halides group; Lead sulfates group; Barium sulfate; Cerussite; Chalk; Galena; Gypsum; Hydrocerussite; Lead carbonate; Lead carbonate hydroxide; Lead chloride hydroxide; Lead phosphate; Lead sulfate; Litharge; Pyrite; Quartz; *Blanc d'argent*; *Body white*; *Ceruse*; *Condy's white lead*; *Cremnitz white*; *Dutch white*; *Flake white*; *Flemish white*; *Kremser white*; *Nottingham white*; *Pattinson's white*; *Roman white*; *Silver white*; *Vienna white; Zinc white*
Clark & Gibbs (1997); Cooper *et al.* (2002); Dunn (1975); Gettens *et al.* (1967); Gettens *et al.* (1993c); Harley (1982) 166–172; Heaton (1928) 65–83; Kuchitsu *et al.* (1996); Lancelot *et al.* (1987); Merrifield (1849) ci; Pliny (1st cent AD/Rackham, 1952) XXXV.xix; Scott Taylor (1885) 97; Terry (1893) 183–245; Tingry (1804) 289; Vitruvius (1st cent BC/Grainger, 1934) VII.xii.1–2; Watin (1773/edition of 1785) 16–18; Weber (1923) 49–50, 55, 120–125; Winter (1981); Zerr & Rübencamp, (1906/1908) 89–116; Zhou *et al.* (1997)

LEAD WHITE, BASIC
White
Synonym, variant or common name

See: lead carbonate hydroxide and hydrocerussite.

LEAD WHITE, NEUTRAL
White
Synonym, variant or common name

See: lead carbonate and cerrusite.

LEADHILLITE
White
Generic compound

See: lead sulfates group.

LEAF GREEN
Green
Synonym, variant or common name

According to Riffault *et al.* (1874), leaf green is 'a very durable pale green pigment obtained by igniting a mixture of chromic oxide and pure aluminium hydroxide'. Mayer (1991) simply lists this as a synonym for chrome green (*q.v.*).

Chromium oxide; *Chrome green*
Mayer (1991) 49; Riffault *et al.* (1874) 551

LEEK GREEN
Green
Synonym, variant or common name

Mayer (1991) lists this as a synonym for chrome green (*q.v.*).

Chrome green
Mayer (1991) 49

LEIPZIG GREEN
Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

LEIPZIG YELLOW
Yellow
Synonym, variant or common name

Listed by Kühn and Curran (1986) as a synonym for chrome yellow (*q.v.*). Also sometimes given as Leipsic yellow (for example, Schiek, 1973).

Lead chromate(VI); *Chrome yellow*
Kühn & Curran (1986); Schiek (1973)

LEITCH'S BLUE
Blue
Synonym, variant or common name

Stated in nineteenth century British sources to be a mixture of Prussian and cobalt blues (*qq.v.*; for example, Salter, 1869; Carlyle, 2001). Heaton (1928) concurs with this, though indicates that it was, by then, an obsolete or rarely used pigment. Other more recent sources imply that it was a phthalocyanine pigment (*q.v.*). The pigment was also known as cyanine blue.

Phthalocyanine group; *Cobalt blue*; *Prussian blue*
Carlyle (2001) 472; Heaton (1928) 382; Salter (1869) 199

LEITCH'S BROWN
Brown
Synonym, variant or common name

Described by Salter (1869) as 'A most beautiful olive brown, soft and rich'; however, there is no actual information on its composition.

Salter (1869) 346

LEITHNER'S BLUE
Blue
Synonym, variant or common name

The earliest modern history of cobalt aluminium oxide ('cobalt blue'; *qq.v.*) pigments commences with Leithner in Vienna, who appears to have discovered the basic process of calcining cobalt oxide and alumina (aluminium oxide) in 1775. Brachert (2001) gives Leithner's blue as a synonym for Cobalt blue. It is also sometimes given as Leidner blue; this may additionally explain, by corruption, the use of Leyden blue for cobalt blue.
See: cobalt blue.

Cobalt aluminium oxide; *Cobalt blue*; *Thénard's blue*
Brachert (2001) 155

LEMNIAN EARTH
Red
Synonym, variant or common name

In the Borradaile edition of the *Strasburg MS* (15th cent; Clarke MS 2000) it is stated that Lemnian earth is synonymous with *Terra sigillata* (*q.v.*), 'sealed earth', as described in Merrifield's *The Art of Fresco Painting* (1846). Lemnian earth is named after a source on the island of Lemnos (Límnos), Greece.

Terra sigillata
Merrifield (1846) xxx; *Strasburg MS* (15th cent/tr. Borradaile, 1966) 24–25, 94–95

LEMON CADMIUM
Yellow
Synonym, variant or common name

A colour variant of cadmium yellow, one of the palest shades and also called mutrie yellow (Collier, 1886).

Cadmium yellow; *Mutrie yellow*
Collier (1886)

LEMON YELLOW

Yellow

Synonym, variant or common name

A term of variable application, the primary reference appearing to be to various chromate pigments: barium chromate, strontium chromate, zinc chromate and, to a lesser extent, lead chromate (*qq.v.*). Carlyle (2001), specifically discussing nineteenth century British sources, states that lemon yellow could also refer to platina yellow (*q.v.*; a term itself probably of variable meaning though originally supposed to be a potassium hexachloroplatinate) as well as zinc chromate. Heaton (1928) and Kühn and Curran (1986) cite it as a term for barium chromate, while Gettens and Stout (1966) and Harley (1982) indicate that it was applied to both barium and strontium chromates; the latter states that lemon yellow was first used as a colour name by the early nineteenth century British colourman Field, although the composition was not given at the time. Further, Sonoda (1999) has identified the azo compound CI Pigment Yellow 3 (CI 11710) in a 1985-purchased sample of a Flashe colour (Lefranc-Bourgeois) labelled 'lemon yellow'.

Azo pigments group; Lead chromates group; Zinc chromates group; Barium chromate(VI); Strontium chromate(VI); *Platina yellow*

Carlyle (2001) 157, 519, 521–523; *Color Index* (1971) 11710; Gettens & Stout (1966); Harley (1982); Heaton (1928) 382; Kühn & Curran (1986); Sonoda (1999)

LEOBSCHÜTZ GREEN

Green

Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's green and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*

Fiedler & Bayard (1997)

LEPIDOCROCITE

Yellow-Orange

Generic compound

The iron oxide hydroxide lepidocrocite (γ-FeOOH) belongs to the orthorhombic system (Buxbaum, 1989). Unlike the other iron oxide hydroxides, it has a layered structure with sheets of FeOOH held together by hydrogen bonds (Cornell and Schwertmann, 1996). Lepidocrocite is common in rusts and soils, though it is far less abundant than goethite and hematite (*qq.v.*); it is absent from calcareous soils. It may also be synthesised by (1) precipitating iron(II) chloride with sodium hydroxide in oxidising conditions, (2) precipitation of iron(II) hydroxide from iron(II) chloride and urotropin, then oxidised at 60°C with sodium nitrite and hydrochloric acid or (3) precipitation of 'green rust' (Fe^{2+} and Fe^{3+} hydroxy salts) from iron(II) chloride with ammonium hydrogen carbonate followed by oxidation at 50°C (Cornell and Schwertmann; Giovanoli and Brütsch, 1974). All processes produce orange, lath-like crystals.

Lepidocrocite is found in both natural and synthetic iron oxide pigments. Colour changes with increasing particle size from yellow to orange. David *et al.* (2001) have identified lepidocrocite as a component of yellow ochres (*q.v.*) used at Tell el Amarna. Wainwright *et al.* (2002) and Watchman *et al.* (1993) have detected it from rock paintings in Argentina and North Queensland, Australia, respectively.

The name lepidocrocite is derived from the Greek, meaning 'saffron-coloured flake'.

Iron oxides and hydroxides group; Goethite; Hematite; Ochre; *Yellow ochre*

Buxbaum (1998) 83; Cornell & Schwertmann (1996); David *et al.* (2001); Giovanoli & Brütsch (1974); Wainwright *et al.* (2002); Watchman *et al.* (1993)

LEPIDOLITE

Pink

Generic compound

Lepidolite is a potassium lithium aluminosilicate mineral with composition $K_2(Li,Al)_{5\text{-}6}[(Si_{6\text{-}7}Al_{2\text{-}1})O_{20}](OH,F)_4$, although substitution by Mn, Fe, Mg, Ca, Na, Rb, Ti and Sr may occur. It belongs to the mica group (*q.v.*) and occurs as relatively soft small scales or as cleavable tabular crystals (Rutley, 1988). Lepidolite is commonly pink due to the presence of minor Mn, but may be purple, red, grey, green or colourless. It was described by Klaproth in 1792 and is named from the Greek word *lepis* meaning 'scale' in allusion to the crystal habit (Dana, 1932). The layered structure of lepidolite (consisting of sheets of $(Si,Al)O_4$ tetrahedra separated by a complete layer of Ki, Li and Al – a trioctahedral mica) causes the crystals to cleave, while differences in the stacking of the layers results in several polymorphs: types 1M and $2M_2$ (both monoclinic) are the most common forms found, while types $2M_1$ and 3T (trigonal) are rare (Bailey, 1984; Deer *et al.*, 1992). Lepidolite occurs in acid igneous rocks, often forming by the replacement of muscovite or biotite (*qq.v.*); it is usually found with quartz, mica group minerals and cassiterite (*qq.v.*; Deer *et al.*, 1992). It is known from areas such as Rozna (Czech Republic), Bihar (India), Minas Gerais (Brazil), Nuristan (Afghanistan), Creuse (France), Saxony (Germany), Tuscany (Italy), Breage (Cornwall, England) and Auburn (Maine, USA).

The *Colour Index* (1971) mentions naturally occurring micaceous potassium aluminium silicates in the description of Pigment White 20/26.

Aluminium group; Mica group; Sheet silicates group; Biotite; Cassiterite; Muscovite; Quartz

Bailey (1984); *Colour Index* (1971) 77019; Dana (1932) 662; Deer *et al.* (1992) 308–311; Rutley (1988) 402–403

LEWIS AND BARTLETT'S WHITE LEAD

White

Synonym, variant or common name

According to Bersch (1901), Lewis and Bartlett's white lead pigment was produced as follows: 'In the lead smelting works at Zoplin, in Missouri, galena is smelted with limestone and coal, lead fume being obtained in addition to metallic lead. The lead fume deposits are ignited, and again worked for lead and lead fume. This last lead fume can at once be used as a white pigment; it consists principally of lead sulphate, lead oxide and zinc oxide.'

Lead oxides and hydroxides group; Galena; Zinc oxide; *Lead white*

Bersch (1901) 115

LEYDEN BLUE

Blue

Synonym, variant or common name

Leyden blue is listed by Zerr and Rübencamp (1906) as a term associated with cobalt blue (*q.v.*). It is probably a corruption of Leithner ('Leidner') blue (*q.v.*).

Cobalt blue; *Leithner's blue*

Zerr & Rübencamp (1906/1908) 202–204

LIBETHENITE

Green
Generic compound

Libethenite is a copper phosphate hydroxide mineral with composition $Cu_2(PO_4)(OH)$ which is sometimes known as chinoite (Yakubovich and Melnikov, 1993). It occurs as pale olive green to dark green crystals which may have prismatic, diamond-shaped or globular habit; it also occurs as aggregates and crusts, or with druse form infilling cavities. Libethenite was described by Breithaupt in 1823 and is named after its type locality of Lubietová (Libethen, in German) in the Slovak Republic. It occurs as a comparatively rare secondary copper mineral in the intensely weathered zones of concentrated copper sulfide ore deposits, where it is often found in association with malachite, quartz, limonite and brochantite (*qq.v.*). Noted localities for this mineral are Cornwall (England), Durango (Mexico), Arizona (USA) and Burra mine (South Australia; e.g. Bywater, 1984), with the best specimens reported to be from Kitwe, Zambia.

Libethenite has been identified by Bouherour *et al.* (2001) as mixed with cupro-wollastonite (*q.v.*) in an Egyptian sample from the period spanning the VIth Dynasty to Roman times. Although the natural mineral may not have been used as a pigment, its synthetic analogue, copper phosphate hydroxide, may be present as a by-product of the production of Egyptian blue and Han ('Chinese') purple (*qq.v.*).

Copper phosphates group; Brochantite; Cupro-wollastonite; Limonite; Malachite; Quartz; *Egyptian blue*; *Han purple*

Bouherour *et al.* (2001); Bywater (1984); Yakubovich & Melnikov (1993)

LICHENS GROUP

Purple
Group term

Lichens are slow growing, but complex life forms consisting of a fungus (mycobiont) and an alga (photobiont). The algae may either be members of the chlorophyta, which includes the green algae such as most plankton, or the cyanobacteria, the blue-green algae. Both contain chlorophyll and therefore undergo photosynthesis. The algae may be either single cells or filamentary chains of cells. Some lichens have more than one type of alga, and the same species of alga may exist in several different lichens. The combined organisms produce a distinct lichen body called a *thallus*. Because each lichen type has a unique fungus, the lichen species are named after this component and belong to the Phylum Ascomyota. Most lichen-forming fungi are members of the ascomycetes, the fungal group that includes the destructive bread moulds, the edible morels, and the commercially important baking and brewing yeast. A very few are members of the basidiomycetes, which include mushrooms. There is still some debate as to whether the relationship between the fungal and algal components is symbiotic or parasitic. While on one hand the cells of both components appear healthy, on the other, the photosynthesising algae appear to be 'trapped' by the fungus, providing it with nourishing carbohydrates, and thus allowing lichens to thrive in a large number of environments lacking in organic matter, which the fungus alone would be unable to colonise. Although lichens are commonly found growing on trees, thousands of species also colonise rocks. Many of these species are specific to the mineralogy of the rock. The biology and diversity of lichens is reviewed by Purvis (2000) and Purvis *et al*. (1992).

Certain lichens produce dyestuffs that are extracted by three methods (see Diadick Casselman, 2001 and Brough, 1988): the ammonia method, the boiling-water method and the photo-oxidised method. Typically, the ammonia method was most widely used and produces red, magenta and violet hued dyes. The boiling water method produces brown, rust and yellow coloured dyes and the photo-oxidising method produces blue dyes. Lichen dyes do not technically require a mordant since they are substantive. However, the use of mordants enables variation in the colours produced. Primarily lichens are used for dyeing fabrics, particularly wools. Their use as pigments on lake substrates is known but limited. Further identifications may be forthcoming.

The dyestuffs extracted by the ammonia method use as raw ingredients orchil (*q.v.*) lichens of the Roccellaceae, particularly a family of coastal lichens, but also a range of others, notably cudbear (*q.v.*), *Ochrolechia tartarea*. In the case of the Roccellaceae the two main colouring substances are erythrin and lecanoric acid (Wallert, 1986b). Treatment with ammonia forms orcin, which then oxidises to orcein, $C_{28}H_{24}N_2O_7$. This is the principal colouring matter and it has been extensively researched by Hans Musso who has published numerous papers on this compound. The key works are listed by Cooksey (1997), while Musso (1956, 1960) provide reviews.

The boiling-water method is the simplest and most traditional of methods used for extracting lichen dyes from all species. The lichens (perhaps pre-soaked) were layered with the material to be dyed, water was added and then everything boiled for anything from an hour up to several days. The material was inspected when the dyebath had cooled and the process was repeated if necessary.

The photo-oxidising method produces blue dyes, but they are not fast and fade rapidly. These dyes are primarily produced from the lichens of the *Xanthoria* species. The lichens are soaked in a small amount of ammonia for two days and then water is added. After about three weeks a pink colour is produced, but a further couple of months of soaking is required. Following this time, the pink liquid is strained off and water added. The material to be dyed is then added, and the bath heated to 28°C for an hour. A pink dye is produced on the substrate. On removal from the bath, the material must then be dried in sunlight and a blue colour forms (Diadick Casselman, 2001).

Other species of lichen stated as being used to produce dyes include *Evernia*, *Cladonia*, *Usnia* and *Ramalina* (Wallert, 1986b), while in a survey of some 250 documentary sources, Diadick Casselman (2002) identifies a number of specific botanical names associated with European dye lichens, including *Parmelia omphalodes* (L.) Ach., *P. saxatilis* (L.) Ach., *P. parietina* (L.) Ach., *Ochrolechia parella* (L.) Massal ('parelle' or 'pommelée') and *O. tartarea* (L.) Massal. (N.B.: *O. tartarea*, 'cudbear', was formerly known as *Lecanora tartarea* (L.) Ach.) and various Roccella species such as *R. fimbrata*, *R. fuciformis* (L.) D.C., *R. montagnei* Bél., *R. phycopsis* (Ach.) and *R. tinctoria*, the latter used to manufacture litmus (*q.v.*). Fugitive, blue dyes can be produced from *Xanthoria* spp. (Diadick Casselman, 2001; Ponting, 1981; Thurstan, 1975). Diadick Casselman (2001) lists all recognised lichen species and the colours they produce by different extraction methods and mordants.

A traditional method for preparing a violet-blue from a lichen source is given by Peacham in *The Gentlemans Exercise*

(1612): 'Korke or Orchall. Take fine Orchall and grinde it with vnslekt lime and vrine, it maketh a pure violet; by putting to more or lesse lime, you may make your violet light or deep as you will' (cf. Harley, 1982). The Bolognese MS (fifteenth century, Clarke MS 160; cf Merrifield, 1849) also contains a description of preparing and using *oricello* (*q.v.*) as a purple underpainting for gold. During the seventeenth to eighteenth centuries, orchella weed or simply 'weed' fetched £1000 per ton on the London market. Collection of the lichens for sale as dyes was centred around cottage industries on the coasts of Scotland, Scandinavia and the Canary Islands, and the dye factory in Glasgow processed 250 tons per year (Purvis, 2000).

Other lichens were also used to prepare paints, particularly by native North Americans (Brough, 1988). For example, *Physcia* species were collected by the Navajo of New Mexico and mixed with resin from the Piñon pine (*Pinus edulis*) to produce a deep yellow paint, while *Letharia vulpina* was collected by the Salishan (North-Western USA and British Columbia, Canada) and the Thompson tribe of British Columbia and used as a yellow paint either by extracting in water or mixing with melted deer fat; the same lichen was also used by the Yuki of California in the form of a thick decoction. *Pseudephebe pubescens* was used by the Haisla and Hanaksiala of British Columbia to make black paint for wood. *Xanthoparmelia chlorochroa* (*Parmelia molliuscula*) was used by the Navajo in a paint for leather. *Xanthoria elegans* was used by the Haisla and Hanaksiala as a pigment for face paint while the Kitasoo (also British Columbia) used it to produce a yellow pigment for paint. Finally, various *Bryoria* species (*B. capillaris*, *B. glabra* and *B. trichodes*) were burned into a black powder by the Haisla and Hanaksiala to make paint for wood.

The historical terminology for lichen-derived dyestuffs has been extremely confused, many mediaeval manuscripts giving the term lachmus (or orthographic variants) to litmus or lichen dyes and others to dyes from Crozophora species. These latter were otherwise called folium or turnsole (*qq.v.*). Boltz (1549), for example equates Legmosus with Tumüss. Brachert (2001) points out that these meanings were confused until the 19th century. Recent research by Diadick Casselman (2002) has helped resolve some of this. Many names are essentially linguistic and dialectic variants on orchil, cork and crottle. Orchil, archil, *orseille* and *oricello* refer primarily to dyes extracted by the ammonia method from *Rocella* species. These lichens are also known as *fucus* and *tournesol*. Further confusion arising as here this does not imply dyes from *Crozophora.* Cork (*q.v.*), *corker*, *corcur*, *korkir*, *korkje* and the synonymous *cudbear* refer to dyes extracted from *Ochrolechia tartarea* by the ammonia method. Litmus has been applied both to cudbear and, more typically, to *Rocella tinctoria* (Thurstan, 1975). However, cork has also been used as a name for dyes extracted from *Parmelia omphalodes* by the boiling water method (Mairet, 1916).

An excellent bibliography on lichen dyes has been compiled by Cooksey (1997). Recently, all aspects of lichen dyes have been reviewed by Diadick Casselman (2001).

Orcein; *Cork*; *Cudbear*; *Folium*; *Litmus*; *Orchil*; *Oricello*; *Turnsole*
Boltz von Ruffach (1549/Benziger 1913) 80; Brachert (2001) 149; Brough (1988); Cooksey (1997); Diadick Casselman (2001) 13, 18, 29, 31–36, 39; Diadick Casselman (2002); Harley (1982) 63; Mairet (1916) 16–23; Merrifield (1849) 474; Musso (1956); Musso (1960); Peacham (1612); Ponting (1981) 7, 48, 121; Purvis (2000) 4–48, 93–94; Purvis *et al.* (1992); Thurstan (1975) 27–30; Wallert (1986b)

LIGHT RED

Red
Synonym, variant or common name

Harley (1982) notes that light red came into current use as a colour name during the eighteenth century, when it generally indicated a brownish red prepared by burning yellow ochre (*q.v.*). However, by the time Ibbetson was writing (Ibbetson, 1803), light red was 'either calcined green vitriol mixed with a quantity of other substance, and called Venetian red; or calcined Yellow Oker which I prefer'. Salter (1869) describes it as 'an ochre of an orange-russet hue', adding that 'Terra Puzzoli, a volcanic production, is a species of light red, as is the Carnagione of the Italians'.

Harley also mentions brown red and English red as associated terms of uncertain composition. Antwerp red appears also to be a related term.

Earth pigments group; Iron oxides and hydroxides group; *Ochre*; *English red*; *Venetian red*; *Yellow ochre*
Harley (1982) 120, 122; Ibbetson (1803); Salter (1869) 149

LIGHT SPAR

White
Synonym, variant or common name

See: witherite.

LIGHT WHITE

White
Synonym, variant or common name

According to the 1757 edition of the *Art of Drawing*, as well as de Massoul, light white was prepared as follows: 'To make this White, take a sheet of silver, which you beat as thin as paper; cut it in pieces about the size of a halfpenny; steep it in Aqua Fortis [nitric acid] for twenty four hours; being dissolved, pour off the Aqua Fortis, and wash what is left at the bottom of the vessel, five or six times in distilled water, till there be no remains of Aqua Fortis left in the dissolution; which may easily be known by touching it with your tongue. It is afterwards dryed.'

One would suppose that this forms silver nitrate ($AgNO_3$), though that compound is readily soluble in water and the washing process would probably dissolve it. A more likely explanation is that a proportion of silver sulfate (Ag_2SO_4) is formed, this being substantially insoluble. In support of this suggestion we note that (a) the recipe implies only a minor precipitate remains; (b) silver sulfate is readily prepared from silver nitrate and sulfuric acid (Richards and Jones, 1907); (c) 'Aqua Fortis', while being 'more or less concentrated' nitric acid, was formed from potassium nitrate and iron(II) sulfate hydrate, allowing for the possible presence of some sulfate ions in solution (for example, Beguin, 1669; Crosland, 1962).

The term is probably synonymous with 'Ackermann's white' (*q.v.*). However, the relationship with 'silver white' is more complex in that this generally referred to lead white in English, to zinc or lead whites in French ('*blanc d'argent*'), with '*blanc léger*' (*qq.v.*) probably being the accurate translation of light white (Harley, 1982).

Ackermann's white; *Blanc d'argent*; *Blanc léger*; *Lead white*; *Silver white*; *Zinc white*
Art of Drawing (1757); Beguin (1669) 50, 58; Crosland (1962) 90–91; Harley (1982) 173–174; Massoul (1797); Richards & Jones (1907)

LIGNITE

Black-Brown
Generic compound

Lignite is the lowest rank of coal (*q.v.*) and represents the earliest phase in the 'metamorphism' of vegetable organic matter by burial and an accompanying increase in temperature over geological time. Lignite deposits are brown in colour, often earthy and friable and contain, in their natural state, recognisable plant fossils. Unlike the higher rank bituminous coals, they are very porous and have a high moisture content. When ground they produce a rich warm brown pigment not unlike umber (*q.v.*), but with a good transparency. However, the pigment may be fugitive when exposed to sunlight.

Lignite-related deposits may also be referred to as humic earths (*q.v.*) and, in earlier literature, 'bituminous earths'; although the latter term is obsolete. Bitumens (*q.v.*) are now defined as a distinct set of organic mineral substances.

Lignite-based pigments are listed under the terms Vandyke brown and its synonyms Cassel earth (*qq.v.*) and Cologne earth (Feller and Johnson-Feller, 1997). Nocera earth is also rich in humic earths, and siennas (*q.v.*) are described by some authors as having traces of 'organic or peaty material' (Church, 1901).

Earth pigments group; Bitumen; Coal; Humic earth; Siema; Umber; *Cassel earth*; *Vandyke brown*
Church (1901); Feller & Johnston-Feller (1997)

LILY GREEN

Green
Synonym, variant or common name

See: iris green.

LIME

White
Generic compound

Strictly speaking, lime is calcium oxide (CaO). This is acquired by burning or 'calcining' limestone to temperatures of c. 900°C, which causes the calcium carbonate (calcite *qq.v.*) to disassociate to calcium oxide and carbon dioxide (Gettens *et al.*, 1993a). Lime forms the base for cements, mortars and concretes. However, the composition of the limestone being variable, the true composition of the lime is also variable, and the term may be used to described calcined limestone in general. Lime may also be referred to as 'quicklime', 'unslaked lime' or 'lump lime'. Lime will only harden into a cement when water is added to it. The process is called 'slaking', hence 'slaked lime', referred to as 'lime putty'. Calcium oxide hydrates in the presence of water to calcium hydroxide which also occurs (rarely) as the mineral portlandite (*q.v.*). A water-rich mixture of slaked lime can be used as a paint – 'limewash'. As the paint dries (cures), water is lost from the compound as carbon dioxide is reabsorbed from the atmosphere and it reverts back to calcium carbonate. This can be a slow process taking several years for the reaction to go to completion, therefore residual amounts of calcium hydroxide are to be expected in the pigment. The reactions are discussed in various sources. Boynton (1979) provides a good review of the suitability of various calcium carbonate sources as limes and the reactions involved in their manufacture.

Calx, lime in Latin, provides the etymological root for calcium, calcite and calcination. The paints produced from this material are known as lime white, limewash and whitewash. Historical synonyms include *bianco di sangiovanni* (*q.v.*; and orthographic variants), the literal translation *St John's white*, and *Vienna white*, however this latter term also refers to lead white (*qq.v.*). It has primarily been used as an industrial and house paint and as an extender to other pigments. Although lime is generally used as a construction material, it has been manufactured since the early Neolithic period (in the Levant) and used for floor and wall covering, the construction of vessels (so called '*vasaille blanche*') and sculpture, notably the two-thirds life scale figurines from 'Ain Ghazal (Grissom, 2000) which have eyes painted in asphalt.

Lime derived calcium carbonates and calcium hydroxides are ubiquitous as pigments used in frescos. Lime white, when used in this technique, required no binder and was a highly stable pigment. Lime-based mortars were used widely as the *intonacco* or *marmorino* final coat for frescos from the Greek through Renaissance periods and remain in use to the present day. Ground marble was commonly used as an aggregate in this uppermost mortar layer.

Lime is well known for its alkaline properties and its abilities to neutralise acids. For this reason it was recommended as an additive to coal tar-based paints. Rivington (1901) describes tar paint, in which 13 lb of slaked lime were added to nine gallons of coal tar, with naphtha and sand. The lime was essential for neutralising the acids in the tar, but would have also furnished the paint with durable, weatherproof properties. Lime reacts strongly with eggwhite to form a very solid pigment. Sciuti *et al.* (2001) discovered that for frescos in a first century AD Roman painting, the pigments were mixed with lime and soap, the soap added to neutralise the lime's effect on the alkali sensitive pigments used.

Calcium carbonates group; Calcium group; Calcite; Calcium hydroxide; Limestone; Portlandite; *Bianco di Sangiovanni*; *Lead white*; *Vienna white*
Boynton (1979); Gettens *et al.* (1993a); Grissom (2000); Rivington (1901) 426; Sciuti *et al.* (2001)

LIME BLUE

Blue
Synonym, variant or common name

The origin of this term probably lies with the production of the synthetic copper carbonate hydroxide pigment known as blue verditer (*q.v.*). According to Harley (1982), traditional copper blue recipes frequently 'suggest the use of some form of lime, such as powdered eggshell'. (N.B.: Of course, eggshell (*q.v.*) is calcium carbonate.)

Bersch (1901) associates lime blue with the term Bremen blue (*q.v.*), describing them as copper hydroxide-based pigments. However, that author also includes blue verditer among his synonyms, which is a copper carbonate hydroxide. In a more detailed description of the manufacture of lime blue Bersch further describes it as a copper blue mixed with gypsum (*q.v.*), different shades being obtained depending on the gypsum content and used 'more for distemper than as an artists' colour'. Zerr and Rübencamp (1906) on the other hand state that the distinction between Bremen and lime blues was in the nature of the precipitating agent mixed with the copper sulfate precursor – sodium hydroxide for the former, calcium hydroxide (prepared from 'purely fresh, burned lime') for the latter. Finally, Heaton (1928) states that lime blue was a then-current term for a 'variety of ultramarine' (*q.v.*).

Copper carbonates group; Copper group; Copper oxides and hydroxides group; Gypsum; Ultramarine; *Blue verditer*; *Bremen blue*; *Eggshell*
Bersch (1901) 228; Harley (1982) 49; Heaton (1928) 382; Zerr & Rübencamp (1906/1908) 162

LIME GREEN

Green
Synonym, variant or common name

According to Bersch (1901), lime green is a mixture of copper arsenite and calcium sulfate. Lime green is also listed under *Colour Index* (1971) reference CI 77412; patent green (*q.v.*) was apparently synonymous.

Calcium sulfates group; Copper arsenite group; *Patent green*
Bersch (1901) 250; *Colour Index* (1971) 77412

LIME WHITE

White
Synonym, variant or common name

See: lime.

LIME-ARSENIC GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*), the term deriving from its mixed nature.

Emerald green
Fiedler & Bayard (1997)

LIMESTONE

White
Generic variety

The term limestone covers an enormous range of sedimentary rock types, composed primarily of the carbonate minerals calcite, and the polymorphs aragonite and vaterite ($CaCO_3$) and dolomite ($MgCO_3$) (*qq.v.*). Detrital clastic grains ('intraclasts' of quartz, etc.) may also be present in minor amounts. Carbonate in sediments exists in two basic and distinct forms; as *micrite*, which is a fine, cryptocrystalline 'mud' or as coarser, crystalline *sparite*. Other particles that may be present are called allochems; these include fossils (bioclasts) and intraclasts. Additional carbonate clasts include ooids which are c. 0.5 mm diameter spheres composed of concentric layers of carbonate enclosing a central nucleus; peloids are essentially the same as ooids only larger, and pellets, carbonate fragments, usually rounded but showing no internal structure. Classification of carbonate rocks follows two schemes: that of Dunham (1962) and Folk (1959, 1974). The range of limestones and their components are discussed in Boynton (1979) and Tucker and Wright (1990).

Carbonate sedimentary rocks are dominantly of marine origin. Many limestones are composed of fossilised shell debris in various states of comminution, some fine grained carbonates such as chalk (*q.v.*) may be entirely composed of sub-microscopic phytoplankton. Algal mats secrete aragonite particles and coral reefs are $CaCO_3$ structures which may be preserved, fossilised, intact or degraded to produce other limestones. As discussed above, allochems such as faecal pellets and ooliths may be present and contribute the dominant component of limestones. Ooliths typically form in shallow water lagoons where there is significant wave action. Non-marine limestones occur in some lacustrine deposits and freshwater limestones form in caves ('speleothems' otherwise known as flowstones, stalagmites and stalactites) as well as infilling fractures and in association with hot springs. In all cases these form as a result of the dissolution and re-precipitation of $CaCO_3$ derived from limestone bedrocks. Such rocks are known as tufa, or when banded, travertine (*q.v.*). Primary carbonate, generally in the form of aragonite, is dominantly derived from the secretions of marine organisms; it is a biogenic mineral. Limestones undergo metamorphism to form marbles (*q.v.*). Because the polymorphs of $CaCO_3$ are stable at a wide range of temperatures and pressures, no new mineral species are produced in this process. Marbles are crystalline and generally possess a medium to coarse grain size. However, architecturally, the term 'marble' may be applied to any calcium carbonate-rich rock capable of taking a polish.

Calcination of limestone produces lime (*q.v.*) which may be slaked with water and during the drying process it converts to synthetic calcium carbonate in the form of cement.

Various forms of limestone (particularly chalk) and lime have found abundant usage as a pigment either as bases for lakes, or as plain white and whitewash. Naruse (1996) has noted that there is documentary evidence for the use of limestone as a white ground coating in the construction of Kofuku-ji Temple, Japan, in 734 AD. Pedersen (1974) has detected limestone in Argentinian rock art. There is some documentary evidence for the use of travertine as a substrate for lake pigments.

Calcium carbonates group; Calcium group; Aragonite; Calcite; Chalk; Dolomite; Lime; Marble; Travertine; Vaterite; *White earth*; *Whiting*
Boynton (1979); Dunham (1962); Folk (1959); Folk (1974); Naruse (1996); Pedersen (1974); Tucker & Wright (1990)

LIMONITE

Yellow
Common generic composite

Once believed to have a definite formula ($2Fe_2O_3.3H_2O$), limonite has now been shown to consist of crypto-crystalline goethite or lepidocrocite (*qq.v.*) plus adsorbed water; therefore the general formula $FeO.OH.nH_2O$ may be more appropriate. Limonite is now used as a field term and is acceptable in the description of poorly crystalline hydrated oxides of iron which have not been identified (Deer *et al.*, 1992). Limonite deposits are likely to contain in addition to goethite and lepidocrocite, hematite, colloidal silica, phosphates (organic), clay minerals (*qq.v.*), minor hydrous aluminium oxides and other products of organic decomposition.

Terms that have been used synonymously include hematite, brown hematite, bog iron ore, pea iron ore (a variety having a pisolitic structure) and yellow ochre (*q.v.*). Turgite is a historical term probably describing hematite-rich limonite, therefore more likely to produce a red ochre (*qq.v.*) than a yellow one.

The numerous historical identifications of limonite in a pigment context (such as Gettens, 1955; Panev, 1979; Watson, 1969; Wei-Yeh *et al.*, 1983; Woodhouse, 1969) should now be viewed with circumspection.

Clay minerals group; Iron oxides and hydroxides group; Goethite; Hematite; Lepidocrocite; Turgite; *Red ochre*; *Yellow ochre*
Deer *et al.* (1992) 582; Gettens (1955); Panev (1979); Watson (1969); Wei-Yeh *et al.* (1983); Woodhouse (1969)

LIQUID RUBIATE

Red
Synonym, variant or common name

According to Field (1835), a 'concentrated tincture of madder of the most beautiful and perfect rose colour and transparency' was available, supplied under the names liquid rubiate and liquid madder lake; Salter (1869) adds the term rose rubiate. It seems to have been suitable for a wide variety of applications from watercolour through oil painting to fabric printing and map washing.

Madder
Field (1835) 98–99; Salter (1869) 145

LITHARGE

Yellow
Generic compound

First described by Wherry in 1917, the mineral litharge is a tetragonal lead(II) oxide mineral with composition PbO. It occurs as soft red crusts, often in association with cerussite and hydrocerussite (*qq.v.*), as an oxidation product of metallic lead deposits in areas such as Lower Saxony (Germany), Laurion (Greece), Tuscany (Italy), Derbyshire (England) and Bisbee (Arizona, USA); it may oxidise further to form minium (*q.v.*). Litharge is the low temperature polymorph of the orthorhombic lead(II) oxide massicot (*q.v.*), which is stable above approximately 540ºC. However, as FitzHugh (1986) has pointed out, mineral litharge is different from 'painter's' litharge.

The term litharge has an extensive historical derivation and distinct range of meaning. Litharge originally referred to a by-product of the extraction (cupellation) of precious metals, particularly silver, which is found in association with the lead ore galena (*q.v.*). This technique is of great antiquity, with direct evidence for its use from about 600–500 BC (Agricola, 1556; Tylecote, 1976). The word litharge itself derives from the Greek λιθαργνροζ, from λιθ–οζ, 'stone', and αργνροζ, 'silver', passing into Latin as *lithargirium*. Use in English then comes by descent from the Latin through orthographic forms such as *litargirij* or *lithargiry*, or French with the *litarge* or *litharge* forms (*OED*, 2002).

Several distinct meanings developed from this, notably the application to oxidation product(s) of lead. For example, Ray (1674) states that 'When the furnace is come to a true temper of heat the Lead converted into Litharge is cast off' (cf. *OED*). Cotgrave (1611) defines litharge as 'Litharge … white lead; lead mixed with the drosse of siluer and brasse.' Chambers (1738) adds that 'Artificial Litharge, which is of two kinds, viz. that of gold, and that of silver; or rather it is the same, with this difference, that the one has undergone a greater degree of fire than the other.' It appears from this that the relationship to silver cupellation was retained in a sense, though 'litharge of silver' and 'litharge of gold' became colour descriptors rather than of chemical origin; the gold variety supposedly contains a small proportion of lead(II,IV) oxide (*q.v.*), 'red lead'.

In the context of painting, litharge is most frequently mentioned historically among European sources in the context of driers (siccatives) added to oil. Baldinucci (1681), for example, states: 'It also has various medicinal properties such as that of a desiccant which is used to accelerate the drying time of walnut and linseed oils. Painters add it to cooked oil when blending colours that would otherwise require much time to dry.' It is also described for this purpose in such texts as the Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849), the Brussels MS (1635, cf. Merrifield, 1849), the notebook by de Mayerne (1620), De Piles, (1684) *Les Premiers Elements de la Peinture Practique* and the MS of Gandy (1673–99). The term and context continued to be used, so that according to Toch (1916) 'flake' litharge was a form used by 'varnish makers or oil boilers' to prepare drying oil.

FitzHugh, referring to Harley (1982), states that early descriptions of the manufacture of red lead from lead metal imply its formation from litharge. Litharge is often found as a major impurity in synthetic red lead (lead(II,IV) oxide) occurring either as relict starting materials or as by-products. Using Raman spectroscopy, Burgio *et al.* (1999a) identified small quantities of litharge and massicot on a Thai manuscript (dated to ca. 1800 AD), which was attributed to impurities in the natural sample of red lead or imperfect synthesis of the red lead used elsewhere on the manuscript. Using the same technique, Edwards *et al.* (2001) identified litharge on eleventh century wall paintings from San Baudelio de Casillas (Soria, Spain); however, Smith and Clark (2002) suggest in this case that the Raman spectrum for the material was erroneously interpreted and is actually that for massicot. Other identifications of litharge include those by: Duang *et al.* (1987) from Buddhist wall paintings in north-west China; Le Fur (1990) as a pigment in dynastic Egyptian painting; Mairinger and Schreiner (1986) among pigments in Carolingian and mediaeval mural paintings in the Müstair Convent, Switzerland; Preusser *et al.* (1981) on painted Greek gravestones; Wang *et al.* (1993a) among mural pigments of the Qutan Temple, Qinghai, China; Yamasaki (1957, 1972) in pigments used in the mural paintings of the twelfth century temple of Hõõdõ, Uji, near Kyoto and the Horyuji Temple, Nara, Japan.

Lead oxides and hydroxides group; Cerussite; Galena; Hydrocerussite; Lead(II,IV) oxide; Massicot; Minium
Agricola (1556/trans. Hoover & Hoover, 1950) 465; Baldinucci (1681) 85; Burgio *et al.* (1999a); *Chambers* (1738); Cotgrave (1611); Duang *et al.* (1987); Edwards *et al.* (2001); FitzHugh (1986); Gandy (1673–99); Harley (1982) 123–125; Le Fur (1990); Mairinger & Schreiner (1986); Mayerne (1620); Merrifield (1849) 692; *OED* (2002) 'Litharge'; Piles (1684); Preusser *et al.* (1981); Ray (1674); Smith & Clark (2002); Toch (1916) 54; Tylecote (1976) 38; Wang *et al.* (1993a); Wang *et al.* (1993b); Yamasaki (1957); Yamasaki (1972)

LITHOL RED

Red
Synonym, variant or common name

This is a red pigment formed by the diazotization of 2-naphthylamine-1-sulfonic acid with 2-naphthol and a barium, calcium or sodium salt, falling in the group of β-naphthol azo pigments. Numerous grades have been produced including lithol maroon, a barium lithol red co-precipitated with a resin (usually tree rosin) to form a barium resinate. It is primarily the barium and calcium lithol reds which are used in paints, however. Lithol red was discovered by P. Julius in 1899. The name lithol red was, according to Ludwig (1973), probably derived from 'lithography', thus implying the pigment's suitability for printing purposes.

It is also known as barium lithol red, calcium l.r. and sodium l.r. depending on the associated anion. Other associated terms include lithol scarlet and l. rubine. Listed by the *Colour Index* (1971) as CI 15630/Pigment Red 49.
See also: azo pigments group: β-Naphthol sub-group.

Azo pigments group: Lakes sub-group; Azo pigments group: β-Naphthol sub-group
Colour Index (1971) 15630; Ludwig (1973)

LITHOPONE

White
Synonym, variant or common name

Lithopone is formed through co-precipitation of zinc sulfide and barium sulfate. Lithopones are intimate mixtures of the components rather than solid solutions. It is said to have been discovered by G.F. de Doubet around 1850 and first produced on a large scale by J.B. Orr in 1874, hence the alternative name of 'Orr's zinc white' (*q.v.*). Other synonyms include Griffith's White, Griffith's Patent Zinc White and Oleum White. The *Colour Index* (1971) designation is CI 77115.

Zinc sulfides group; Barium sulfate; *Griffith's white*; *Orr's zinc white*
Colour Index (1971) 77115

LITMUS

Red-Blue
Synonym, variant or common name

Certain lichens, notably those of the Roccellaceae family produce dyestuffs and it is to these, and primarily *Rocella tinctoria*, that the term litmus refers. Tingry (1804) states that 'another kind of lichen which grows on the rocks like moss' is employed to make litmus in Lyon. This is, however, 'inferior to that of the Canaries'. Litmus, produced from *R. tinctoria* was being manufactured until the 1960s by the firm of Messrs Johnson of Hendon and Radlett in the UK (Purvis, 2000).

A traditional method for preparing a violet-blue from litmus ('orchil') is given by Peacham in *The Gentlemans Exercise* (1612): 'Korke or Orchall. Take fine Orchall and grinde it with vnslekt lime and vrine, it maketh a pure violet; by putting to more or lesse lime, you may make your violet light or deep as you will' (cf. Harley, 1982). Goeree (1670) comments that litmus '*soll… ein wenig mit einer andern blauen Farbe brechen, weil es sonsten dunkelroth und bald von der lufft verzrhret wird*' ('should be broken with another blue colour as otherwise it will become dark red and soon fade in the air').

The specific term 'litmonsy' was used by Hilliard in the seventeenth century, while the *Compendium* of 1808 lists it as litmus, and this is still a familiar term in chemistry today as a pH indicator. The term litmus is now also used in a strictly chemical sense to refer to one of the molecular species that occur in these lichens. The chemistry involved is initially the same as for orcein (*q.v.*) where the same precursors in lichens are hydrolysed to orcinol, which is then oxidised by air in the presence of ammonia to give phenoxanone derivatives; under the more alkaline conditions further oxidation and polymerisation occurs to give litmus (Cooksey, 1997).

Other associated terms include *orchil* (*q.v.*) (and variants such as 'orchall' and 'arcel') and *cork* ('korke'), as mentioned by Peacham. Other terms listed by Harley include *vercella* (citing Ray, a later seventeenth century visitor to Malta, where this grew) and the Welsh *cencerig*.

Evidence for the use of litmus as a pigment has been found in documents relating to the revels at court in the time of King Edward VI and Queen Mary in Britain where litmus was purchased (Losley MS, 1551), probably to paint a stage set; it is mentioned in original documents from Hampton Court palace in 1532 which state that, 'lytmouse, a lichen purple' was purchased (Law, 1885) and in accounts for work carried out at the parish church in Bletchingly, Surrey, 1546–52(53) in which lyttmouse was also included (Daniel-Tyssen, 1869).
See: lichens group for a fuller discussion of lichens.

Lichens group; Orcein; *Cork*; *Orchil*
Compendium (1808); Cooksey (1997); Daniel-Tyssen (1869) 101 ff.; Goeree (1670) 277; Harley (1982) 63–64; Hilliard (1624/Thornton & Cain, 1981) 88; Law (1885) 363–365; Losley MS (1551/1914) 101 ff.; Peacham (1612) 85; Purvis (2000) 94; Ray (1673) 296; Tingry (1804) 356–357

LOGWOOD

Blue-Purple
Common generic composite

Dye derived principally from *Haemotoxylum campechianum* L. (formerly *Haemotoxylon c.* L.) and also *H. brasiletto* Karsten (Leguminosae). The former species grows in Central America and the West Indies. European explorers originally found this in the area around Campeche (Yucatan Peninsula, Mexico) in the sixteenth century exporting it in the form of large blocks, hence the names logwood and blockwood, as well as campeche (or campeachy) and peachwood; it was also known as Province or St Martin's wood. *H. brasiletto* has an American distribution and is called peachwood as well as Limawood; there appears to have been little commercial distinction in practice (Standley, 1967, cf. Haude, 1998; Nowik, 2001). The Aztecs called the tree from which the logwood dyestuff was extracted *quamochitl*, *huitzeuahuitl* and *uitzquauitl*, while the Spanish referred to it as *brasil* (Emmart, 1961; cf. Haude, 1998); Wallert (1995c) indicates that the dyestuff was used in Mesoamerica for manuscript illumination. (The use of the term 'brasil' has historically caused confusion with 'brazilwood' (*q.v.*), a term normally applied to various species of *Caesalpinia*.)

About 10% of the heartwood is hematoxylin, with tannins and resins also present. The hematoxylin oxidises to the compound *haematin* during the dyeing process; because it is pH sensitive, a range of colours can be prepared ranging from red to purple and blue, as well as black (*Colour Index*, 1971). These are listed by the *Colour Index* as CI 75291/Natural Black 3 and 4.

Logwood is mentioned as a cheap and commonplace raw material in seventeenth century works on watercolour painting (Harley, 1982).

Brazilwood; Haematin
Colour Index (1971) 75291; Emmart (1961); Harley (1982) 64–65; Haude (1998); Nowik (2001); Standley (1967); Wallert (1995c)

LOKAO

Green
Synonym, variant or common name

Green dye produced from the bark and roots of *Rhamnus utilis* Decne. (*hong-pi-lo-chou* in Chinese) and *R. globosa* Bunge (hist.: *R. chlorophora* (*-us*) Decne.) (*pé-pi-lo-chou*) and *R. catharticus* (Schweppe, 1992). This colour was first brought from China in 1845, arriving in to Europe (Lyon) in 1846 on a piece of cloth by the delegate from their chamber of commerce. Its properties, however, were not known until 1852. The Dutch obtained it in 1853 from their consul in China (Rondot, 1858). This pigment is described by Terry (1893): 'This pigment, which is also known as "Chinese green," was first met with as a sediment left after dyeing cotton cloths with the barks of one or more species of buckthorn, notably *Rhamnus chlorophorus* and *R. utilis*, and passing in China under the general name of Lo-Kao. This sediment is spread on blotting paper and thus dried, forming thin cakes. Latterly, the juice afforded by the berries of the same trees is extracted by pressure, absorbed by alum, and dried in the same form of little cakes.' Terry also mentions the London

price in 1861 (7s. 6d. an ounce), so presumably it was available there from at least around that time.
See: rhamnus.

Flavonoids group; Rhamnus; *Chinese green*
Rondot (1858); Schweppe (1992) 542–3; Terry (1893) 129

LOMBARD GOLD
Yellow
Synonym, variant or common name

See: gallstone.

LOMBARDY INDIGO
Blue
Synonym, variant or common name

Eikema Hommes (2002) has recently pointed out that lumps of indigo imported into Europe from India via Italy are referred to as 'Lombardian' indigo in certain German treatises – for example, the *Illuminierbuch* of Boltz von Ruffach (1549) gives particular praise to *Lampartischen endich* as a grade of indigo.
See: *lamptschen endich*.

Boltz von Ruffach (1549/Benziger 1913) 145; Eikema Hommes (2002)

LONDON INDIGO
Blue
Synonym, variant or common name

See: *lamptschen endich.*

LONDON WHITE
White
Synonym, variant or common name

This is a form of lead white (*q.v.*), the name probably being a source variant. Field (1835) treats it with Nottingham white (*q.v.*).

Lead white; *Nottingham white*
Field (1835)

LONSDALEITE
Black
Generic compound

Lonsdaleite is a crystalline form of carbon, and is named after the English crystallographer K.Y. Lonsdale (1903–71). It is polymorphous with the other hexagonal forms of crystalline carbon, chaoite and graphite (*qq.v.*), and the cubic form, diamond. Lonsdaleite was first described by Frondel and Marvin in 1967 from the Canyon Diablo meteorite (Meteor Crater, Arizona, USA), and has since been identified in further meteorites, impact crater sites (such as Tunguska, Russia), in diamond placer deposits and high-grade metamorphic rocks (Golovnya *et al.*, 1977). It occurs as microscopic brown to brown-yellow or black crystals, usually as disseminated grains or as aggregates. Lonsdaleite is a rare mineral and unlikely to have been used as a pigment (Winter, 1983); it is included here, however, for completeness in the discussion of crystalline carbons.

Carbon-based blacks group; Carbon-based blacks group: Crystalline carbons sub-group; Chaoite; Graphite
Frondel & Marvin (1967); Golovnya *et al.* (1977); Winter (1983)

LUCIDIN
Red-Orange
Generic compound

Lucidin, 1,3-dihydroxy-2-hydroxymethylanthraquinone, is found as a major component in roots of *Coprosma lucida* Forst and is a lesser component of various *Rubia*, *Galium* and *Morinda* species. It is therefore a constituent of madder dyes (Schweppe and Winter, 1997).
See: madder.

Anthraquinones group
Schweppe & Winter (1997)

LULAX
Blue
Synonym, variant or common name

See: indigo.

LUTEOLIN
Yellow
Generic compound

Luteolin is a flavonoid (flavone) dyestuff, 2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-4H-1-benzopyran-4-one (3',4',5,7-tetrahydroxyflavone). It is found in many plants as a glycoside, notably in the present context in *Reseda luteola*, the source of the dyestuff known as weld in *Petroselinum crispum* (Miller) A.W. Hill (*parsley*) and *Genista tinctoria* L. ('dyer's broom') (Schweppe, 1992).
See: weld, parsley and rhamnus.

Flavonoids group; Rhamnus; Weld; *Parsley*
Schweppe (1992) 322

LUTEOLUM NAPOLITANUM
Yellow
Synonym, variant or common name

See: Naples yellow.

M

MACHIM

Yellow
Synonym, variant or common name

Term used in the *Arte poetica* of Nunes (1615), apparently for a lead-based yellow pigment such as lead tin yellow. Machim does not seem to appear in the various later works of golden-age Spain (Veliz, 1986).

Lead tin yellow
Nunes (1615) 55ff, 60ff, 62ff, 63ff; Veliz (1986) 3, 7, 9, 10

MACPHERSON'S TINT

Grey
Synonym, variant or common name

Salter (1869) mentions Harding's and Macpherson's tints; these were commercial compound products 'sold ready prepared in cakes and boxes for miniature and water painting'.

Harding's tint
Salter (1869) 380

MADDER

Red
Common generic composite

Dyestuff derived from the root of various members of the Rubiaceae family, notably *Rubia* species such as *R. tinctorum* L., as well as *Odenlandia*, *Morinda*, *Relbunium* and *Galium* species. Documented sources of *madder* dye among *Rubia* include *R. tinctorum* L., *R. peregrina* L. (also known as Levant or wild madder), *R. cordifolia* L. (Indian madder or munjeet), *R. sikkimensis* Kurz., *R. akane* Nakai, *R. iberica* C. Koch and *R. rigidifolia* Pojark; *Morinda* plants include *M. citrifolia* L. (soranjee), *M. umbellata* L. (mang kouda)*, M. longiflora* G. Don., and others include *Gallium verum* L. (yellow ladies' bedstraw); *Oldenlandia umbellata* L. (Indian madder or chay root); and in South America, *Relbunium hypocarpium* Hemsel., *R tetragonum* Griseb.; in Australia and New Zealand *Coprosma lucida* Forst., *Coprosma acerosa* Cunn.; and in Japan *Rubia akane* Nakai, and *Damnacanthus major* Seib. and Zucc. (var. *parvifolius* Koidz.) (Schweppe and Winter, 1997). A plant known as 'field madder' is *Sherardia arvensis* L. (Rubiaceae); it is native to Europe, the Mediterranean and western Asia.

Madder is characterised by the presence of a series of key anthraquinone components, the most important of which are alizarin, purpurin and pseudopurpurin, morindone, xanthopurpurin, rubiadin (*qq.v.*), although a large group of other anthraquinones is also present. Schweppe and Winter list the following additional components found in the various madder species: munjistin, ibericin, lucidin, 2-hydroxyanthraquinone, xanthopurpurin-3-methyl ether, alizarin-1-methyl ether, anthragallol, nordamnacanthal, 1,4-dihydroxy-6-methylanthraquinone, 1-hydroxy-2-methylanthraquinone and 1,8-dihydroxy-3-methyl-6-methoxyanthraquinone. These are generally present in minor quantities.

Madder produces a wide range of colours from yellow through orange to red and purple or brown. The different colours result from many variables (both the production of the organic colourants and the inorganic substrates) which make madder lakes difficult to replicate from recipies, even under controlled conditions; Schweppe, for example, reports variously that tin-madder lakes can be orange and scarlet. Madder production is best considered more of an art than a science thus the large number of intermediate treatments are often not known or reported and these can all vary the result. Gentele (1860) states that partial precipitation of madder dye with soda or potash gives a deep red colour while a complete precipitation gives a lighter lake, adding that this is also true for chalk precipitates and that the intensity is increased if a small amount of tin is added at the end of precipitation. Cremer (1895, cf. Chenciner, 2000) further states that the addition of iron sulfate results in black violet and madder violet. Chromium alum gives a red-brown and iron salts in the alum also produce a brown colour. Modern synthesis of the indivudual dye components alizarin and purpurin is also known; Meyer (1911, cf. Chenciner) states that lakes made of pure alizarin on alumina are somewhat 'bluer than natural madder lakes'.

Although clearly used as a dye since ancient times it is possible to use it in an unmordanted form as an applied wash and it has probably also been in use as a pigment since this time as well. Foster and Moran have reported it on pottery shards from the eight to seventh century BC. It is mentioned by both Pliny (77 AD) and Vitruvius (first century BC) particularly as a purple colour and has been found by the authors among the pigments excavated from the painter's shop at Pompeii (Walsh *et al*., 2004) and it is also mentioned for example by Heraclius (tenth–thirteenth centuries) and Neri (1612).

There appears to be no mention of madder as a pigment in the period between these authors and the early seventeenth century; Merrifield (1849) states that there is no other discussion of madder in Italian texts after Neri until 1733 and that the French texts do not mention it until 1788. It has been speculated that this is because the source for madder during this period was the shearings from madder dyed cloth. Ploss (1962) gives fourteenth and fifteenth century texts from northern Europe describing the methods by which these shearings, 'vlocken' or 'bourre', are reduced to a gelatinous amorphous mass in order to extract the dyestuff from textile waste. The resultant coloured solution was then precipitated using alum. This method was also used in Italy where the resultant lake was called *cimatura*. (Note that this method of colourant production was also used with other dyes as well.) Possible evidence of this technique may have been found by the discovery of textile fibres within a sample of red pigment from Pompeii analysed by the authors (Walsh *et al.*) and a red lake from Titian's *Venus and Adonis* (c. 1560) analysed at the J. Paul Getty Museum (Birkmaier *et al.*, 1995).

In the mid-nineteenth century Salter (1869) records the adulteration of commercial madder root 'with brickdust, red ochre, red sand, clay, mahogany sawdust, logwood, sandal and japanwood, and bran.' This appears to have been a particular problem with French madder (Osborn, 1845). There were regulations in place as early as the fourteenth and fifteenth centuries in Flanders and Artois detailing the proportion of earth allowed in the different grades of madder and in 1630 an official inspector and sealer of madder was appointed (Chenciner). In the nineteenth century several treatments were applied in the processing of madder to strengthen and refine the resultant dye. These are discussed in the entry for *garancine*.

Madder use has been identified by Wallert (1995a) who found wild madder (*Rubia peregrina*) as the basis for a purple pigment in the polychromy of a fourth century BC Greek marble basin, although he comments that the use of madder as a colourant in classical painting has rarely been analytically determined; by Roosen-Runge (1973) on a marriage certificate dated 972 AD; by Mehra (1970) on Tibetan thang-ka paintings of the fifteenth to the nineteenth centuries, by Kühn (1985, 1977, 1968) on a painting by Leonardo (fifteenth century Italy), Manuel (sixteenth century Swiss) and Vermeer (c. 1655 Dutch), and by Townsend (1993) on Turner's palettes (c. 1792–1850 England).

The historical terminology associated with madder and madder production has been reviewed extensively by Schweppe and Winter, including a discussion not only of the dyestuff, but also specific local names for plants and commercial production names such as Alsatian madder, Avignon madder and Dutch madder. The German term for madder is *Krapp* and *Krapplak* refers to madder lake.

Alizarin; Lucidin; Munjistin; Pseudopurpurin; Purpurin; Rubia; Rubiadin; *Aal*; *Cimatura*; *Ciocchi*; *Garancia*; *Pandius*; *Retzel*; *Retzwurz*; *Rezza*; *Robbia*; *Roete*; *Roza*; *Rubea radix*; *Warencia*
Birkmaier *et al.* (1995) 123; Chenciner (2000); Gentele (1860) 310–311; Kühn (1986); Kühn (1977a); Kühn (1985); Heraclius/Romano (10–13th cent/1996) 23; Mehra (1970); Merrifield (1849) clxxviii; Neri (1612/Mentasti, 1980) 102; Osborn (1845) 22; Pliny (1st cent AD/Rackham, 1952) XXXV.xxvi.45; Ploss (1962) 113; Roosen-Runge (1973); Salter (1869) 139–141; Schweppe & Winter (1997); Schweppe (1992) 242; Townsend (1993a); Vitruvius (1st cent BC/Grainger, 1934)VII.xiv, Wallert (1991b); Wallert (1995a)

MADDER BROWN

Brown
Synonym, variant or common name

According to Field (1835), this is a gently calcined madder lake. See: Field's russet.

Madder; *Field's russet*
Field (1835) 146

MADDER CARMINE

Red
Synonym, variant or common name

A term used by Field (1835) and in Salter's (1869) edition of Field's *Chromatography* to denote the most intense category of madder lake, it also being called Field's carmine. Field adds that 'It differs from the rose lakes of madder principally in texture, and in the greater richness, depth and transparency of its colour … the only durable carmines for painting either in water or oil.' Salter says that it was difficult to make, 'exceeding care and nicety being required to obtain the fullest tint'. As a result of this, and the implicit cost of production, it was apparently liable to adulteration, Salter remarking: 'Mérimée states that samples were sent to him from Berlin, under the name of "carmine madder," which evidently owed their brightness to tincture of cochineal. It is certain that madder lakes have been imitated on the Continent with various success by those of lac, cochineal, and carthamus or safflower. The best we have seen is the *laque de garance*, which was tinged with the rouge of carthamus.'

Madder
Field (1835) 101; Salter (1869) 142–143

MADDER LAKE

Red
Synonym, variant or common name

Madder lakes are prepared by depositing an extract of the roots from various plants of the Rubiaceae (madder, *q.v.*) onto an insoluble base. Carlyle (2001) has noted from nineteenth century English sources that the reds derived from madder could be listed in decreasing intensity as: madder carmine, madder lake, rose madder and pink madder. Concerning adulteration, Salter (1869) notes that 'The French madders are in a state of very fine powder, containing one half their weight of gum, sugar, salts, and other soluble substances, which water specifically dissolves', saying further that madder is often adulterated with brickdust, red ochre, red sand, clay, mahogany sawdust, logwood, sandal (wood), japan-wood and bran. Osborn (1845) gives the terms madder purple, purple rubiate or Field's purple for madder lakes.

Anthraquinones group; Madder; *Field's purple*; *Madder purple*
Carlyle (2001) 508; Osborn (1845) 22; Salter (1869) 142–143

MADDER ORANGE

Orange
Synonym, variant or common name

Mentioned in Field (1835) and others such as Salter (1869) and Scott Taylor (1885), where it is linked to the term orange lake. It was seemingly produced from madder, though the special processing presumably required to differentiate it from other forms of madder colours is unclear. The British artists' colourmen Robersons latterly supplied a product they called 'Orange madder'.

Madder
Field (1835) 120; Salter (1869) 258; Scott Taylor (1885) 193

MADDER PURPLE

Purple
Synonym, variant or common name

This was a colour created by the early nineteenth century British colourman George Field, who described it as 'a very rich and deep carmine, prepared from madder. Though not a brilliant purple, its richness, durability, transparency and superiority of colour, have given it the preference to the purple of gold … and to burnt carmine' (Field, 1835). Later in the nineteenth century Salter (1869) agreed that it is 'the only durable organic purple the palette possesses'. Salter's caveat, however, is that madder purple was available in such small quantities and was consequently so expensive that its use was confined to watercolour. Winsor & Newton listed 'Extra purple madder' in 1864, while Robersons bought 'Best purple madder' from George Field between 1845 and 1852 (cf. Carlyle, 2001). Other terms listed by Field for this pigment are *Purple rubiate* and *Field's purple*.

Carlyle (2001) 501; Field (1835) 137; Salter (1869) 301

MADDER YELLOW

Yellow
Synonym, variant or common name

According to the early nineteenth century colourman Field 'Madder yellow is a preparation from the madder-root. The best is of a bright colour, resembling Indian yellow, but more powerful and transparent' (Field, 1835). Salter adds to this in his 1869 edition of Field's *Chromatography* that he had never been able to produce a comparable material, stating that 'It is certain that no true madder yellow, brilliant and pure, ranks as a pigment at the present day. A variety known as Cory's Yellow Madder may be briefly described as Cory's *Brown* Madder'.

Carlyle (2001) considers the composition to be unclear, although it may have been a quercitron lake pigment (lake formed from quercitron, the inner bark of the oak *Quercus tinctoria*).

Quercitron; *Cory's yellow madder*
Carlyle (2001) 520; Field (1835) 82; Salter (1869) 119

MADDERINE LAKE

Purple
Synonym, variant or common name

See: copper chromates group.

MAGENTA

Purple
Generic compound

Synthetic dyestuff: 4-[(4-aminophenyl)(4-imino-2,5-cyclohexadien-1-ylidene)methyl]-2-methylbenzenamine monohydrochloride. Also known as fuchsine, it was said to be part of the pigment known as Tuscan red in combination with an iron oxide (Heaton, 1928). Also related to Hofmann's violet.

Listed by the *Colour Index* as CI Basic Violet 14.

Iron oxides and hydroxides group; *Aniline*; *Fuchsine*; *Hofmann's violet*; *Tuscan red*
Colour Index (1971); Heaton (1928) 384

MAGHEMITE

Brown
Generic compound

Maghemite, γ-Fe_2O_3, is isostructural with magnetite, from which it forms in, particularly, tropical and subtropical soils (where it is often titanium-bearing) as a weathering product. Goethite and ferrihydrite readily convert to maghemite under such circumstances. Naturally occurring maghemite belongs to the cubic system, whereas synthetic varieties are tetragonal. Like magnetite it is one of the few naturally occurring magnetic minerals.

Synthetic maghemite may be produced by several methods. By far the commonest is heating (synthetic) lepidocrocite or magnetite at 250°C for 2–5 hours in oxidising conditions. It may also be produced from the controlled heating of other iron oxides at 500°C and in the presence of organic matter (Cornell and Schwertmann, 1996).

Maghemite is a minor, but not unusual component of burnt ochres. It has been recorded by Pomiès *et al.* (1999) from the French Palaeolithic site of Troubat (Pyrenées). David *et al.* (2001) have indicated that it is present in red and yellow ochres from Tell el Amarna, Egypt.

The magnetic properties of maghemite have made it an important component of magnetic inks employed in photocopiers, laser printers, etc., and as the chief magnetic compound in electronic recording media (see review by Buxbaum, 1998). The name 'maghemite' is a contraction of magnetite and hematite.

Iron oxides and hydroxides group; Hematite; Magnetite; *Burnt ochre*
Buxbaum (1998) 83; Cornell & Schwertmann (1996); David *et al.* (2001); Pomiès *et al.* (1999)

MAGISTERY OF BISMUTH

White
Synonym, variant or common name

A 'magistery' was 'The residuum obtained by precipitation from an acid solution, e.g. magistery of bismuth, pearls, etc.; a precipitate' (*OED*, 2002); thus magistery of bismuth was an insoluble (white) bismuth compound formed in this manner. The compound concerned is likely to be either bismuth hydroxide nitrate oxide, $Bi_2O_3.2HNO_3$ (*Merck Index*, 1996; also given as $4BiNO_3(OH)_2.BiO(OH)$) or bismuth chloride oxide (BiOCl). Other sources suggest additional compounds such as bismuth nitrate (which decomposes in water to form the above compound) and bismuth oxide (which could not form by aqueous precipitation), neither of which are chemically likely.

The preparation of a magistery from both bismuth and pearls is interesting since there was a synonymy between magistery of bismuth, bismuth white and pearl white (*qq.v*) in the nineteenth century, possibly suggesting a common derivation of terminology. See: bismuth white.

Bismuth nitrates group; *Bismuth white*; *Pearl white*
Merck Index (1996) 1326; *OED* (2002) 'Magistery'

MAGNESIA

White
Synonym, variant or common name

See: periclase.

MAGNESIA WHITE

White
Synonym, variant or common name

Mayer (1991) states that magnesia white is 'an unstandardized name for artificial or native magnesium carbonate'. The mineralogical term is magnesite.

Magnesite; Magnesium carbonate
Mayer (1991) 49

MAGNESITE

White
Generic compound

Magnesite, also known as bitter spar, is a magnesium carbonate mineral with composition $MgCO_3$. It was described by Karsten in 1808 and is named after its type locality of Magnesia (Greece). Magnesite occurs as rhombohedral, tabular or prismatic crystals, but is more commonly found with fibrous, granular or massive form. It is usually white but may be brown or yellow if impurities such as Fe are present; it forms a complete solid solution series with siderite, $FeCO_3$. Magnesite is closely related to calcite and dolomite (*qq.v.*) but is less common and differs in that it rarely occurs in sedimentary environments and lacks twinning. It occurs instead as a secondary mineral produced from the low-temperature metamorphism of Mg-rich rocks in contact with carbonate solutions (Dana, 1932; Deer *et al.*, 1992; Rutley, 1988). Magnesite is a common mineral, known from localities such as Buskerud (Norway), Tarrekaise (Lappland), Valais (Switzerland), Kynance Cove (Cornwall, England), Bisbee (Arizona, USA) and Bahia (Brazil).

Terry (1893) and Heaton (1928) both state that magnesite was occasionally ground and levigated for use as a pigment.Terry also states that it resembles barytes and is a suitable substitute for it, while Heaton states that it resembles Paris white (chalk) and was very white, heavy and opaque. Patton (1973e) has indicated that magnesite is a mineral commonly associated with pigmentary talc. Newton and Sharp (1987) have also identified magnesite in certain plasters, introduced with the dolomite used. Using thermal analyses, Bruni *et al.* (1998) identified magnesite, in association with calcite and hydromagnesite, in ancient plasters from northern Italy; its formation was attributed to the natural carbonation of the original lime plaster that contained brucite (*qq.v.*).

Also known as magnesia white when used as a pigment (Mayer, 1991).

Magnesium carbonates group; Brucite; Calcite; Dolomite; Hydromagnesite; *Magnesia white*
Bruni *et al.* (1998); Dana (1932) 517; Deer *et al.* (1992) 633–634; Heaton (1928) 109; Mayer (1991) 50; Newton & Sharp (1987); Oh *et al.* (1973); Patton (1973e); Rutley (1988) 291–292; Terry (1893) 245

MAGNESIUM CARBONATE
White
Generic compound

See: magnesium carbonates group.

MAGNESIUM CARBONATE HYDROXIDE
White
Generic compound

See: magnesium carbonates group.

MAGNESIUM CARBONATES GROUP
White
Group term

Magnesium carbonate, as the mineral magnesite ($MgCO_3$), has a documented record of use as the pigment, magnesia white. Four carbonate hydroxides or carbonate hydroxide hydrates also exist: Magnesium carbonate hydroxide ($4MgCO_3.Mg(OH)_2$); Magnesium carbonate hydroxide hydrate ($5MgCO_3.Mg(OH)_2.3H_2O$, $5MgCO_3.2Mg(OH)_2.7H_2O$ and $3MgCO_3.Mg(OH)_2.4H_2O$). The calcium magnesium carbonate mineral, dolomite ($[Ca,Mg]CO_3$), is a common component of limestones and is likely to occur in some calcium carbonate-based pigments.

Magnesium group; Dolomite; Magnesite

MAGNESIUM EUXANTHATE
Yellow
Generic compound

Euxanthic acid, a major constituent of so-called Indian yellow, will form salts with various elements; however, those of calcium and (as here) magnesium, are the ones encountered.
See: Indian yellow.

Indian yellow

MAGNESIUM FERRITE
Brown
Synonym, variant or common name

See: iron magnesium oxide.

MAGNESIUM GROUP
Variable
Group term

The following magnesium compounds are known in the context of pigments, as either naturally occurring or synthetic forms:

Carbonates: Dolomite ($CaMg(CO)_2$); Huntite ($Mg_3Ca(CO_3)_4$); Hydromagnesite ($Mg_5(CO_3)_4(OH)_2 \cdot H_2O$); Magnesite ($5MgCO_3.Mg(OH)_2.3H_2O$); Magnesium carbonate ($MgCO_3$); Magnesium carbonate hydroxide hydrate ($5MgCO_3.Mg(OH)_2.3H_2O$); Magnesium carbonate hydroxide hydrate ($5MgCO_3.2Mg(OH)_2.7H_2O$); Magnesium carbonate hydroxide ($4MgCO_3.Mg(OH)_2$); Magnesium carbonate hydroxide hydrate ($3MgCO_3.Mg(OH)_2.4H_2O$).
Oxides and hydroxides: Periclase (MgO); Magnesium oxide (MgO); Iron magnesium oxide ($MgFeO$); Brucite ($Mg[OH]_2$).
Silicates and hydrous silicates: Forsterite (Mg_2SiO_4); Antigorite ($Mg_6[Si_4O_{10}][OH]_8$); Talc ($Mg_3[Si_4O_{10}][OH]_2$); Magnesium silicate (Mg_2SiO_4); Magnesium silicate ($MgSiO_3$).

The magnesium carbonates have been frequently identified in fresco paintings and in examples of rock and cave art (see relevant entries for fuller discussion). Brucite has also been identified in these contexts (Newton and Sharp, 1987).

Indian yellow occurs as the magnesium salt of euxanthic acid.

Modern texts such as Buxbaum (1998) describe the incorporation of cobalt into magnesium and zinc titanium spinels (Mg_2TiO_4 and Zn_2TiO_4) to produce blue to green compounds with a general formula $Mg_aCo_bZn_cTiO_4$, where $a + b + c = 2$.

Magnesium has been found to be a common component of cobalt arsenates in the pigment cobalt violet (Corbeil *et al.*, 2002).

The magnesium silicates, though common and abundant rock forming minerals, do not have wide application as pigments.
See: magnesium silicates group.

Magnesium carbonates group; Magnesium oxides and hydroxides group; Magnesium silicates group; Antigorite; Brucite; Dolomite; Huntite; Hydromagnesite; Indian yellow; Iron magnesium oxide; Magnesite; Magnesium carbonate; Magnesium euxanthate; Magnesium oxide; Magnesium silicate; Periclase; *Cobalt blue*; *Cobalt green*; *Cobalt violet*
Buxbaum (1998) 101; Corbeil *et al.* (2002); Newton & Sharp (1987)

MAGNESIUM OXIDE
White
Generic compound

See: periclase.

MAGNESIUM OXIDES AND HYDROXIDES GROUP
Variable
Group term

See: periclase.

MAGNESIUM SILICATES GROUP
White
Group term

A number of magnesium silicates have found either direct or indirect use in pigments, though these fall into two broad groups, silicates and hydrous silicates.

Silicates: Forsterite (Mg_2SiO_4); Magnesium silicate (Mg_2SiO_4); Magnesium silicate ($MgSiO_3$).
Hydrous silicates: Antigorite ($Mg_6[Si_4O_{10}][OH]_8$); Talc ($Mg_3[Si_4O_{10}][OH]_2$.

Forsterite is the naturally occurring magnesium silicate, belonging to the olivine family of minerals. Olivines have the chemistry $(Fe,Mg)SiO_4$ and there is complete solid solution (mixing) between the end-members forsterite and fayalite (Fe_2SiO_4). It is not generally recognised as a pigment but may be a component of some plaster supports for wall paintings (see Newton and Sharp, 1987). Antigorite is a member of the serpentine group of minerals (*qq.v.*).

According to Patton (1973e), in the pigment industry the designation 'talc' covered a wide range of natural products. He lists for example a series of synonyms, form variants and other associated terms, including asbestine, french chalk, hydrous magnesium silicate, pyrophyllite (the aluminium analogue of talc), soapstone, steatite and talc (*qq.v.*). Steatite is a name generically given to massive talc or talc-rich rocks. Asbestine is synonymous with talc. The *Colour Index* (1971) lists hydrous magnesium silicates as CI 77718/Pigment White 26.

Many other magnesium-containing silicates exist, which are too numerous to discuss here. Those with pigment applications include those from the amphibole group, the chlorite group (important in green earths), the mica group and the rare mineral aerinite (*qq.v.*).

Amphibole group; Chlorite group; Clay minerals group; Magnesium group; Serpentine group; Sheet silicates group; Silicates group; Aerinite; Antigorite; Forsterite; Pyrophyllite; Steatite; Talc; *Asbestine*; *French chalk*; *Soapstone*
Colour Index (1971) 77718; Newton & Sharp (1987); Patton (1973e)

MAGNETITE

Black
Generic compound

Magnetite is an iron oxide mineral with ideal composition $Fe^{2+}Fe_2^{3+}O_4$ (or Fe_3O_4), although minor amounts of Mg, Al, Ti, Mn, Ca and Ni may be present. It is one of the members of the magnetite series of minerals, which includes franklinite, jacobsite (*qq.v.*) and the Ni-rich member, trevorite. As with the other members, magnetite is cubic and occurs most commonly as black octahedral crystals with metallic lustre, or with granular or massive form. As its name suggests, it is a strongly magnetic mineral. Magnetite is one of the most common and abundant oxide minerals in igneous and metamorphic rocks, although the larger workable deposits are of metamorphic origin. In igneous rocks magnetite occurs as an accessory mineral or may be concentrated into bands due to crystal settling (such as the Bushveld Complex, South Africa). Magnetite occurs as lenses in metamorphic schists (for example, Adirondack, USA and Kythnos, Greece), hydrothermal sulfide veins and in thermally metamorphosed iron-rich sediments and limestones. It is a robust mineral and also occurs as a detrital mineral in sediments and placer deposits formed by the weathering of the aforementioned rock types, often becoming concentrated to form magnetite sands. It is one of the most valuable ore sources for iron and may be found in natural iron oxide pigments. As an integral part of the magnetite series, magnetite also belongs to the spinel group (*q.v.*) of minerals, which are all cubic oxides with the general chemical formula $X^{2+}Y_2^{3+}O_4$ (Deer *et al.*, 1992; Rutley, 1988).

Despite the common occurrence of magnetite, especially in naturally occurring iron oxide deposits, few explicit identifications have been made in artefacts. Duang (1987), for example, found magnetite among materials in wall paintings at Dunhuang, China, while Jaksch *et al.* (1983) detected titanomagnetite in their studies of Egyptian blue.

Iron group; Iron oxides and hydroxides group; Franklinite; Jacobsite
Deer *et al.* (1992) 558–568; Duang (1987); Jaksch *et al.* (1983); Rutley (1988) 282–283

MAGNOFLORINE

Yellow
Generic compound

Magnoflorine, a basic dyestuff of composition 5,6,6a,7-tetrahydro-1,11-dihydroxy-2,10-dimethoxy-6,6-dimethyl-4H-dibenzo[de,g]quinolinium, is a major colouring component of dyes derived from *Phellodendron amurense* Rupr. ('Amur cork tree'); it is also found as a minor component in the rootbark of *Berberis vulgaris* L. (*Merck Index*, 1996; Schweppe, 1992). See: phellodendron and berberis.

Berberis; Phellodendron
Merck Index (1996) 5736; Schweppe (1992) 441

MAHOGANY LAKE

Red
Synonym, variant or common name

A red or brown lake formed on a substrate of burnt sienna; also known as cashew lake (Mayer, 1991). Perhaps related to catechu brown (*q.v.*).

Burnt sienna; *Catechu brown*
Mayer (1991) 50

MALACHITE

Green
Generic compound

Malachite is a green basic copper carbonate mineral with composition $Cu_2CO_3(OH)_2$. Its name is derived from the Greek word *μαλαξι* meaning 'mallow', and referring to its leaf green colour. Malachite may be found as prismatic crystals but it most commonly occurs as botryoidal masses with an internal fibrous structure and a banded appearance; it also occurs with granular, earthy and stalactitic forms. Malachite forms as a secondary mineral in the upper oxidised zones of copper ore deposits. It is deposited slowly in fissures and cavities from carbonate solutions percolating through the copper-bearing rocks, resulting in the banded structure. Malachite is commonly found in association with azurite (*q.v.*), although malachite is the more abundant copper carbonate. It may occur as pseudomorphs after azurite, and is also found with chrysocolla and cuprite (*qq.v.*; Rutley, 1988); hence, these may be present as impurities in malachite pigments. Malachite is a common mineral close to ore deposits and is found in areas such as Cornwall (England), Chessy (France), Attica (Greece), Saxony (Germany), Oujda (Morocco), the Ural Mountains (Russia), Burra Burra mine (S. Australia), Katanga (Democratic Republic of Congo), Tsumeb (Namibia), Cordoba (Argentina) and Utah (USA); smaller deposits are also known in China and Japan.

For use as a pigment, malachite was prepared by crushing, grinding, washing and levigating. The deposits in Russia and Congo have been the most important recent sources of malachite. However, in mediaeval times, the source of malachite as a pigment is not well known, although the copper mines in Hungary, Central Europe and France may have been used.

Historically, malachite has been called chrysocolla (in classical and mediaeval literature), *molochites*, mountain green, *Berggrün*, *verde azzuro*, *verdetto della magna*, Hungarian green, mineral green, Bremen green, copper green, iris green, Olympian green and green bice; the *Colour Index* (1971) lists CI Basic Green 4, a triphenylmethane dye as malachite green (*q.v.*). Burmester and Resenberg (2003) have discussed the confusion in the terminology surrounding malachite, chrysocolla (*q.v.*) and green earth, particularly in German literature from 1550–1732, where they indicate that the terms may have been applied differently by different authors. See: chrysocalla.

Lucas (1962) reported the use of malachite in Egyptian cosmetics as early as predynastic times, and its use on post-fourth dynasty tomb paintings. In the Far East, Waley has reported the use of malachite mixed with azurite in ninth to tenth century AD western Chinese paintings at Dunhuang and in other central Asian sites; Gettens (1938b) identified malachite on Ming dynasty wall paintings in central China, and Yamasaki (1953) observed it on seventh to eighth century Buddhist wall paintings of the Horyuji Temple near Nara, Japan. Gettens and FitzHugh (1993b) report that malachite was used abundantly in scroll and screen paintings in Japan until the present day. In Europe, malachite has been identified by Laurie (1914) on eighth to sixteenth century illuminated mediaeval manuscripts, and by Flieder (1968) on eleventh to sixteenth century illuminated manuscripts; authors such as Dunkerton and Roy (1996) and Gettens and FitzHugh (1974), have reported that malachite is used on European easel paintings in a period within the fourteenth to seventeenth centuries. Burmester and Resenberg believe that there may have been mumerous misattributions between malachite and chrysocolla.

Both Harley (1982) and Thompson (1956) have pointed out that malachite is less commonly mentioned in art literature than azurite, and Thompson has suggested that this may because grinding malachite to a small grain size reduces its green colour to a pale version. Kühn has suggested that artificial copper greens such as verdigris and copper resinate (*qq.v.*) made from malachite may have been more satisfactory green pigments and that in European paintings, transparent copper resinate was applied over malachite, or malachite was mixed with a yellow pigment to produce a better green pigment. Artificial basic green copper carbonate (*q.v.*) pigments, often known as green verditer or green bice, are widely mentioned in seventeenth century sources, though not as prolifically as blue verditer.

Simpson *et al.* (1964) have described that the heating of malachite to around 600°C results in dehydration, the release of CO_2 and the formation of a black residue of tenorite (*q.v.*).

Copper carbonates group; Azurite; Chrysocolla; Berggrün; Bremen green; Copper green; Copper resinate; Green bice; Green verditer; Hungarian green; Iris green; Mineral green; Mountain green; Olympian green; Spherulitic malachite; Verde azzuro; Verdetto della Magna
Burmester & Resenberg (2003); *Colour Index* (1971); Dunkerton & Roy (1996); Flieder (1968); Gettens & FitzHugh (1974); Gettens & FitzHugh (1993b); Gettens (1938b); Harley (1982) 79; Kühn (1993a); Laurie (1914); Lucas (1962); Rutley (1988) 307–309; Simpson *et al.* (1964); Thompson (1956) 161; Yamasaki (1953); Yamasaki (1967)

MALACHITE GREEN

Green
Synonym, variant or common name

This term could refer to a number of pigments, including material derived from the natural mineral: Seward (1889) states that the artificial versions were subject to fading and that on his recommendation the British colourmen Rowney's used powdered mineral; Winsor & Newton also stated that they used the mineral in 1896. However, Reeves (in a catalogue of about 1898) describe their Malachite green as 'now made from chromium and zinc oxides'. Martel (1860) indicates that due to the scarcity of the mineral 'found in the mountains of Hungary and Siberia', several artificial pigments had been produced to supply its place, adding that 'Some of these are carbonates, others are arseniates of copper.' Other possibilities include combinations of Prussian blue and gamboge (Carlyle, 2001).

The *Colour Index* lists CI Basic Green 4, a triphenylmethane dye, as malachite green.

Hexacyanoferrate group; Gamboge; *Hooker's green*; *Prussian green*
Carlyle (2001) 494; *Colour Index* (1971); Martel (1860) 28; Seward (1889)

MANGANBLAU

Blue
Synonym, variant or common name

See: manganese blue and barium manganate(VI) sulfate.

MANGANESE AMMONIUM PHOSPHATE

Purple
Generic compound

Modern sources, such as Hackman (1973), typically give manganese ammonium phosphate ($(NH_4)_2Mn_2(P_2O_7)_2$) as the formula for manganese violet.
See: manganese phosphates group.

Manganese phosphates group; *Manganese violet*
Hackman (1973)

MANGANESE BLACK

Black-Brown
Synonym, variant or common name

Field (1841, cf. Carlyle, 2001) stated that manganese black was 'similar to mineral black'; however, it was rarely referred to in the literature. Standage (1883, 1887) listed it under manganese brown and simply noted that 'The peroxide of manganese forms manganese black' (cf. Carlyle, 2001). However Mayer (1991) distinguishes between 'black oxide of manganese' as being derived from the natural mineral (which is pyrolusite) and 'manganese black' the synthetic form (manganese(IV) oxide; manganese dioxide).

Kühn (1975) has identified manganese(IV) oxide among pigments on nineteenth century German paintings. Manganese black has also been identified as an Etruscan pigment (Schweizer and Rinuy, 1982), though in that case the material was a synthetic manganese iron oxide analogue of jacobsite in combination with hematite and bixbyite (Mn_2O_3) rather than a manganese oxide alone.

Manganese group; Manganese oxides and hydroxides group; Bixbyite; Hematite; Jacobsite; Manganese(IV) oxide; Pyrolusite; *Black oxide of manganese*; *Manganese brown*
Carlyle (2001) 468; Field (1841) 317; Kühn (1975); Mayer (1991) 50; Schweizer & Rinuy (1982); Standage (1883); Standage (1887)

MANGANESE BLUE

Blue
Synonym, variant or common name

Salter (1869) lists manganese blue as formed when 'An aqueous solution of permanganate of potash yields with baryta-water a violet mixture, which afterwards becomes colourless, and deposits a blue precipitate.' He does not recommend it as a pigment, though also lists a manganese green as 'manganate of baryta' as does Terry (1893). Terry on the other hand also describes a series of blue compositions based on manganese. The first of these is what is also known as Kuhlmann's blue, a calcium manganate. As

Terry describes the chance discovery: 'Kuhlmann found a blue mass of manganate of lime in furnaces used for making calcium chloride by calcining a mixture of chalk and residues from chlorine making … [u]nsuccessful attempts to reproduce this result were apparently due to the lime not being under such favourable conditions for acting upon the manganese oxide as when it is in solution in the calcium chloride. As accidentally produced in reverberatory furnaces, the manganate of lime is of an ultramarine tint.' Additionally, three formulations according to Bong ('Bong's manganese blue') are provided: the first a composition of soda ash, calcium carbonate, silica and manganese oxide, the second of barium nitrate, kaolin and manganese oxide, the third of barium nitrate, silica and manganese oxide. Each is 'heated to redness in an oxidising atmosphere', giving a tint that can be varied from violet to green by altering the proportions. In the modern sense of the term, manganese blue refers to barium manganate(VI) sulfate of composition $x\mathrm{BaSO_4}.y\mathrm{BaMnO_4}$ with proportions 89% of the sulfate and 11% of the manganate (*Colour Index*, 1971). This compound was patented by IG Farbenindustrie AG in 1935 and continued to be made commercially until the early 1990s.

Terms associated with manganese blue and barium manganate include bleu azural, Bong's blue, cement blue (because of its use in colouring Portland cement), Kuhlmann's blue, manganblau and turquoise blue.

For additional discussion, see: barium manganate(VI) and barium manganate(VI) sulfate.

Barium manganate(VI); Barium manganate(VI) sulfate; *Bleu azural*; *Bong's blue*; *Kuhlmann's blue*; *Manganblau*; *Turquoise blue*
Colour Index (1971); Salter (1869) 232; Terry (1893) 49, 109–112

MANGANESE BROWN

Brown
Synonym, variant or common name

Field (1841) stated that this was 'similar to mineral black'; however, it was rarely referred to in the literature. He also related Cappagh brown (*q.v.*) to Native manganese brown. Salter (1869) says that it is 'an oxide of manganese … a fine, deep, semi-opaque brown of good body'. Standage listed it under manganese brown and simply noted that 'The peroxide of manganese forms manganese black' (cf. Carlyle, 2001). Terry (1893) gives an aqueous preparation method starting with an aqueous solution of manganese chloride or sulfate, then adding sodium or potassium hypochlorite to precipitate the pigment. By the time Heaton was writing in the early twentieth century, he lists manganese brown among obsolete or rarely used pigments; the composition is given as 'precipitated manganic oxide' (Heaton (1928)).

The mineral pyrolusite, a naturally occurring manganese oxide, is brown to black in colour. It is also possible that this may refer to an earth pigment with a high pyrolusite content, such as certain umbers.

Manganese oxides and hydroxides group; Manganese(IV) oxide; Pyrolusite; Umber; *Manganese black*; *Manganese brown*
Carlyle (2001) 486; Field (1841) 279–280; Heaton (1928) 382; Salter (1869) 358; Terry (1893) 103

MANGANESE CARBONATE

White
Generic compound

See: manganese carbonates group and manganese white.

MANGANESE CARBONATES GROUP

White
Group term

Synthetic manganese carbonate, $\mathrm{MnCO_3}$, is listed by the *Colour Index* (1971; 77733) as being used as a pigment under the name manganese white. The mineral analogue is rhodocrosite.

Manganese group; *Manganese white*
Colour Index (1971) 77733

MANGANESE CHROMATE

Brown
Generic compound

The *Colour Index* (1971) lists a hydrous manganese chromate as a brown pigment (CI 77735) used in watercolour painting. Preparation is by treating manganese chloride with a solution of a dichromate to give a brown solid with composition $\mathrm{2MnO.CrO_3.2H_2O}$.

Chromates group; Manganese group
Colour Index (1971) 77735

MANGANESE DIOXIDE

Black-Brown
Synonym, variant or common name

See: manganese(IV) oxide.

MANGANESE GREEN

Green
Synonym, variant or common name

Sources invariably seem to indicate that this was barium manganate (*q.v.*). The earliest reference found appears to be Salter (1869), who says of it: 'By several methods, manganate of baryta may be obtained either as an emerald-green, a bluish-green, or a pale green', adding little beyond this except to express concern that it would react with the paint medium; we may conclude that it was otherwise probably obscure and unused by artists at that time. However, Terry (1893) also mentions adding 'a little dextrine to make sure of its stability' while various twentieth century sources such as Bersch (1901) and the *Colour Index* give fuller accounts. Heaton (1928) includes the term among obsolete or little-used pigments.

Barium group; Manganese group; Barium manganate(VI); *Baryta green*; *Cassel green*; *Manganese blue*; *Rosenstiehl's green*
Bersch (1901) 270; *Colour Index* (1971); Heaton (1928) 382; Salter (1869) 288; Terry (1893) 130

MANGANESE GROUP

Variable
Group term

The following manganese compounds are known or thought to have been used as pigments or are of close association chemically or structurally:

Carbonates: Manganese carbonate ($\mathrm{MnCO_3}$); Rhodochrosite.
Oxides and hydroxides: Manganese(II) oxide (MnO); Manganosite; Bixbyite; Manganese(III) oxide ($\mathrm{Mn_2O_3}$); Braunite; Manganese(IV) oxide; Pyrolusite ($\mathrm{MnO_2}$); Manganese(II,III) oxide ($\mathrm{Mn(II)Mn_2(III)O_4}$); Hausmannite; Polianite ($\mathrm{MnO_2}$); Manganese(II) hydroxide ($\mathrm{Mn(OH)_2}$); Manganese(III) hydroxide ($\mathrm{Mn(OH)_3}$); Manganite (MnO(OH)); Manganese(II,IV) oxide hydrate ($\mathrm{MnO.MnO_2.H_2O}$); Manganese oxide hydroxide (MnO(OH)); Hollandite; Romancheite.

Phosphates: Ammonium manganese phosphate ($(NH_4)_2Mn_2(P_2O_7)_2$); Manganese(III) phosphate; Purpurite ($MnPO_4$) (older texts give this as an iron manganese phosphate).

See: barium manganate(VI) and barium manganate(VI) sulfate.

Manganese oxides and hydroxides group; Manganese oxides and hydroxides group; Manganese phosphates group; Manganese carbonate

MANGANESE OXIDE

Black
Synonym, variant or common name

See: manganese oxides and hydroxides group.

MANGANESE OXIDE HYDROXIDE

Black
Generic compound

See: manganese oxides and hydroxides group.

MANGANESE OXIDES AND HYDROXIDES GROUP

Black
Group term

A number of manganese oxides occur such as MnO (Mn(II)), Mn_2O_3 (Mn(III); the minerals braunite and bixbyite), Mn_3O_4 (Mn(II,III); the mineral hausmannite), MnO_2 (the minerals pyrolusite and polianite) and Mn_2O_7 (Mn(VII); this is explosive). Several hydroxides also exist: manganese(II) hydroxide ($Mn(OH)_2$); manganese(III) hydroxide ($Mn(OH)_3$); manganese(II,IV) oxide hydrate ($MnO.MnO_2.H_2O$); manganese oxide hydroxide (MnO(OH)). Manganese hydroxides occurring in nature are generically referred to under the term psilomelane (Deer *et al.*, 1992; MacIntyre, 1992; Cotton *et al.*, 1999). Of these, hausmannite, pyrolusite and polianite have been specifically noted as pigments. By definition, manganese oxides and hydroxides are present in umbers to the extent of 5–20%; correspondingly, *siennas* have less than 10%. Additonally, the earth pigment wad is a mixture of various manganese oxides and hydroxides with iron oxides (Ford, 2001). Two other minerals, hollandite (a black barium manganese oxide) and romanechite (a black barium manganese hydroxide of the psilomelane group) are also known as pigments.

Manganese oxides and hydroxides have been widely noted as occurring in prehistoric cave and rock art (for example: Zolensky, 1982; Guineau *et al.*, 2001; Sánchez-Moral *et al.*, 2002). Bixbyite has been identified as an Etruscan pigment by Schweizer and Rinuy (1982). Terry (1893) writes that manganese oxides are both costly and dry too quickly. Church (1901) notes that ground pyrolusite is used as a drier for oil media, also listing 'manganese oxide' as being used as a lake base. Heaton (1928) states that MnO_2 is occasionally used as a pigment, but is more typically used as a drier, being only soluble in oil on heating.

Manganese group; Bixbyite; Braunite; Hausmannite; Hollandite; Polianite; Pyrolusite; Romanechite; Sienna; Umber; Wad
Church (1901) 110, 173; Cotton *et al.* (1999); Deer *et al.* (1992); Ford (2001); Guineau *et al.* (2001); Heaton (1928) 182; MacIntyre (1992); Sánchez-Moral *et al.* (2002); Schweizer & Rinuy (1982); Terry (1893) 318; Zolensky (1982)

MANGANESE PHOSPHATES GROUP

Purple
Group term

A number of manganese phosphates are listed in the literature, notably ammonium manganese phosphate ($(NH_4)_2Mn_2(P_2O_7)_2$), manganese(III) phosphate and the mineral purpurite (though older mineralogical texts give this as an iron manganese phosphate).

Permanent mauve was a term used historically for a manganese phosphate pigment. However, although permanent mauve is treated as manganese phosphate here, the terminology is actually somewhat more confused. Winsor & Newton listed permanent violet and permanent mauve in 1892, stating in their 1896 catalogue that the former was 'Phosphate of Manganese'. However, about 1898 Reeves list permanent mauve as synonymous with permanent violet and that it was made with a 'combination of alizarin'. Moreover, according to Standage (1892) permanent mauve was a violet toned variety of French ultramarine. Therefore the presence of alizarin (possibly as a lake) and synthetic ultramarine may also be anticipated. Manganese violet was also used as a term (Carlyle, 2001).

Manganese group; Manganese ammonium phosphate; Purpurite; *Manganese violet*; *Nürnberg violet*; *Permanent mauve*
Carlyle (2001) 503; Standage (1892)

MANGANESE RED

Red
Synonym, variant or common name

Described by Salter (1869) thus: 'Bisulphide of arsenic combines with basic metallic sulphides forming a class of sulphur-salts, called by Berzelius, hyposulpharsenites. The hyposulpharsenite of manganese is a dark red precipitate … and so far applicable as a pigment.' It is clear, however, that Salter had not in fact used this compound.

Arsenic group; Manganese group
Salter (1869) 168–169

MANGANESE VIOLET

Purple
Synonym, variant or common name

The terminology is somewhat confused. Winsor & Newton listed permanent violet and permanent mauve in 1892, stating in their 1896 catalogue that the former was 'Phosphate of Manganese'. However, about 1898 Reeves list permanent mauve as synonymous with permanent violet and that it was made with 'a combination of alizarin'. Moreover, according to Standage (1892) permanent mauve was 'a violet toned variety of French ultramarine' (cf. Carlyle, 2001).

Burgundy violet; *Nürnberg violet*; *Permanent mauve*; *Permanent violet*
Carlyle (2001) 503; Standage (1892)

MANGANESE WHITE

White
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77733) manganese carbonate ($MnCO_3$) is known as a pigment under the name manganese white. Manganese carbonate occurs naturally as the mineral rhodochrosite and in some other minerals. Synthesis is reported to be by precipitation of iron-free manganese chloride with soda ash.

Manganese carbonates group
Colour Index (1971) 77733

MANGANESE(II) HYDROXIDE

Black
Generic compound

$Mn(OH)_2$.
See: manganese oxides and hydroxides group.

MANGANESE(II,III) OXIDE

Black
Generic compound

See: hausmannite and manganese oxides and hydroxides group.

MANGANESE(II,IV) OXIDE HYDRATE

Black
Generic compound

$MnO.MnO_2.H_2O$.
See: manganese oxides and hydroxides group.

MANGANESE(III) HYDROXIDE

Black
Generic compound

$Mn(OH)_3$.
See: manganese oxides and hydroxides group.

MANGANESE(III) OXIDE

Black
Generic compound

See: manganese oxides and hydroxides group.

MANGANESE(IV) OXIDE

Black
Generic compound

Manganese dioxide, MnO_2. Seccaroni has presented an extensive discussion of the probable use of the mineral analogue pyrolusite. Used alone as a pigment Field (1841) stated that this was 'similar to mineral black'; however, it was rarely referred to in the literature. Standage (1887) listed it under manganese brown and simply noted that 'The peroxide of manganese forms manganese black' (cf. Carlyle, 2001). However, Mayer (1991) distinguishes between 'black oxide of manganese' as being derived from the natural mineral and 'manganese black' the synthetic form, though it is more likely to be encountered as a component in umbers, where it may form 5–20% of the pigment (Buxbaum, 1998).

Compositionally the mineral and certain methods of manufacture of the synthetic form (such as by the common technique of thermal decomposition of $Mn(NO_3)_2.6H_2O$ at 530°C in air) give rise to non-stoichiometric analogues. Manganese(IV) also occurs in a number of mixed oxides.

Manganese(IV) oxide has been identified among pigments on nineteenth century German paintings (Kühn, 1975).

Pyrolusite; *Manganese dioxide*
Buxbaum (1998); Carlyle (2001) 468; Field (1841) 317; Kühn (1975); Mayer (1991) 50; Seccaroni (1999a); Standage (1887)

MANGANITE

Black
Generic compound

Manganite is a black manganese oxide hydroxide mineral with chemical composition MnO(OH). Its name is derived from its composition and it forms as sub-metallic orthorhombic or fibrous crystals, or with massive form.

Various related manganese oxides are known to have been used as pigments, notably bixbyite and hausmannite (*qq.v.*; Schweizer and Rinuy, 1982; Nirmaier, 2000).

Manganese group; Manganese oxides and hydroxides group; Bixbyite; Hausmannite
Nirmaier (2000); Schweizer & Rinuy (1982)

MANGANOSITE

Black
Generic compound

Manganosite is a cubic manganese(II) oxide mineral with a composition of MnO, after which it is named. It occurs as granular aggregates of green to green-black anhedral crystals or as euhedral octahedra. It forms in metamorphosed manganese deposits, low temperature hydrothermal veins in manganese ore deposits, and in iron manganese ocean floor nodules. Manganosite was first described from the Langban mine (Varmland, Sweden) by Blomstrand in 1874 and is comparatively rare, known only from Otavi (Namibia), Rhiw (Wales), Franklin mine (New Jersey, USA), where it is found intergrown with franklinite and zincite (*qq.v.*), and from Hutter mine (Virginia, USA), where it is found with hausmannite and jacobsite (*qq.v.*). Manganese is more commonly found as oxides such as pyrolusite, polianite, braunite, franklinite, hausmannite and manganite (*qq.v.*), and the surfaces of manganosite crystals are often coated with a layer of black pyrolusite (Beard and Tracy, 2002).

Church (1901) indicates that 'manganese oxide' was used as a lake base. However, as already listed, several manganese oxides exist (including bixbyite, *q.v.*) which may be that referred to by Church. The majority of these minerals are naturally dark brown, green or grey to black and may not be suitable for use as lake base.

Manganese oxides and hydroxides group; Bixbyite; Braunite; Franklinite; Hausmannite; Jacobsite; Manganite; Polianite; Pyrolusite; Zincite
Beard & Tracy (2002); Church (1901)

MANGIFERIN

Yellow
Generic compound

The xanthone mangiferin, 2-β-D-glucosidyl-1,3,6,7-tetrahydroxy-9H-xanthen-9-one, is the principal colouring matter derived from the leaves of *Iris germanica* L. (Schweppe, 1992).
See: iris green.

Xanthones group; *Iris green*
Schweppe (1992) 432, 439

MANOX IRON BLUE

Blue
Synonym, variant or common name

Commercial trade name for an iron blue-type pigment used by Manox, UK (Buxbaum, 1998; Berrie, 1997).

Prussian blue
Berrie (1997); Buxbaum (1998) 131

MARBLE

White
Generic variety

Strictly speaking, a marble is a limestone that has been metamorphosed by an incresase of temperature and/or pressure; however, in architectural and building circles, the name is used to describe any calcium carbonate-rich rock which will take a polish. The creation of true, metamorphic marbles results in complete recrystallisation of the rock, obliterating relicts of sedimentary origin such as fossils and bedding. Marbles are found in continental metamorphic terranes. The majority of marbles are essentially monomineralic and are dominated by the mineral calcite (calcium carbonate) or less commonly dolomite (magnesium carbonate). Although other phases may be present (typically muscovite, quartz, haematite) they are usually either finely disseminated or concentrated into discrete bands or layers. The 'white' eastern Mediterranean marbles (that is: Carrara, Pentelic, Thasian, Parian, etc.) commonly used in sculpture and decoration are typical of this mineralogy and are distinguishable by their grain size, presence or absence of banding, their colour (which may be variable and lost on crushing, and is imparted by finely disseminated traces of minerals), and more recently by their carbon and oxygen isotopic signatures (see Herz, 1990).

Marbles containing abundant additional phases such as tremolite, diopside, wollastonite, brucite and olivine occur but these are uncommon relative to the monomineralic marbles described above and they appear greenish and mottled in their massive form, and their impurity of colour makes them unlikely pigment sources.

Powdered white marble has found limited use as a pigment in its pure form. It is mentioned as a pigment for tempera painting by Palomino (*Museo Pictorico*, II, 113, 152; cf. Merrifield, 1849). However, it has been widely used as the sand-grade aggregate in lime mortars for the fresco technique. The top coat of lime plaster (*intonaco*) is whitened with ground marble (see Orton, 1992). This top coat is also described by the Roman author Vitruvius (first century BC) and he calls it *marmorino* (Latin *marmor* is marble). Consequently characteristic angular fragments of crushed marble are characteristic in pigments derived from frescos. The authors have identified marble in association with hematite and yellow ochre from Roman domestic frescos at ancient Corinth (Gadbery, 1993; Siddall, 1997).

Marble white was also a term applied to a combination of lead sulfate and zinc oxide used for housepainting (Laurie, 1895), though Doerner (1935) lists this as a synonym for chalk.

Calcium carbonates group; Calcium group; Aragonite; Calcite; Chalk; Lime; Limestone; Vaterite; *White earth*; *Whiting*
Doerner (1935) 11; Gadbery (1993); Herz (1990); Laurie (1895); Merrifield (1849) cliii; Orton (1992); Palomino (1715–24) 113, 152; Siddall (1997); Vitruvius (1st cent BC/Grainger, 1934) 93

MARC BLACK
Black
Synonym, variant or common name

Mayer (1991) lists this as a synonym for vine black, typically a wood char prepared from twigs of vines (*Vitis* species); however, it would seem more reasonable that this should be made from wine lees.

Frankfort black; *Vine black*
Mayer (1991) 50

MARCASITE
Yellow-Brown
Generic compound

Marcasite and pyrite are naturally occurring iron sulfide compounds (FeS_2). Terry (1893) mentions iron black as a ground iron sulfide; however, it is not clear if this is from the mineral source.

Iron sulfides group; Pyrite
Terry (1893) 26

MARIENGLAS
White
Synonym, variant or common name

Term found in various German sources referring to the selenite (*q.v.*) form of gypsum. In Germany it was called *Marienglas* ('Mary's glass'), reputedly because it was used to cover small pictures of the Virgin Mary.

Funders and Möller (1989) lists a number of other terms used for Marienglas since the sixteenth century, including *Fraueneis* ('women's ice'), *Gipsspat* ('gypsum spar'), *Erdglas* ('earth glass'), *Alumen scariolae*, *Alumen squamosum*, *Lapis specularis*, *Glacie divae Maria*, *Selenita*, *Aphroselenes*, *Diaphanes*, *Crustae Longae*; Brachert (2001) also lists *Erdglas*, *Specularis lapis*, *Selenites lapis*, *Aphroselenus*, *Frauenglas*, *Spiegelstein*, *Glacies diue Mariae*, *Alumen scaiolae*, *Speclarium*, *Alumen squamosum* and *Alumen scariole*; Rose (1916) additionally uses the term *Leichtspat*.

'Marienglas' is also mentioned as a pigment in sources such as Gentele (1860) and Rose (1916).

Selenite
Brachert (2001) 161; Funders & Möller (1989); Gentele (1860) 9; Rose (1916) 70

MARINE GREEN
Green
Synonym, variant or common name

This is included with the copper greens in Scott Taylor's 1875 edition of Field's *Chromatography*.

Scott Taylor (1885) 72

MARNE
White
Synonym, variant or common name

A term used to refer to a form of calcareous clay. Watin (1785), for example, mentions the use of marne as part of several formulations for ceruse. Ceruse is, he states, lead white mixed with chalk or marne either 50/50 or 6 oz of lead white to 10 oz of 'marne' from Holland. In later editions Watin also says that a certain marne from Canteleu near Rouen was used and gave good results. Finally, *Blanc de Bougival*, also called *Blanc d'Éspagne*, is stated to be an earth or white marne.

Clay minerals group
Watin (1773/edition of 1785) 16–18, 20

MARS BLACK
Black
Synonym, variant or common name

Mars black is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). The starting point was the production of mars yellow, a synthetic form of the iron oxide hydroxide occurring naturally as goethite.

Iron oxides and hydroxides group; Goethite; Hematite; Magnetite; *Mars pigments*

MARS BROWN
Brown
Synonym, variant or common name

Mars brown is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). The precipitate produced a yellow or yellow-brown pigment (mars yellow) which then required washing to remove traces of acid (Weber, 1923; Helwig, 1998). Terry (1893) describes mars brown as either calcined mars yellow, or else prepared from 'alum, sulphate of iron, and chloride of manganese'. In notes left by the colourman Blockx in 1865 (cf. Helwig, 1998), mars brown was made by adding vine black to mars yellow during the washing process. Alternatively Riffault *et al.* (1874) indicates that various shades of mars brown could be prepared directly by precipitating iron oxide salts mixed with salts of manganese, zinc, cobalt or nickel with an alkali. Salter (1869) states that mars brown was 'either a natural or artificial ochre containing iron, or iron and manganese'. However, the term is best applied to synthetic iron oxide-based colours prepared by aqueous precipitation.

Laar and Burnstock (1997) have found mars brown in the archives of the Amsterdam-based materials firm Claus & Fritz (1841–1931), adulterated with a small amount of chalk, and containing trace amounts of silica.

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type

Helwig (1998); Laar & Burnstock (1997); Riffault *et al.* (1874) 500–501; Salter (1869) 313–314; Terry (1893) 103; Weber (1923) 89

MARS ORANGE

Orange

Synonym, variant or common name

Mars orange is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). This process produced a yellow or yellow-brown pigment (mars yellow) which then required washing to remove traces of acid. Mars yellow, essentially iron oxide hydroxide, could then be roasted to oxidise it to iron(III) oxide and thus produce a range of colours through oranges to reds (Weber, 1923; Helwig, 1998).

Newman *et al.* (1980) have tentatively identified mars orange in a paint-box owned by Winslow Homer, called 'rust orange', adulterated with calcite. Laar and Burnstock (1997) have detected mars orange in the archives of the Amsterdam-based materials firm Claus & Fritz (1841–1931), adulterated with a 'large amount' of chalk. Analyses of this pigment revealed it also contained trace amounts of copper and silica. The implications for this in the manufacturing processes are unexplained. Helwig (1998) identified the presence of chrome orange, 'hematite' and 'goethite' in mars orange supplied by the Belgian firm of Blockx et fils (1865–1913).

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type

Helwig (1998); Laar & Burnstock (1997); Newman *et al.* (1980); Weber (1923) 89

MARS PIGMENTS

Variable

Synonym, variant or common name

A group of synthetically produced iron oxide pigments with colours in the yellow-red-violet-black range, the term typically qualified by a colour descriptor (such as 'Mars red'). The mars colours emerged in the eighteenth century.

Mars pigments were manufactured from iron(II) sulfate (also called 'green vitriol' or 'martial vitriol') mixed with alum and then precipitated with an alkali (lime, caustic soda (NaOH), potash, etc.). The precipitate then required thorough washing (see Martel, 1860; Weber, 1923). According to Helwig (1998) other iron salts (iron chloride, iron nitrate or iron acetate) could also be used. This method of precipitating iron oxides was new in use for pigment manufacture. Jacques Blockx gave instructions from the production of mars colours in 1865 (cf. Helwig, 1998). The recipes needed to be followed closely and carefully and took six days. A yellow-brown pigment was produced by the precipitation of iron salts and alkali alone. Other colours could be produced with the addition of other chemicals. Alum added to the iron sulfate solution produced a light yellow colour. Varieties of mars yellow were the starting point for the preparation of the other colours which are heated to various degrees, with increasing temperature promoting the colour change through orange, red, scarlet. Mars violet may in some cases have been produced by further calcination but may also have been iron oxides mixed with cobalt oxides (Sennelier, 1896; cf. Helwig) however, Helwig's analyses of archive samples of mars brown showed them to be pure hematite. Mars brown, according to Blockx, was made by adding vine black to mars yellow (cf. Helwig). Riffault *et al.* (1874) say that mixing iron salts with zinc, manganese, cobalt or nickel salts (and presumable precipitating them with alkalis) made mars brown. Helwig analysed a sample of Roberson's mars brown and found it was 'amorphous iron and chromium compounds'.

Helwig also showed that the mars pigments were variously extended with gypsum, barytes and aluminium oxides and occasionally brightened with other inorganic and organic pigments.

The earliest mention of these pigments is by de Mayerne (BL MS Sloane 2052; cf. Harley, 1982). Harley makes the assumption that manufactured iron oxides were relatively uncommon, probably due to the fact that the naturally occurring equivalents were so widely and readily available. Field (1835) describes the orange *jaune de Mars*, describing it as 'an artificial iron ochre … We formerly prepared a variety brighter, richer, and more transparent [than natural ochres]'; Salter (1869) subsequently, though erroneously, attributes the introduction of mars colours to Field.

Osborn (1845) describes these pigments: 'In the first class [of permanence], then, there are the pigments known by the prefix or addition Mars. They are all of the same character and nature; artificial ochres (formed by a combination of the oxide of iron with alumin), of great beauty and solidity, and differing only in their hues of Yellow, Brown, &c. The Violets of this tribe, which are produced by a very powerful and oft-repeated calcination, are of high price.'

Laar and Burnstock (1997) have found mars colours in the archives of the colourmen Claus & Fritz, variously extended with chalk. Townsend (1993) has identified mars colours in Turner's palette.

The title 'mars yellow' and the mars colours that are its derivatives emerged in the eighteenth century as a literal translation of the Latin *crocus martius*. To alchemists, Mars symbolised iron and crocus was synonymous with saffron and hence yellow.

Iron group; Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type; *Caput mortuum*; *Mars black*; *Mars brown*; *Mars orange*; *Mars red*; *Mars scarlet*; *Mars violet*; *Mars yellow*

Field (1835) 119; Harley (1982) 91–92, 120–122; Helwig (1998); Laar & Burnstock (1997); Martel (1860) 23; MS Sloane 2052 (nd); Osborn (1845) 49; Riffault *et al.* (1874) 500–501; Salter (1869) 248–249; Townsend (1993); Weber (1923) 89

MARS RED

Red

Synonym, variant or common name

Mars red is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). Mars red was produced by roasting the precipitate produced by this process, which was yellow iron oxide hydroxide, converting it to iron(III) oxide (Helwig, 1998). Carlyle (2001) found relatively little reference to this pigment and remarks on the surprising lack of interest since Salter (1869) says that mars red possesses 'the richness and depth of Indian red, it is distinguished by the russet orange hue or light red'. Field (1835) describes mars red as a very permanent, artificial iron ochre.

Helwig (1998) identified the presence of chrome orange, hematite and goethite in mars red supplied by the Belgian firm of Blockx et fils (1865–1913).

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type
Carlyle (2001) 510; Field (1835) 108; Helwig (1998); Salter (1869) 145–146

MARS SCARLET

Red
Synonym, variant or common name

Mars scarlet is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). Red shades were produced by oxidising the precipitate, yellow iron oxide hydroxide, converting it to iron(III) oxide (Helwig, 1998).

Mars scarlet was apparently a form of mars red (*q.v.*), Carlyle (2001) notes that Winsor & Newton began listing this pigment in 1846, while Roberson purchased it from the colourmen Lechertier & Barbe in 1872.

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type
Carlyle (2001) 510, 528; Helwig (1998)

MARS VIOLET

Purple
Synonym, variant or common name

Mars violet is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). This process produces yellow iron oxide hydroxide (*mars yellow*), which can be roasted and oxidised to produce red shades of iron(III) oxide (Weber, 1923; Helwig, 1998). Mars violet shades, however, were listed by the French pigment company Sennelier as 'oxide de fer, cobalt', suggesting that this particular shade was a mixture of iron and cobalt oxides. Sennelier also advocated the method of roasting mars yellow to high temperatures to produce mars violet, and also suggested mixing the iron salt raw materials with manganese salts and precipitating this mixture with the alkali. Analyses of mars violet pigments by Helwig (1998) failed to identify either cobalt or manganese. Her conclusions were that they consisted of pure hematite, but were coarser grained than the prepared mars reds. Particles of size 0.1–0.2 μm appear bright red whereas a blue-red to purple colour is observed with 1–5 μm grain size. Her work also implies that mars violet could also be made by calcining hematite, natural iron(III) oxide. This pigment is analogous to caput mortuum.

Mars violet pigments supplied by Roberson and analysed by Helwig (1998) were 'brightened' by the addition of an organic violet dye Helio Bordeaux (CI Pigment Red 54).

Field (1835) describes purple ochre as a native ochre from the Forest of Dean, Gloucestershire, England, though in the 1841 edition he notes that it can be made artificially by calcining natural red ochres and 'has been employed under the denomination of Violet de Mars'. Salter (1869) remarks on the difficulty of obtaining the pigment and says mars violet was often compounded, though usually with Indian red as the base; he also adds the synonym mineral purple. Vibert (1892) on the other hand included it with permanent iron oxide colours that were either naturally fixed on clay or artificially on alumina.

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type; *Caput mortuum*; *Mineral purple*; *Purple ochre*
Field (1835) 137–138; Helwig (1998); Salter (1869) 299; Vibert (1892); Weber (1923) 89

MARS YELLOW

Yellow
Synonym, variant or common name

Mars yellow is one of the mars pigments (*q.v.*), developed during the eighteenth century and manufactured by the aqueous precipitation of iron salts (sulfates, chlorides, nitrates and acetates) with an alkali (lime, caustic soda (NaOH), potash, etc.). Mars yellow is the first shade produced by this process, which may then be further roasted or adulterated to produce the other mars colours. Unlike other earlier synthetic iron oxides and oxide hydroxides, the mars colours were pure and very fine grained while retaining a strong colour. Mars yellow is originally a yellow-brown shade. It could be brightened to a pale yellow by mixing the iron sulfate raw material with alum before precipitating the iron oxide (Weber, 1923; Helwig, 1998). Various early descriptions of the manufacturing process exist. Martel (1860) states: 'The Mars pigments are prepared by precipitating certain soluble salts of iron by means of the alkalis, or alkaline earths, such as potash, soda, lime and alumina … by calcining Mars Yellow we obtain, (according to the degree of heat applied, and by other means kept secret by the manufacturers) orange, brown, red and violet Mars.'

The name mars is derived from the god of war, whose metal is iron. The pigment was also called *crocus martius*, with crocus referring to saffron or yellow; for example, the seventeenth–eighteenth century chemist Boerhaave has a section in his 1727 treatise on chemistry titled 'Exhibiting the reduction of Vitriol of Iron to a Calx or Crocus; or the preparation of Crocus Martis astringens.'

Two patent applications of 1780 and 1794 for *crocus martis* or saffron of mars indicate the earliest period the colour was made (Harley, 1982). Salter (1869) gives *Jaune de Mars*, *Jaune de Fer* and Iron yellow as synonyms, also adding that it was sometimes mixed with orpiment or lead chromate to brighten the colour. The Fishwick MS (dated to 1795–1816), mentions a different concoction, perhaps producing a similar shade – 'Mars yellow: best yellow orpiment, dutch pink, grind very fine in water, then dry on chalk.' Zerr and Rübencamp (1906) additionally mention a pigment they call siderin yellow, apparently an iron chromate, as being sold under the name mars yellow.

Mars yellow has been identified by Laar and Burnstock (1997) in the archives of the Amsterdam-based pigment firm Claus & Fritz. Their analyses of these pigments detected trace amounts of copper and silica, the presence of which is not absolutely explained by the understood manufacturing process.

Iron oxides and hydroxides group; Goethite; Hematite; Iron(III) oxide, hematite type
Boerhaave (1727); Harley (1982) 92; Helwig (1998); Laar & Burnstock (1997); Martel (1860) 23; Salter (1869) 102; Weber (1923) 89; Zerr & Rübencamp (1906/1908) 126

MASSICOT

Yellow
Generic compound

Massicot is currently taken to refer to an orthorhombic lead(II) oxide mineral with composition PbO, first described by Huot in 1841. It occurs as soft yellow scaly or earthy masses in association with lead ore deposits worldwide. It is the high temperature polymorph of litharge (*q.v.*), the tetragonal form, and is stable above approximately 540°C. Modern studies of the structure of massicot in this sense have been published by White *et al.* (1961) and Hill (1985).

The historical terminology associated with massicot is, however, more complex. The word massicot probably derives from the Arabic term *sabb Kubti*, meaning Egyptian alum or soda. This became modified to '*marzachotto*' (or '*mazacote*'), which referred to a glaze on ceramics of the type known as faience, which are essentially a tin-enamelled earthenware. Techniques for producing faience wares were then probably introduced into Italy via Spain by the fourteenth century from where it seems to have been disseminated into northern European countries (such as the basis of 'Delft' ware). In this way *marzachotto* perhaps passed into the northern potters' language as 'massicot', still meaning in that context a soft transparent ceramic glaze; recipes for this can be found until the eighteenth century called by the same name. However, a further transition took place, perhaps as a result of the association of tin and lead in ceramic glazes, whereby massicot came to mean a lead tin yellow pigment. Early examples of the use of massicot for a painting pigment are those dated 1449 cited by de Vries, an entry of 1472 in the Fabric Rolls of York Minster in England and a French reference dated to c. 1480 by Dunlop (cf. Eastaugh, 1988). By the seventeenth century recipes and descriptions leave no doubt that massicot generally referred to lead tin yellow (for example, Haydocke's 1598 translation of Lomazzo replaces '*gialolino*' – a term currently accepted as largely synonymous with lead tin yellow – with 'masticot'). Some other sources do, however, give alternate meanings; for example, two late sixteenth to early seventeenth century English texts (MS Ashmole 1494, a primarily alchemical text) states: 'Lyttarge in lattine is called litargirum and in the Arrabian and greke tongue yt is called Mazechet', while Cotgrave (1611) describes massicot as a calcination product of ceruse (Harley, 1982, states that in the sixteenth century English writers would use the term ceruse indiscriminately for a white pigment made from lead or tin). It would seem therefore that at some point in the eighteenth or early nineteenth century 'massicot' then came to be applied to a lead monoxide; as the original description of the mineral is Huot in 1841, this probably forms a *terminus post* date for terminological usage in that context. Zerr and Rübencamp (1906) give the recipe for the production of massicot for artist's pigment by heating white lead to a high temperature.

Massicot in the modern sense has been reported by a number of authors on artefacts. These include: Filatov *et al.* (1965) among pigments on Byzantine and post-Byzantine icons in Russia, Yugoslavia, Rumania and Poland, dating from the eleventh to the eighteenth centuries; Le Fur (1990) in Egyptian painting; Mairinger and Schreiner (1986) in Carolingian and mediaeval mural paintings in the Müstair Convent, Switzerland; Nord and Tronner (1998) in mural paintings from various thirteenth and fifteenth century churches in Sweden; Preusser *et al.* (1981) on painted gravestones from an excavation near Volos in central Greece; Riederer (1977b) among 80 wall paintings from Central Asia. Using Raman spectroscopy, Burgio *et al.* (1999b) identified minor amounts of massicot on a Thai manuscript (dated to c. 1800) and the *Flora Danica*, however in this case it was suggested that the massicot might be derived from the red lead (*q.v.*) used elsewhere on the manuscript, either as an impurity in a natural sample or due to imperfect synthesis. Applying the same technique, Andalò *et al.* (2001) identified massicot as applied over a blue pigment (predominantly lapis lazuli, plus azurite and malachite, *qq.v.*) on the *Trionfo D'Amore*, attributed to Botticelli. However, Smith *et al.* (2001) suggest that the massicot-like Raman spectrum obtained by Andalò *et al.* (2001) was caused by the laser heating-induced degradation of lead(IV) oxide or lead sulfide on the painting, present as a degradation product of the lead white (*q.v.*) used.

Lead group; Lead oxides and hydroxides group; Litharge; *Lead tin yellow*

Andalò *et al.* (2001); Burgio *et al.* (1999a); Burgio *et al.* (1999b); Eastaugh (1988); Filatov *et al.* (1965); Harley (1982) 171–172; Hill (1985); Huot (1841); Le Fur (1990); Mairinger & Schreiner (1986); MS Ashmole 1494; Nord & Tronner (1998); Preusser *et al.* (1981); Riederer (1977b); Smith *et al.* (2001); White *et al.* (1961); Zerr & Rübencamp (1906/1908) 258

MASTICOT

Yellow
Synonym, variant or common name

See: massicot.

MATHIEU-PLESSY'S GREEN

Green
Synonym, variant or common name

See: Arnaudon's chrome green.

MATRAITE

Black-Brown
Generic compound

Matraite is a zinc sulfide mineral with composition ZnS. It was first described by Koch in 1958 from Gyongyosoroszi (Matra Mountains, Hungary) and is still only known from this locality. It occurs as aggregates of brown to brown-yellow anhedral or hemimorphic pyramidal crystals. It is a rare mineral in nature; the iron-bearing varieties of zinc sulfide, sphalerite and wurtzite (*qq.v.*), are more commonly encountered.

The rarity of matraite means that it is unlikely to have been used as a pigment. However, its pure synthetic analogue, zinc sulfide (*q.v.*), may be encountered in the manufacture of zinc sulfide pigments.

Zinc sulfides group; Sphalerite; Wurtzite; Zinc sulfide
Koch (1960)

MAUVE

Purple
Synonym, variant or common name

Mauve (also mauveine) may refer to a number of purple compounds based on aniline dyestuffs – so-called 'coal tar' colours – which became available in the second half of the nineteenth century. The name mauve also refers specifically to the dye developed by William Henry Perkin in 1856. Perkin initially called this Tyrian purple (*q.v.*) as this would enhance its value; however, his detractors preferred to call it 'purple sludge' (Garfield, 2000).

Coal tar colours
Garfield (2000)

May green

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*), the term probably indicating a shade variant.

Emerald green
Fiedler & Bayard (1997)

Maya blue

Blue
Generic compound

Extensive research on Maya blue indicates that it is indigo on a base of palygorskite (formerly attapulgite; sepiolite may also be present) that are the principal components (Gettens, 1962; van Olphen, 1966; Kleber *et al*., 1967). This produced a remarkably stable pigment used by the ancient Mesoamericans.

Studies have shown that heating a mixture of the palygorskite and indigo at approximately 150°C for two days produces this blue pigment. Using high resolution transmission electron microscopy (TEM), José-Yacamán *et al*. (1996) and Polette *et al*. (2002) have described how the heating results in the formation of a palygorskite superlattice and iron nanoparticles (1–10 nm) which reside both outside the crystallite lattice and within channels in the palygorskite as the indigo binds to the clay surface. Polette *et al*. using X-ray absorption spectroscopy further showed that the iron in the nanoparticles from authentic samples (from Chitzen Itza and Tulum, Mexico) was present in the form of α-Fe_2O_3 and FeO(OH)-goethite, or an intermediate stage of hydration. The origin of the goethite particles was suggested to have been secondary, caused by alteration of the α-Fe_2O_3 nanoparticles during exposure.

Several sixteenth century manuscripts have led to the identification of the terms *xuiquilitl and tlacevili* as the Aztec language (Nahuatl) terms for indigo (*Indigofera suffrictiosa*) (Wallert, 1995c). South American sources of indigo are discussed by Schweppe, who notes that a number of plants were used in the Pre-Columbian period, certainly for textiles. These include the *Indigofera* species *I. anil* L., *I. suffruticosa Miller*, *I. guatamalensis* (and possibly *I. erecta* Thunb. and *I. secundiflora*) as well as (citing Bruyas, 1970) *Fuchsia parviflora* Lindl. (Onagraceae), *Justicia spicigera* Schlenchtendal (formerly *Jacobinia s.*; Acanthaceae) and one he lists as *Chiropetalum lanceolatum*, but which is possibly now either *Argythamnia lanceolata* (Benth.) Müll. Arg. or *Ditaxis lanceolata* (Benth.) Pax & K. Hoffm. (Euphorbiaceae). According to Clavijero (1780, cf. Colombo, 1995) the Spanish introduced *Indigofera tinctoria* L. from India into their colonies in Venezuela and Guatemala in the seventeenth century.

Maya blue was widely used for painting on murals, sculptures, ceramics and textiles by the Mayans (Roundhill *et al*., 1994; cf. Balfour Paul, 1998), and Kleber indicates that it was also used by the Toltecs, Mixtecs and the Aztecs.

Indigoid group; Indigo; Palygorskite; Sepiolite
Balfour Paul (1998) 22; Bruyas (1970); Clavijero (1780) VII.189–190; Colombo (1995) 174; Gettens (1962); José-Yacamán *et al*. (1996); Kleber *et al*. (1967); Olphen (1966); Polette *et al*. (2002); Roundhill *et al*. (1994); Wallert (1995c)

Meadow green

Green
Synonym, variant or common name

Rose (1916) describes this under the German term '*Wiesengrün*', meadow green, as a mixture of copper arsenite, copper phosphate and copper carbonate.

Copper arsenite group; **Copper phosphates group**
Rose (1916)

Melaconite

Black-Brown
Generic compound

See: tenorite.

Melanterite

Green
Generic compound

Iron sulfate hydrate mineral of composition $FeSO_4.7H_2O$.
See: iron sulfates group.

Melian white

White
Synonym, variant or common name

In a description of natural colours, Vitruvius (first century BC) states that: 'Paraetonium white gets its name from the place where it is dug up. The same is the case with melinum ['Melian white'], because there is said to be a mine of it in Melos, one of the islands of the Cyclades.' Pliny (77 AD) states that melinum came from Melos and that a similar material was found in Samos but was not used by painters because it was too 'greasy'.

Although Wallert (1995a) has made a tentative suggestion that *melinum* (and *paraetonium*) are actually deposits of cerussite (neutral lead carbonate), recent work by McNulty (2000) and Hall *et al*. (2003) have concluded that Melian earth is probably a mixture of kaolinite, silica and alunite ($KAl_3[SO_4]_2[OH]_6$) from deposits on Melos formed through acid sulfate alteration of volcanic tuffs. McNulty also found that the presence of the impurities enhanced the kaolinite's performance as a white pigment. Hall *et al*. (2003) have identified evidence of tunnels and other workings (undated) in kaolinite-silica-alunite deposits in the region of Aghia Kyriaki.

Alunite; Cerussite; Kaolinite; Lead carbonate; Silica; *Paraetonium white*
Hall *et al*. (2003); McNulty (2000); Pliny (1st cent AD/Rackham, 1952) XXXV.xix; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.3; Wallert (1995a)

Mendipite

White
Generic compound

Mendipite is a lead chloride oxide mineral with composition $Pb_3Cl_2O_2$, closely related to chibutite, $Pb_7O_6Cl_2$. Mendipite, also known as churchillite, was first listed by Glocker in 1839 and is named after Churchill, Mendip Hills (England), where good samples are found. It occurs as relatively soft white fibrous or nodular masses (which may be pale yellow, grey or blue if impurities are present) and forms as a secondary mineral by the weathering of lead ore deposits (Dana, 1932; Pasero and Vacchiano 2000; Vincent and Perrault, 1971).

Mendipite is not known to have been used as a pigment but synthetic lead chloride oxide (*q.v.*) has been synthesised as a yellow pigment with composition given as $PbCl_{2.5\text{–}7}PbO$ listed in the *Colour Index* (1971) as CI Pigment Yellow 30 (CI 77592).

Lead halides group; Lead oxides and hydroxides group; Lead chloride oxide
Colour Index (1971) 77592; Dana (1932) 567; Pasero & Vacchiano (2000); Vincent & Perrault (1971)

Menning

Red
Synonym, variant or common name

See: minium.

Mercadmium

Red
Synonym, variant or common name

See: cadmium mercury sulfide.

Mercury chromate

Orange
Generic compound

According to the chemical literature, two common forms of mercury chromate exist: a red mercury(II) chromate (mercuric chromate), $HgCrO_4$, and mercury(I) chromate, Hg_2CrO_4, a darker brown solid (MacIntyre, 1992). However, in the art literature, the type of mercury chromate referred to is not always clear. According to Kühn and Curran (1986), mercuric chromate, Hg_2CrO_4, is precipitated from a mixture of mercury salts and potassium chromate or nitrate. Mercuric chromate with composition given as Hg_2CrO_4 is mentioned in 1807 by Klaproth and Wolff, and although Field (1835) mentions mercury chromate as a possible component of chrome orange (*q.v.*), according to Carlyle (2001), no other British sources apart from the later editors of Field (for example, Salter, 1869) mention it. However, it is mentioned in the German literature, and Kühn and Curran cite Hartmann who was writing in 1840, as discussing mercuric chromate as a commercial pigment. Gentele (1860), however, states that mercuric chromate was not suitable as a pigment when used in oil as it lacked permanence and darkened significantly. Riffault *et al*. (1874) describe two varieties of mercury chromate – one a dark brick red, the other with a violet tinge. These may refer to the two different mercury chromates listed above.

Walker (2003) states that a sketchbook belonging to Bouguereau dated to 1869 lists a set of pigments available to the artist which included a purple red material with composition given as mercuric chromate.

Also known as chromate of mercury (Field).

Chromates group; Mercury group; *Chrome orange*
Carlyle (2001) 504; Field (1835) 118; Gentele (1860) 272; Hartmann (1840); Klaproth & Wolff (1807); Kühn & Curran (1986); MacIntyre (1992) 3074–3075; Riffault *et al*. (1874) 439–440; Salter (1869) 256–257; Walker (2003)

Mercury group

Variable
Group term

Although the mercury sulfides are perhaps the most familiar group of pigments, a number of other mercury compounds have also been used. Among the halides, mercury(II) iodide has found use as a pigment (though mercury(I) iodide and mercury(II) iodate do not appear to have been). Two chromates are included here, mercury(I) chromate, Hg_2CrO_4 and Mercury(II) chromate, $HgCrO_4$. Several sulfates are known and may have pigment use, notably mercury sulfate hydroxide and schuetteite ($Hg_3SO_4O_2$). Finally, among the sulfides, cinnabar and its mercury(II) sulfide analogue, prepared according to several historically important manufacturing processes (commonly known as the ‘dry’ and ‘wet’ processes) are of major importance; however, several crystal modifications also exist, these being the hypercinnabar and metacinnabar types.

Mercury halides group; Mercury sulfates group; Mercury sulfides group; Cinnabar; Hypercinnabar; Mercury iodide; Metacinnabar; Schuetteite

Mercury halides group

Variable
Group term

See: mercury iodide.

Mercury iodide

Red
Generic compound

The mercury iodide normally referred to in the context of pigment usage – mercury(II) iodide (HgI_2) – is a red compound also known historically under the name iodine scarlet. In fact two crystalline forms of mercury(II) iodide (HgI_2) – α- and β-types – exist, the former red and the latter yellow. A sample of the pigment from the palette of J.M.W. Turner (Townsend, 1993) examined by the authors apparently contained both crystalline phases.

A mercury(I) iodide and other mercury(II) iodides are known: HgI being a bright yellow amorphous, heavy, odourless powder which darkens in light, HgI_2 and metallic mercury being formed; mercury(II) iodate, HgI_2O_6, being a white powder. Neither of these two compounds appears to have been used as a pigment. Fading of mercury(II) iodide has been discussed by Daniels (1987b), who attributed the phenomenon to sublimation. Its instability appears to have been well known historically, Salter (1869), for example, commenting that ‘Nothing certainly can approach it as a colour for scarlet geraniums, but its beauty is almost as fleeting as the flowers.’

The pigment was apparently first made in 1814 by the French chemist Vauquelin by grinding together mercury and iodine. Iodine scarlet mentioned by Mérimée (1830), who pointed out it was sold in England as scarlet lake, although Field (1835) states that this is based on cochineal and vermillion, and calls mercury iodide, iodine scarlet. Martel (1860) refers to it as scarlet, Salter (1869), Scott Taylor (1885) and Seward (1889) as pure scarlet, and Reeves & Son sold it as royal scarlet in the later nineteenth century. Heaton (1928) calls this brilliant scarlet. Salter also mentions a pink form, pink scarlet. It was apparently used almost exclusively for watercolour (cf. Carlyle, 2001).

Mercury group; *Brilliant scarlet*; *Iodine pink*; *Iodine scarlet*; *Pure scarlet*; *Scarlet*; *Scarlet lake*
Carlyle (2001) 504–505; Daniels (1987b); Field (1835) 94; Heaton (1928) 380; Martel (1860) 25; Mérimée (1830/trans. Taylor, 1839) 120–122; Salter (1869) 150–151; Scott Taylor (1885) 74; Seward (1889); Townsend (1993)

Mercury sulfates group

Yellow
Group term

Of the various mercury sulfates, that of principal importance is the yellow mercury oxide sulfate (given in the literature as the equivalent $Hg_3SO_4O_2$ or $HgSO_4.2HgO$) and its mineral analogue schuetteite (*q.v.*). This is listed by the *Merck Index* (1996) as mercury oxonium sulfate and given as synonymous with 'Turpeth mineral' (turbith mineral, *q.v.*; see that entry for a discussion of the terminology and history); X-ray diffraction studies of the structure show that the polymeric oxonium cations $(Hg_3O_2)x$ form two-dimensional infinite layers, the sulfate ions lying inside the loops of the wide-meshed cation lattice.

Of other closely related compounds, a white mercury sulfate ($HgSO_4$) and a mercury sulfate hydroxide ($HgSO_4(OH)_2$) are known but do not appear to have found practical use as pigments.

Mercury group; Schuetteite; *Mercury yellow*; *Turbith mineral*
Merck Index (1996) 5941

MERCURY(II) SULFIDE, CINNABAR TYPE

Red
Generic compound

Mercury(II) sulfide, HgS, can take on several crystal structures (also hypercinnabar and metacinnabar) of which that of cinnabar is the most important in pigments.

Despite the presence of significant sources of the mineral cinnabar, much of the mercury sulfide used historically as a pigment in post-classical times seems to have been derived from synthetic routes. Moreover, perhaps until the nineteenth century the vast majority was prepared by a sublimation technique. A typical recipe is given in the Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield, 1849): '*179. To make vermilion*. Take of quicksilver two parts, of sulphur one part; first melt the sulphur, then add the quicksilver, mix them well, and reduce them to powder, and then put the powder into a flask luted with lutum sapientiae as high as the neck. Place the flask on the ashes until all the humidity is driven off; then close the mouth of the flask with cotton, and give it a tolerably strong fire until the matter rises to the neck of the flask and is very red; then take it from the fire, let it cool, and it is done.' (An interesting modification is given in a following recipe, where a small proportion of tin is incorporated.) Both Thompson and Harley note numerous MSS where instructions are provided for the preparation of vermilion, from the tenth century onwards (Thompson, 1935; Harley, 1982). Aqueous methods of preparation are thought to have been known since the later seventeenth century, though there appears to have been little commercial impact before the nineteenth.

For further information on the mineral analogue, see cinnabar; for a discussion of the history and terminology, see vermilion; for mercury sulfides in general see mercury sulfides group.

Mercury group; Mercury sulfides group; Cinnabar; Hypercinnabar; Mercury(II) sulfide, hypercinnabar type; Mercury(II) sulfide, metacinnabar type; Metacinnabar; *Vermilion*
Harley (1982) 125–126; Merrifield (1849) 478; Thompson (1935) 430

MERCURY(II) SULFIDE, HYPERCINNABAR TYPE

Red
Generic compound

See: hypercinnabar.

MERCURY(II) SULFIDE, METACINNABAR TYPE

Black
Generic compound

Synthetic analogue of metacinnabar (*q.v.*), α'-HgS. The formation of metacinnabar can occur from cinnabar and vermilion (*q.v.*) in an art context, resulting in the darkening of the pigment. Daniels (1987a) has shown that alkali metal halide impurities in vermilion are effective in catalysing the conversion to metacinnabar, while trituration and exposure to light of wavelengths between 400 and 570 nm also encourages the transformation. Plesters *et al.* (1982) have observed the darkening of vermilion used in various binding media including egg tempera, oil and animal glue, as well as on church interior paintings accessible to light.

Cinnabar; Mercury(II) sulfide, cinnabar type; Metacinnabar; *Vermilion*
Daniels (1987a); Plesters *et al.* (1982)

MERCURY SULFIDES GROUP

Variable
Group term

The mercury sulfide compounds are undoubtedly the most important of the mercury group pigments as they include the red mineral cinnabar (HgS) and its synthetic analogue mercury(II) sulfide, commonly known as vermilion (*q.v.*). Two other crystal modifications of mercury(II) sulfide occur, the hypercinnabar type (β-HgS) and the metacinnabar type (α'-HgS), the latter primarily significant as a black alteration product. Additionally, cadmium mercury sulfide ((Cd,Hg)S) is relevant in the context of cadmium sulfide pigments.

Cadmium sulfides and selenides group; Mercury group; Cadmium mercury sulfide; Cinnabar; Hypercinnabar; Mercury(II) sulfide, cinnabar type; Mercury(II) sulfide, metacinnabar type; *Vermilion*

MERCURY YELLOW

Yellow
Synonym, variant or common name

According to Heaton (1928) mercury yellow was an obsolete or rarely used pigment. The composition is given as a 'basic sulphate of mercury'. It is equivalent to the term turbith mineral (*q.v.*).

Mercury sulfate; *Turbith mineral*
Heaton (1928) 382

MERCURY(II) OXIDE

Red
Generic compound

Described by Salter (1869) as 'Red precipitate'. In more recent times, mercury(II) oxide has found use as a functional pigment in antifouling paints (Patton, 1973).

Mercury group; *Red precipitate*
Patton (1973j); Salter (1869) 173

MÉRIMÉE'S YELLOW

Yellow
Synonym, variant or common name

Mérimée's yellow is lead antimony oxide together with lead chloride oxide. This is often confused with the lead antimony oxide Naples yellow (*q.v.*), for example see: Rabaté (1947) and Reclus (1956) (cf. Wainwright *et al.*, 1986). Mérimée (1830) found in a memoir by Passari (1758) a collection of recipes from Venice including a series of formulations for yellow: 'antimony, 1 lb.; lead, 1½ lb.; common salt 1 oz.; tartarate of potass 1 oz.'. He states that the proportions can be changed, and in four recipes the salt is omitted. He further states that 'the effect of the salt would be to render the colour more clear, but less rich, because it produces a portion of chloride of lead'.

Lead antimony oxide; *Naples yellow*
Mérimée (1830/trans. Taylor, 1839) 100–101; Wainwright *et al.* (1986) 220

METACINNABAR

Black
Generic compound

Metacinnabar is a black cubic mercury sulfide mineral with composition α'-HgS. As the name suggests, it is a polymorph of cinnabar and the rarer form hypercinnabar (*qq.v.*). It is the high temperature form of the three polymorphs, stable above 345°C. Metacinnabar has also been identified in nature as existing metastably with granular or encrusting form and as spherical crystals with metallic lustre at the Reddington and Mount Diablo mines (California, USA) and Chauvay (Alai, Kyrgyzstan). In these cases it was also found with small crystals of hypercinnabar; metacinnabar has also been reported from Donbass, Ukraine and Carniola, Slovenia.

The formation of metacinnabar can occur from cinnabar and vermilion (*q.v.*) in an art context, resulting in the darkening of the pigment (Gettens *et al*., 1993b). Daniels (1987a) has shown that alkali metal halide impurities in vermilion are effective in catalysing the conversion to metacinnabar, while trituration and exposure to light of wavelengths between 400 and 570 nm also encourages the transformation. Plesters *et al.* (1982) have observed the darkening of vermilion used in various binding media including egg tempera, oil and animal glue, as well as on church interior paintings accessible to light.

Metacinnabar has also been observed to form during the roasting of mercury ores, with corderoite, schuetteite (*qq.v.*) and other mercury chlorides also precipitated. In the roasting process, cinnabar transforms to metacinnabar and impurities can become incorporated into the structure, which hinders the complete reversal back to cinnabar during cooling.

Metacinnabar has been identified among pigments in the frescos of the Loggia di Psiche, Villa Farnesina, Rome, by Raphael and his assistants (Bassotti *et al*., 2000).

Mercury group; Cinnabar; Hypercinnabar; Schuetteite
Bassotti *et al.* (2000); Daniels (1987a); Gettens *et al.* (1993b); Plesters *et al.* (1982)

METAHALLOYSITE

White
Generic compound

See: halloysite.

METAKAOLINITE

White
Generic compound

White mineral pigment reported by Stos-Fertner *et al.* (1979) in Minoan painted pottery as well as being described as occurring in calcined clays by Huxtable and Pickering (1979).
See: kaolinite.

Huxtable & Pickering (1979); Stos-Fertner *et al.* (1979)

METAL PIGMENTS

Metal
Group term

The following metals are recorded as having been used as pigments in their elemental form: Aluminium (Al); Antimony (Sb); Bismuth (Bi); Gold (Au); Nickel (Ni); Silver (Ag); Cupro-Nickel alloys; Cupro-Zinc or Cupro-Aluminium alloys (‘gold bronze’).

Aluminium powder has been used as a metallic flake pigment. The term ‘Aluminium bronze powder’ also seems to refer to this (Gettens and Stout, 1966). Heaton (1928) writes that aluminium powder used as a pigment was called silver bronze.

Iron black is powdered metallic antimony according to the *Colour Index* (1971). Metallic bismuth has been used in southern Germany; pure powdered bismuth was applied in a medium and then burnished with an agate to produce a false silver, or gold when glazed (Mayr, 1984).

Metallic lead is known to have been present with lead(II) oxide to produce the pigments *Ashes of lead* or *Grey oxide* (Bristow, 1996b; Martin, 1813; Tingry, 1804).

Powdered gold has been used as a pigment (‘shell gold’). Milled silver was used in illuminated manuscripts and used to imitate gold with the addition of a dye such as saffron (Thompson, 1956).

Bieganska *et al.* (1988) describe the use of metallic flakes of aluminium, zinc, stainless steel, nickel and cupro-nickel. Heaton (1928) describes gold bronze (either cupro-zinc or cupro-aluminium alloy) as ranging in colour from ‘deep copper to pale lemon’ and being used as a metallic pigment.

Pseudo-metallic pigments such as mosaic gold and silver (*qq.v.*) are also found in art. Furthermore Terry (1893) writes that ‘metallic paints’ is a name given to the sienna earths quarried at Lehigh Gap, Pennsylvania. These are unrelated to true metallic pigments. For a more detailed discussion see the individual entries.

Gold group; Aluminium; Antimony; Bismuth; Gold; Lead; Silver; *Aluminium bronze powder*; *Ashes of lead*; *Grey oxide*; *Iron black*; *Mosaic gold*; *Mosaic silver*
Bieganska *et al.* (1988); Bristow (1996b); *Colour Index* (1971) 77050; Gettens & Stout (1966) 92; Heaton (1928) 324; Martin (1813); Mayr (1984); Terry (1893) 274; Thompson (1956) 184; Tingry (1804) 343–344

METAVIVIANITE

Green
Generic compound

Metavivianite is an iron phosphate hydroxide mineral with composition $Fe_{4-x}(PO_4)_2(OH)_x.(8-x)(H_2O)$, first described by Ritz *et al.* in 1974. Metavivianite occurs as soft sub-metallic prismatic striated crystals which are commonly green, although grey, yellow-brown and red forms have also been found. Metavivianite has a higher oxygen content and lower water content than vivianite (*q.v.*) and forms from the alteration of the latter mineral and other phosphates in metallic ore deposits (Dormann *et al*., 1982; Henderson *et al*., 1984); it also forms in sedimentary settings when mineralisation occurs in the presence of organic matter. Metavivianite is not a common mineral but is known from areas such as Borne (Netherlands), Lower Saxony (Germany), Orivesi (Finland), Mangualde (Portugal; Rodgers, 1989), Glendale (South Dakota, USA), Oruro (Boliva) and Hyogo (Japan).

Howard (1995) identified blue vivianite on a Romanesque wall painting that had altered to yellow, producing an overall green pigment. This alteration may be due to conversion of the original vivianite to metavivianite, or due to changes in the oxidation state of the constituent iron.

Iron phosphates group; Vivianite
Dormann *et al.* (1982); Henderson *et al.* (1984); Howard (1995); Ritz *et al.* (1974); Rodgers (1989)

MEUDON WHITE

White
Synonym, variant or common name

This is a white pigment containing chalk (*q.v.*) from the area of Moudon to the south of Paris; for this reason also referred to as Paris white. However, it should not to be confused with the white clay from Moudon or Morat in Switzerland described by Tingry (1804).

Calcite; Chalk; *Paris white*
Tingry (1804) 289

MICA GROUP

Variable
Group term

The mica group consists of a suite of sheet silicate minerals described by the chemical formula $X_2Y_{4-6}[Z_8O_{20}](OH,F)_4$ where, in general, X = K, Na or Ca, Y = Mg, Fe or Al and Z = Si and Al. The micas are closely related compositionally to the members of the chlorite group (*q.v.*) but contain essential alkali elements. The mica group has many members, the main ones considered here being biotite, celadonite, glauconite, lepidolite, muscovite (including varieties fuchsite, binnite and phengite), paragonite and phlogopite (*qq.v.*); pyrophyllite and talc (*qq.v.*) are closely related to the micas and are included here also. The micas are characterised by flexible platy crystals which cleave into thin lamellae along weak structural planes (Deer *et al.*, 1992; Rutley, 1988). The cleaved flakes, often called 'splittings', are elastic and when indented develop six-rayed percussion figures about the indent (Rutley, 1988). The mica structure consists of sheets of $(Si,Al)O_4$ tetrahedra weakly bonded to layers of X and Y cations and hydroxyl anions in octahedral coordination. The octahedral sites available in these layers may be completely filled (trioctahedral micas; Y = 6), or only partially filled (dioctahedral micas; Y = 4). The common dioctahedral micas are celadonite, glauconite, muscovite, paragonite and pyrophyllite; the common trioctahedral micas are phlogopite, biotite and lepidolite. In the micas, the structural sheets can be stacked in different sequences resulting in several polymorphs. The most common structural types are the 1M (one layered monoclinic), 1M*d* (disordered one layered monoclinic), $2M_1$ and $2M_2$ (two-layered monoclinic) and 3T (three-layered triclinic) types (Bailey, 1984; Deer *et al.*, 1992). Mica group minerals occur in a wide variety of geological settings, in acid igneous, metamorphosed and sedimentary rocks, in hydrothermal veins and hydrothermally altered basic and ultrabasic rocks (Deer *et al.*, 1992). Mica is a common component in china clay (*q.v.*) and may be found as a component of pottery; it has many other industrial uses.

As a general pigment term, mica has been taken by the modern paint industry to be a generic name for the whole group of micas, although according to Preston (1973) it is muscovite which has had the greatest commercial value and is ground into pigment grades. Pigments involving mica often have a coloured pigment deposited on the mica to produce a metallic effect; the mica-ilmenite and mica-magnetite pigments are discussed by Maisch (1993). The *Colour Index* (1971) describes naturally occurring micaceous potassium aluminium silicates as Pigment White 20/26.

Other associated terms used in the pigment literature include muscovite mica, graphitic mica (a dark grey form containing small quantities of graphite) and sericite (a fine-grained muscovite).

Couraud (1987) lists mica among prehistoric pigments. Duncan *et al.* record the use of mica on Japanese paintings and, according to Naruse, 'white mica' has been found by X-ray diffraction on two Japanese *gigaku* masks (Duncan *et al.*, 1990; Naruse, 1996). Mica is also recorded with quartz and talc by Wang *et al.* (1993a) as a common component of pigments used at the Qutan Temple, Qinghai, China. 'Black mica' has been found by Dalla Nave *et al.* (2002) in wall paintings by Hans Clemer (late fifteenth/early sixteenth century) decorating the church at Elva, Piemonte, Italy. Odlyha *et al.* (1992) have found mica present in iron gall ink used to write a letter in the archives of Sir Richard Fanshawe (1608–66). Modern use of mica in paints is discussed by Lawrence (1960) and Preston (1973).

Aluminium group; Chlorite group; Iron group; Magnesium group; Sheet silicates group; Biotite; Brucite; Gibbsite; Glauconite; Muscovite; Phlogopite; Pyrophyllite; Talc
Bailey (1984); *Colour Index* (1971); Couraud (1987); Dalla Nave *et al.* (2002); Deer *et al.* (1992) 279–317; Duncan *et al.* (1990); Lawrence (1960); Maisch (1993); Naruse (1996); Odlyha *et al.* (1992); Preston (1973); Rutley (1988) 397–404; Wang *et al.* (1993a)

MICONIA

Yellow
Common generic composite

A species of *Miconia* (*M. laevigata*) is listed by Wallert (1995c) as forming the basis of an organic colourant used for illuminating manuscripts in Mesoamerica. The Aztec (Nahuatl) name, as derived from the sixteenth century 'Florentine Codex' (Florence, Biblioteca Laurenziana MS Palatina 218–220) and others, is given as *tezvatl*.

Flavonoids group
Wallert (1995c)

MICROCLINE

White
Generic compound

Microcline is a potassium-rich aluminosilicate mineral, with composition $KAlSi_3O_8$. It belongs to the feldspar group (*q.v.*) of minerals and is one of the alkali feldspars. It forms a solid solution series with albite (*q.v.*), and may contain up to 20% of the albite ($NaAlSi_3O_8$) component, as well as impurities such as Ba, Fe^{3+}, Li, Ca and Sr, which alter the mineral colour from white to green, yellow, grey or blue. Microcline occurs as prismatic crystals that form in slowly cooled igneous rocks such as alkali granites; it also occurs in metamorphic rocks and in the sediments derived from them. It is polymorphous with orthoclase (*q.v.*) and sanadine that have disordered Si-Al atoms as a consequence of more rapid cooling (Deer *et al.*, 1992; Ribbe, 1983; Rutley, 1988). Microcline was described by Breithaupt in 1830 and is named from the Greek words *mikron* and *klinos*, meaning 'small' and 'inclined', referring to the small deviation of the microscopic cleavage planes from 90° (Dana, 1932). It is a common mineral, occurring in association with quartz, biotite, plagioclase feldspars and amphibole group (*qq.v.*) minerals in areas such as Orissa and Madras (India), Norra Kärr (Sweden), Galacia (Spain), Broken Hill (New South Wales, Australia), Ilmen Mountains (Russia) and Bancroft (Ontario, Canada). As with the other feldspar minerals, microcline decomposes to clay minerals, and may occur as a relict component in materials such as kaolin (*qq.v.*) and pottery.

Jercher *et al.* (1998) have identified microcline as a minor component in Aboriginal red ochre (*q.v.*) deposits in South and Western Australia.

Amphibole group; Clay minerals group; Feldspar group; Silicates group; Albite; Biotite; Ochre; Orthoclase; Quartz; *Kaolin*
Dana (1932) 540; Deer *et al.* (1992) 396–430; Jercher *et al.* (1998); Ribbe (1983); Rutley (1988) 418–421

MIDNIGHT SUN

Red
Synonym, variant or common name

Synonymous with chrome scarlet (Kelly and Judd, 1976; Kühn and Curran, 1986) and a variant of chrome red (*q.v.*).

Chrome red; *Chrome scarlet*
Kelly & Judd (1976); Kühn & Curran (1986)

MILORI BLUE

Blue
Synonym, variant or common name

A term originally used to denote a blue produced by Milori & Co., Lyon, France, it became synonymous with Prussian blue (Berrie, 1997).

Prussian blue
Berrie (1997)

MILORI GREEN

Green
Synonym, variant or common name

Riffault *et al*. (1874) suggest that *Milori green* refers to a chrome green, a composite pigment based on Prussian blue with either a yellow chromate (such as lead chromate(VI)) or gamboge respectively. Milori & Co. were a colourman's firm from Lyon, France.

Gamboge; *Chrome green*; *Chrome yellow*; *Prussian blue*
Riffault *et al*. (1874) 551

MILTOS

Red
Synonym, variant or common name

The fourth century BC author Theophrastus describes *miltos* (μιλτος) as composed of earth and mined in Cappadocia along with ochre. He notes also that iron mines contain miltos and that low quality (artificial) miltos is produced by burning ochre. Strabo (first century BC) mentions that the form of miltos known as sinopea comes from Cappadocia and is 'the best in the world', although the Iberian rivals it. It was named 'Sinopean' because the merchants were 'wont to bring it down thence to Sinope before the traffic of the Ephesians had penetrated as far as the people of Cappadocia'.

The term has continued to be listed as a synonym for red ochre where reference is made to the classical authors, for example nineteenth and early twentieth century sources such as Church (1901).

Iron oxides and hydroxides group; *Red ochre*
Church (1901); Strabo (1st century BC/1928) 12.2.10; Theophrastus (c. 315 BC/Caley & Richards, 1956) 52

MIMETITE

Variable
Generic compound

Mimetite is a lead arsenate mineral, with composition $Pb_5(AsO_4)_3Cl$. It is isostructural with pyromorphite (*q.v.*) and the other members of the apatite group (*q.v.*) of minerals to which it belongs. It forms a complete chemical series with pyromorphite in which the anion groups (PO_4, AsO_4) are exchanged so that intermediate compositions can form. Mimetite forms in the oxidising portions of lead ore deposits where it occurs as brightly coloured prismatic crystals, as granular crusts or botryoidal massive deposits. It is most commonly bright yellow but also occurs as colourless, white, red, orange, brown or pale green crystals depending on the presence of impurities (Rutley, 1988). It is a relatively rare mineral found in the same localities as pyromorphite, such as Cornwall and Cumbria (England), Idaho (USA), Durango (Mexico), Harz and Saxony (Germany), Broken Hill (New South Wales, Australia), Tsumeb (Namibia) and Attica (Greece). It is most commonly found in association with limonite, galena, baryte and anglesite (*qq.v.*). First described by Beudant in 1832, mimetite was named from the Greek word mimethes meaning 'a mimicker' due to its strong similarity to pyromorphite (Dana, 1932).

Analysis on 22 Greek stèles in the Louvre (Rouveret and Walter, 1998; Walter *et al*., 1998) showed mimetite to be present. Winter (1981) has also identified a form of lead phosphate (*q.v.*) on a fourteenth century Japanese (Kamakura) panel to which mimetite, pyromorphite and oxypyromorphite ($Pb_{10}(PO_4)_6O$) are the most closely related natural minerals.

Apatite group; Arsenic group; Lead group; Lead phosphates group; Anglesite; Baryte; Galena; Pyromorphite
Dana (1932) 708; Rouveret & Walter (1998); Rutley (1988) 339–340; Walter *et al*. (1998); Winter (1981)

MINERAL BLACK

Black
Synonym, variant or common name

The term mineral black is applied to several materials. Field (1835) describes mineral black as a 'native impure oxide of carbon, of a soft texture, found in Devonshire'. This definition is probably synonymous with Bideford black (*q.v.*), since Field also states that his sample came from the Union mine, Bideford.

Heaton (1928) gives mineral black as a then-current term encompassing 'carbonaceous earth' or 'black chalk'. From his brief description this appears to be a carbonate- and organic-rich black shale, similar to the Kimmeridge clays of Dorset and equivalents in East Yorkshire. According to Mayer (1991), mineral black could also be applied to graphite, vine black and mars black (*qq.v.*). However, this may be a confusion from the categorisation used by the *Colour Index* (1971) where CI 77268/Pigment Black 8 covers all 'impure carbon of organic and mineral origin' where 'various organic and mineral substances rich in carbon, particularly lignite, ethiops mineral, anthracite, bituminous coal, slate, etc., waste from expressing seeds or fruit, nut shells, hop residues from breweries, paper mill refuse, various kinds of bark or wood, etc., are carbonised or distilled in absence of air' and, notably, 'carbonaceous earths […] the best known in the UK being Bideford Black'.

Russian black appears to be a comparable or related term and wad is furthermore, a term generally applied to manganese rich blacks.

Carbon-based blacks group; Coal; Graphite; *Bideford black*; *Mars black*; *Native black*; *Russian black*; *Vine black*; *Wad*
Carlyle (2001) 469; *Colour Index* (1971) 77268; Field (1835) 181; Heaton (1928) 382; Mayer (1991) 51

MINERAL BLUE

Blue
Synonym, variant or common name

Mierzinski (1881) indicates that the term mineral blue was associated with azurite and Prussian blue (*qq.v.*); however, he indicates that it was used to denote a pale Berlin blue (a form of Prussian blue) containing zinc oxide. Rose (1916) uses the term to describe tungsten oxide (tungsten blue, *q.v.*). According to Kittel (1960), mineral blue was a copper sulfate compound, giving the composition as $3CuSO_4.2CaSO_4$. Mayer (1991) further notes that both Antwerp blue and manganese blue (*qq.v.*) have been sold under this name.

Azurite; *Antwerp blue*; *Berlin blue*; *Manganese blue*; *Prussian blue*; *Tungsten blue*
Kittel (1960) 236–242; Mayer (1991) 51; Mierzinski (1881) 26; Rose (1916) 378

MINERAL BROWN

Brown
Synonym, variant or common name

Salter (1869) reports that this term was a commercial name applied to Cappagh brown, a humic earth related to so-called Vandyke brown. Mineral brown is also said to be a synonym for burnt umber. The term was still listed by Love in 1973 as equivalent to CI 77499, which is described by the *Colour Index* (1971) as 'feroso-ferric oxide $FeO.Fe_2O_3$ or ferroso-ferric hydroxide $Fe(OH)_2.Fe_2O_3$'.

Umber; *Burnt umber*; *Cappagh brown*
Colour Index (1971) 77499; Love (1973); Salter (1869) 342

MINERAL GREEN

Green
Synonym, variant or common name

The term mineral green has been applied to a huge variety of formulations. Fishwick (1795–1816), for example, gives a recipe for mineral green using '8¼th blue verditer, 5¾ th masticot, grind in water & dry on boards'. Field's *Chromatography* (1835) states it was the commercial name for green lakes and was a copper sulfate pigment. Salter, in his 1869 edition of Field, repeats this and adds that it could also refer to a pigment developed in Germany as a replacement for Schweinfurt green (a form of emerald green) consisting of lead chromate, copper carbonate, iron oxide and chalk. On the other hand Mierzinski (1881) uses mineral green as a synonym for green cinnabar, a pigment typically (but not exclusively) composed of a Prussian blue-type pigment co-deposited with a yellow pigment such as lead chromate. According to Terry (1893), mineral green was malachite, although he also indicates that it could be a synthetic copper carbonate or other formulation such as a copper-arsenic compound; the most complex recipe he gives involves treating copper sulfate with calcium hydroxide, then adding 'a solution of arsenic and soda', then treating with tartaric acid. The identification of mineral green as malachite is further indicated by later authors such as Heaton (1928), and by Gettens and FitzHugh (1993b) in their review of that mineral as a pigment.

Two samples labelled '*Minraalgroen*' are in the Hafkenscheid Collection along with another labelled '*papegaaigroen*' ('Parrot green'); analysis of these has shown that they consist of artificial copper-arsenic compounds, tentatively identified as a 'copper formo-arsenite' (copper formate arsenite; Pey, 1987).

Malachite; *Bremen green*; *Green lake*; *Parrot green*; *Scheele's green*
Field (1835) 130; Fishwick (1795–1816) 17; Gettens & FitzHugh (1993b); Heaton (1928) 382; Mierzinski (1881) 185; Pey (1987); Salter (1869) 288; Terry (1893) 131

MINERAL GREY

Grey
Synonym, variant or common name

According to Field (1841), and various of his later editors, mineral grey was an inferior form of ultramarine ash (*q.v.*) though Martel (1860) identified it as finely levigated slate. Heaton (1928) lists this as an obsolete or rarely used term for 'low grade natural ultramarine', by which he probably means so-called ultramarine ash (later extractions of lazurite high in associated minerals).

Slate; Ultramarine; *Ultramarine ash*
Carlyle (2001) 497; Field (1841) 300; Heaton (1928) 382; Martel (1860) 37

MINERAL LAKE

Purple
Synonym, variant or common name

Two methods of preparation for mineral lake are described by Riffault *et al.* (1874), the original method according to Malaguti (reputedly the discoverer) uses 100 parts stannic oxide to 2 parts chromium oxide; this is then calcined at dull-red heat. An alternative method follows an aqueous preparation process for tin chloride which is then calcined with 'nitrate of potassa'. Potter's pink and tin pink (*qq.v.*) are apparently alternate terms (Mayer, 1991).

Tin chromate; *Potter's pink*
Mayer (1991) 51; Riffault *et al.* (1874) 395–396

MINERAL ORANGE

Red-Orange
Synonym, variant or common name

Carlyle (2001) states that various preparations of lead(II,IV) oxide (that is, the synthetic analogue of minium, also known as red lead) were listed among orange colours in nineteenth century British sources, either as red lead, orange lead or mineral orange. Mérimée (1830) states: 'If instead of massicote we calcine ceruse, a peculiar red, called "mineral orange" is obtained, it is a minium, but of a tint more pure and brilliant than any of its class.'

Lead(II,IV) oxide; Minium; *Orange lead*; *Red lead*
Carlyle (2001) 501; Mérimée (1830/trans. Taylor, 1839) 112

MINERAL PURPLE

Purple
Synonym, variant or common name

Salter (1869) gives this as a synonym for mars violet (*q.v.*), a term which could be applied to various compounds including a naturally occurring ochre, a mixture that duplicated the colour or other compounds. A mineral violet was produced by the British colourmen Roberson's. Heaton (1928) also refers to mineral violet, although he indicates that it was at that time an obsolete or rarely used term for manganese phosphate. None-the-less, Hackman was still listing the term (as a manganese ammonium phosphate) in 1973.

Manganese phosphates group; *Mars violet*
Hackman (1973); Heaton (1928) 382; Salter (1869) 299

MINERAL RED

Red
Synonym, variant or common name

See: lead(II,IV) oxide.

MINERAL WHITE

White
Synonym, variant or common name

Mineral white is listed by Feller (1986) as a synonym for barium sulfate. However, Heaton (1928) uses the term for a synthetic calcium sulfate pigment precipitated from solutions of calcium acetate and aluminium sulfate, also associating it with the term terra alba.

Barium sulfate; Calcium sulfate; *Terra alba*
Feller (1986); Heaton (1928) 382

MINERAL YELLOW

Yellow
Synonym, variant or common name

Mérimée (1830) gives three recipes for Mineral yellow: (a) from lead(II,IV) oxide and sodium chloride to form lead chloride oxide (lead chloride oxide, $PbCl_{2.5-7}PbO$); (b) by the 'English method', using lead acetate and litharge (lead monoxide); (c) with additions of bismuth and antimony. However, Osborn (1845), while acknowledging Mérimée, states in one place that it is lead chromate, in another 'a combination of litharge and sal ammoniac … of a brilliant citron-yellow'. Bouvier (1861) says that this pigment is turbith mineral. In the German literature, both Mierzinski (1881) and Rose (1916) describe *Mineralgelb* as synonymous with *Kasseler Gelb* ('Cassel yellow'), which the former gives as a lead chloride oxide pigment. However, they both also add that *tungsten yellow* (a compound given as H_2WO_4) was a pure yellow colour also known under the name Mineralgelb. Further, Linke and Adam (1913) describe *Mineralgelb*, formed from alkaline lead chloride in solution with warm nitric acid, as a surrogate for *Naples yellow*. (This may be the source of the listing of *Mineralgelbe* as a synonym for lead antimonate by Wainwright *et al*., 1986.) Mineral yellow is also listed by Salter (1869) and Church (1901) as a synonym for yellow ochre.

Synonyms listed in the Salter edition of Field's *Chromatography* (1869) are patent yellow, Turner's yellow, Montpellier yellow and Cassel yellow, all of which typically refer to lead chloride oxide; this identification is essentially repeated by Heaton (1928), although that author indicates that the term is obsolete or rarely used.

Lead chloride oxide; *Cassel yellow*; *Montpellier yellow*; *Patent yellow*; *Turner's yellow*; *Yellow ochre*
Bouvier (1861) 51; Church (1901) 138; Heaton (1928) 382; Linke & Adam (1913) 41; Mérimée (1830/trans. Taylor, 1839) 96–97; Mierzinski (1881) 228; Osborn (1845) 14–15; Rose (1916) 306; Salter (1869) 106; Wainwright *et al*. (1986)

MINERALGELB

Yellow
Synonym, variant or common name

See: mineral yellow.

MINIUM

Red
Generic compound

The current meaning and application of the term *minium* is for the red lead(II,IV) oxide mineral of composition Pb_3O_4. It commonly occurs in small amounts as a bright red or orange powder or crust forming as a secondary mineral in the weathering zone around lead ore deposits, particularly through the partial alteration of other lead-bearing minerals, such as galena and cerrusite (*qq.v.*). The mineral minium may have been used as a pigment in ancient times although the synthetic analogue, often known as red lead (*q.v.*), was one of the first pigments to be manufactured.

However, we should note that the term *minium* was used by classical authors such as Vitruvius (first century BC) and Pliny (77 AD) to refer primarily to cinnabar (*q.v.*), with *minium secondum* used for the artificial lead(II,IV) oxide. Cinnabar was reportedly often mixed with red lead, the mixture also being referred to as minium. The sixteenth century German author on mineral matters Agricola records in his *De re metallica* that minium became a term used to refer to red lead exclusively. For a more complete discussion of the term in the context of its meaning as a mercury sulfide, see cinnabar.

Red ore of lead is sometimes used for the lead chromate mineral crocoite. As noted by FitzHugh (1986), Forbes and Petrie have suggested that natural minium was the source of the pigment of Greco-Roman date found at Hawara in Egypt. For a fuller discussion, see: *Lead(II,IV) oxide*.

Lead group; Lead oxides and hydroxides group; Cinnabar; Lead(II,IV) oxide
Agricola (1556/trans. Hoover & Hoover, 1950) 110, 222; FitzHugh (1986); Pliny (1st cent AD/Rackham, 1952) XXXIII.xxxvi.111 ff.; Vitruvius (1st cent BC/Grainger, 1934) VII.viii.1, VII.ix.1

MISY

Yellow
Synonym, variant or common name

According to Pliny (77 AD) the 'misy' of the ancients was either iron or copper pyrites, or oxidation products of these. Pliny reports that some people obtained misy by burning minerals in trenches; the fine yellow powder mixed with the wood ashes could be easily separated. He adds: 'the best kind is obtained in the copper-factories of Cyprus, its marks being that when broken it sparkles like gold and when ground it has a sandy appearance'.

Wallert (1995a) points out though that it is not possible to unambiguously identify this substance from its antique description alone, the Latin terminology of the various naturally occurring sulfates being very confused. However, the name '*misy*', along with the term '*gelbeisenerz*', was (and sometimes still is) used to indicate substances like jarosite, natrojarosite and carphosiderite, which are iron sulfate hydroxides.

Jarosite; Natrojarosite; Pyrite; *Carphosiderite*; *Gelbeisenerz*
Pliny (1st cent AD/Rackham, 1952) XXXIV.c.31; Wallert (1995a)

MITIS GREEN

Green
Synonym, variant or common name

Although Mitis green is a term basically associated with emerald and Scheele's greens, its application within this complex group of compounds and manufacturing variants is loose. Fiedler and Bayard (1997), for example, state that Mitis green might refer to 'either pure copper acetoarsenite, a specially prepared Scheele's green, a copper arsenite compound, or a mixture of emerald and Scheele's green or emerald and imperial green. It is also possible that Mitis green was actually a variety of Scheele's green based on Wurzbach's (1868) description of the pigment.'

According to Zerr and Rübencamp (1906) Mitis green was a mixture of 35–55 parts emerald green and 45–65 parts '*imperial green*', the latter being an emerald green-derived compound. On the other hand Gentele's *Lehrbuch der Farbenfabrikation* (1860) uses the name Mitis green (and parrot green) to designate a mixture of copper arsenite and copper acetate arsenite.

Emerald green; *Imperial green*; *Scheele's green*
Fiedler & Bayard (1997); Gentele (1860) 262–263; Zerr & Rübencamp (1906/1908) 212

MITSCHERLICHITE

Blue-Green
Generic compound

Mitscherlichite is a hydrated potassium copper chloride mineral with composition $K_2CuCl_4.2H_2O$. It occurs as soft green or blue-green prismatic crystals, or as aggregates of crystals which form in volcanic regions through sublimation. Mitscherlichite was first discovered in 1925 by Zambonini and Carobbi who named it after the German chemist E. Mischerlich (1794–1863) and it is known from its type locality of Vesuvius, Italy (Dana, 1932).

The use of a synthetic form of potassium copper chloride (*q.v.*), has been noted by Riederer (1982).

Copper group; Copper halides group; Potassium copper chloride
Dana (1932) 469; Riederer (1982)

Mittler's green

Green
Synonym, variant or common name

Newman (1997) lists this as a varietal term for the chromium oxide hydrate pigment viridian (*q.v.*).

Chromium oxide hydrate; *Viridian*
Newman (1997)

Mixed green

Green
Synonym, variant or common name

Mixed green is not a single pigment but a combination of a blue and a yellow. According to Field (1835), a number of colours were specially formulated in this way and sold to artists as particular hues. Examples he cites are Hooker's and Varley's greens (*qq.v.*).

Hooker's green; *Varley's green*
Field (1835) 128

Mixed white

White
Synonym, variant or common name

Doerner (1935) lists this as a mixture of Cremnitz white and zinc white.

Cremnitz white; *Zinc white*
Doerner (1935) 58

Modan white

White
Synonym, variant or common name

See: terrene white.

Molybdate orange

Orange
Synonym, variant or common name

Listed by Kühn and Curran (1986) as an orange pigment with composition $PbCrO_4.PbMo_4.PbSO_4$. It is considered here as a variant of molybdate red (*q.v.*).

Molybdate red
Kühn & Curran (1986)

Molybdate red

Red
Synonym, variant or common name

The origin and development of molybdate red is well described by de Keijzer (1989): 'Molybdate red is a synthetic inorganic pigment, the first indication is from mineral origin when Schultz in 1863 noticed that the mineral Wulfenite ($PbMoO_4$) had a strong red colour when it appeared with Crocoite ($PbCrO_4$). Schultz carried out fusions with salts and noticed that 42% $PbCrO_4$ dissolved in molten lead molybdate and after cooling a series of salts was set up with a dark red colour. Along the same lines Jaeger & Germs worked in 1921 by fusions at high temperatures. Mixed crystal pigments of lead chromate and lead molybdate were first described in August 1930 by Lederle in a German patent. Useful precipitations of mixed crystals of lead chromate and lead molybdate were later described in the patents of Lederle and Grimm. The second American patent of Lederle (1936) described a process of producing red pigments by precipitating mixed crystals of normal lead chromate, sulfate and molybdate, using strongly acid solution. The first commercial pigment appeared on the market in 1934–35 in the United States. The Belgian patent by Linz (1937) described the production of orange and red mixed crystals of lead chromate, lead molybdate and lead carbonate or phosphate […] Much research has been carried out to eliminate imperfections: the instability of the crystal structure and the lightfastness. Two patents are of importance: [one of 1944 by] Botti where he describes that the lightfastness increases by depositing on the pigment particles a film which is a combination of aluminium hydroxide, titanium oxide and rare earth oxide. The second patent is by Huckle and Polzer (1943). They discovered that by reacting trivalent antimony compounds with lead chromate pigments the resistance of such pigments to colour deterioration by action of light and weather is materially increased.'

This pigment is also produced in orange shades as molybdate orange. CI Pigment Red 3 ('Toluidine red') is often used in conjunction with molybdate red.

Toluidine red
Colour Index (1971); Keijzer (1989a)

Molybdenum blue

Blue
Synonym, variant or common name

Harley (1982) found various references in British documentary sources to molybdenum blue, and suggests that it was the mineral ilsemannite (*q.v.*). Bersch (1901) on the other hand describes molybdenum blue as follows: 'This fine but costly pigment is obtained by mixing a solution of sodium molybdate with a solution of stannous chloride. A blue precipitate is formed, which, after washing and drying, may be used as an artists' colour. It is distinguished by great durability. A good shade of molybdenum blue can be obtained with greater certainty by adding finely-powdered tin and a few drops of hydrochloric acid to a solution of pure molybdic acid. In composition it is a mixture of stannic molybdate and the blue modification of molybdenum oxide.' The *Colour Index* (CI 77769) refers to producing molybdenum blue from sodium molybdate and aqueous stannous chloride; the precipitate is stated to be of the same composition as that given above.

Molybdenum group; Ilsemannite; *Blue carmine*
Bersch (1901) 239; *Colour Index* (1971) 77769; Harley (1982) 59

Molybdenum green

Green
Synonym, variant or common name

Salter (1869) lists this, giving two formulations. In the first he says that 'A clear malachite green colour, when dried, is produced from molybdate of soda and potash-chrome-alum, or from the molybdate and alum with ammonia.' Second, 'There is likewise obtainable a copper molybdate, by adding neutral molybdate of soda in excess to sulphate of copper. The precipitate is a very pale green colour.' It is otherwise obscure and was probably unused by artists.

Molybdenum group
Salter (1869) 289

MOLYBDENUM GROUP

Variable
Group term

Molybdenum is named (confusingly) from the ancient Greek *molybdos*, meaning lead. The main pigment-related compounds are the primary ore molybdenite, which though not used directly is the main source of molybdenum used in syntheses of molybdenum compounds and the molybdates (molybdenum oxides and hydroxides), both natural and synthetic. (*Sulfides*: molybdenite (MoS_2); *oxides and hydroxides*: wulfenite and lead molybdate ($PbMoO_4$); molybdenum oxide (MoO_3); ilsemannite ($Mo_3O_8.nH_2O$)).

The bright red colour of wulfenite and its synthetic analogue (see molybdate orange) have been employed as pigments and have been found in cosmetics.

Ilsemannite may be the source of molybdenum blue (*q.v.*; Harley, 1982), but it is more likely to be a synthetic compound, as described by Bersch (1901). The *Colour Index* (1971) describes this pigment as 'tin molybdate with the blue modification of molybdenum oxide'.

Salter (1869) also discusses what he refers to as 'persulphomolybdates', compounds of various metals with 'persulphomolybdic acid'; barium gives a red colour, calcium a scarlet, chromium, uranium, lead, platinum and copper a dark red. Other reds were obtainable from zinc, cadmium, iron, mercury and tin.

A secondary deposit, associated with the weathering of molybdenum ores is molybdic ochre and consists primarily of molybdite, MoO_3.

Ilsemannite; Lead molybdate; Ochre; Wulfenite; *Blue carmine*; *Molybdate orange*; *Molybdate red*; *Molybdenum blue*; *Molybdenum green*
Bersch (1901) 239; *Colour Index* (1971) 77769; Harley (1982) 59; Salter (1869) 171–172

MOLYBDENUM OXIDES AND HYDROXIDES GROUP

Variable
Group term

See: molybdenum group.

MONASTRAL BLUE

Blue
Synonym, variant or common name

Commercial name for phthalocyanine-based pigments (*q.v.*). The British company Imperial Chemical Industries ('ICI') announced the pigment in 1935 (*New York Times*, 25 November 1935) as '*Monastral fast blue*'; *Monastral* has remained a trade mark of ICI.

Phthalocyanine group; *Monastral pigments*

MONASTRAL GREEN

Green
Synonym, variant or common name

Commercial name owned by the British company Imperial Chemical Industries ('ICI') for green phthalocyanine-based pigments (*q.v.*).

Phthalocyanine group; *Monastral pigments*

MONASTRAL PIGMENTS

Variable
Synonym, variant or common name

Commercial name for certain phthalocyanine-based pigments ('*Monastral blue*', '*Monastral green*') as well as various quinacridone colours ('*Monastral red* B'; '*Monastral red* Y'; '*Monastral violet* R') (de Keijzer, 1988, 1990).

Phthalocyanine group; Polycyclic pigments group: Quinacridone sub-group
Keijzer (1988); Keijzer (1990)

MONGHYR PURI

Yellow
Synonym, variant or common name

Term synonymous with so-called Indian yellow (*q.v.*; Baer *et al.*, 1986).

Indian yellow
Baer *et al.* (1986)

MONICON

Orange
Synonym, variant or common name

See: damonico.

MONOAZO PIGMENTS

Red-Orange-Yellow
Synonym, variant or common name

See: azo pigments group: monoazo sub-group.

MONOLITE YELLOW

Yellow
Synonym, variant or common name

Trade name for a variety of monoazo ('Hansa') yellow.
See: azo pigments group: monoazo sub-group.

MONTHIERS BLUE

Blue
Synonym, variant or common name

See: ammonium Prussian blue.

MONTMORILLONITE

White
Generic compound

Montmorillonite is a hydrous sodium, calcium aluminosilicate mineral with composition $(½Ca,Na)_{0.7}Al_6[Si_8O_{20}](OH)_4{\cdot}nH_2O$, although K, Fe and Mg can also be incorporated. It is a clay mineral, belonging specifically to the smectite group, and forms a series with fellow members beidellite and nontronite (*qq.v.*) through the exchange of Al and Fe (Deer *et al.*, 1992; Rutley, 1988). Montmorillonite was first described by Mauduyt in 1847 from Montmorillon (Vienne, France) after which it is named (Dana, 1932). It occurs as small white tabular crystals or as soft earthy microcrystalline masses which may be coloured pink, grey, yellow, yellow-brown, blue, red or green with impurities. As with the other smectite clays, montmorillonite readily absorbs water (and organic molecules) between the constituent sheets of SiO_4 tetrahedra; the amount of water absorbed depends upon the alkali atom present so that, for example, Na-montmorillonite can absorb more water than Ca- or K-montmorillonite (Rutley, 1988). Montmorillonite forms mainly from the weathering of plagioclase feldspar (*q.v.*) in the presence of water or in poorly drained soils under alkaline conditions. It is a common mineral worldwide and occurs at Chambers (Arizona, USA), Burra (South Australia), Mt St Hilaire (Quebec, Canada), Minas Gerais (Brazil), Nagal

(Bavaria, Germany), Vicenza (Italy), Otavi (Namibia) and Okehampton (Devon, England). Montmorillonite together with beidellite form a significant part of bentonite (*q.v.*), a clay mixture derived from the weathering of volcanic ash; montmorillonite is also a principal component of Fuller's earth (*q.v.*), a clay mixture with well-known absorbent properties (Deer *et al*., 1992).

Montmorillonite has been identified by Sánchez-Moral *et al.* (2002) as mixed with kaolinite, illite and chlorite group minerals in plasters used in the ancient caves at Galdar (Grand Canary Island, Spain). Montmorillonite is also found as a minor component of green earth (*q.v.*), along with chlorite group minerals and kaolinite, with the principal components of the pigment being celadonite or glauconite (*qq.v.*; Grissom, 1986).

Aluminium group; Chlorite group; Clay minerals group; Clay minerals group: Smectite sub-group; Sheet silicates group; Beidellite; Celadonite; Glauconite; Green earth; Illite; Kaolinite; Nontronite; *Bentonite*; *Fuller's earth*
Dana (1932) 683; Deer *et al.* (1992) 369–376; Grissom (1986); Rutley (1988) 412–413; Sánchez-Moral *et al.* (2002)

MONTPELLIER GREEN

Green
Synonym, variant or common name

Montpellier was an important production area for verdigris from the twelfth through eighteenth centuries, as a by-product of the wine industry. Benhamou (1984) describes the manufacturing processes, which were entirely organised and carried out by women, involving the fermentation of stacked plates of imported Swedish copper with wine lees. Sixteenth century literature (for example, Guicciardini, cf. Eikema Hommes, 1998) mentions verdigris from Montpellier being imported to Amsterdam and in the seventeenth century Pomet (1694, cf. Eikema Hommes, 1998) states that 'most of the verdigris used in France and even abroad, is made in and around Montpellier'. However Kühn (1993a) points out that the term Montpellier green or Montpellier verdigris was actually used generically and was not necessarily specific to verdigris manufactured in the Montpellier region alone.

Copper acetate group; *Basic verdigris*; *Neutral verdigris*; *Verdigris*
Benhamou (1984); Eikema Hommes (1998) 83; Kühn (1993a)

MONTPELLIER YELLOW

Yellow
Synonym, variant or common name

Nineteenth century recipes (Tingry, 1804) for Montpel(l)ier yellow indicate it to be litharge (vitreous oxide of lead) and sea salt in water which is allowed to crystallise and then is heated to form a yellow colour. This lead chloride oxide is equivalent to 'Turner's' or 'Patent' yellow. The term appears as late as Heaton (1928) with this particular meaning, although it is listed there among obsolete or rarely used pigments. Hartshorne (1881) describes it as 'yellow ochre mixed with ceruse'. Some sources also state that Montpellier yellow is a 'yellow oxide of lead', though this may represent a misunderstanding of the lead chloride oxide composition.

Lead chloride oxide; *Patent yellow*; *Turner's yellow*; *Yellow ochre*
Hartshorne (1881); Heaton (1928) 382; Tingry (1804) 322–323

MORAT WHITE

White
Synonym, variant or common name

See: white of Morat and terrene white.

MORELLENSALZ

Red
Synonym, variant or common name

See: pabonazo.

MORELLIC ACID

Yellow-Brown
Generic compound

See: gambogic acid.

MORELLO DI FERRO

Red
Synonym, variant or common name

See: pabonazo.

MORELLO DI SALE

Red
Synonym, variant or common name

See: pabonazo.

MORGANITE

Black
Synonym, variant or common name

Field's *Chromatography* of 1835 indicates that this is lamp black – a flame carbon.

Lamp black
Field (1835)

MORIN

Yellow-Brown
Generic compound

Morin is 2-(2,4-dihydroxyphenyl)-3,5,7-trihydroxy-4H-1-benzopyran-4-one (also, 2′,3,4′,5,7-pentahydroxyflavone); it is a flavonoid (flavonol) compound and is the principal component of so-called 'old fustic', a dye derived from *Maclura tinctoria* (L.) Steudel (Moraceae; formerly *Chlorophora tinctoria* (L.) Gaud.) (Schweppe, 1992; *Merck Index*, 1996). Use of old fustic in pigments has been mentioned by Harley (1982). Morin is listed in the *Colour Index* as CI 75660/Natural Yellow 8 and 11.
See: fustic.

Flavonoids group; *Fustic*
Color Index (1971) 75660; Harley (1982) 104–105; *Merck Index* (1996) 6352; Schweppe (1992) 330.

MORINDONE

Red-Orange
Generic compound

Morindone, 1,5,6-trihydroxy-2-methylanthraquinone, is an anthraquinone colouring matter produced from the roots, rootbark and seeds of *Morinda citrifolia* L., the rootbark and seed of *M. tinctoria* Roxb., the rootbark of *M. umbellata* L., the root of *M. persicaefolia* Buch.-Ham. and the bark of *Coprosma australis* Robinson. Several glycosides of morindone exist, notably the 6-β-Rutinoside in *Coprosma australis*, the 6-β-Primveroside in *Morinda persicaefolia* and the 6-β-Gentianoside in *M. tinctoria*. It is a principal colouring matter in madder dye where it has been derived from any of the above sources (Schweppe, 1992;

Schweppe and Winter, 1997). Morindone is listed in the *Colour Index* as CI 75430.
See: madder.

Anthraquinones group
Colour Index (1971) 75430; Schweppe (1992) 208; Schweppe & Winter (1997)

Mosaic gold

Yellow
Synonym, variant or common name

Mosaic gold is tin(IV) sulfide. While there are various mineral tin sulfides such as herzenbergite (SnS) and ottemannite (β-Sn_2S_3), appears to be the berndtite type (SnS_2; this actually occurs in two crystalline forms) which is found in a pigment context (such as Smith *et al*., 1981; Speleers, 1999). We might note that some minor differences from reference material have been observed; while both sources identify tin(IV) sulfide, Smith *et al*. match their analyses well to an early X-ray diffraction pattern though Speleers found a better match with more recent data. No match to the ottemannite form was found, suggesting production at a relatively low temperature (see below).

Needham (1974) cites Ko Hung (c. 300 AD) who described the making of stannic sulfide, but suggests that this technique was developed in China before this date. Also called *purpurino* or *purpurinus* this pigment was developed far later in Europe. It is discussed in the MS of le Begue (1431, Clarke MS 2790; cf. Merrifield, 1849) which provides the recipe 'to make the colour purpurinus' and in the Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield, 1849) where there are instructions (Rp. 141) 'To make purpurino, that is to say, a golden colour.' This was by taking quicksilver and tin melted together, cooled, ground, placed in a fluted glass flask. The flask was placed open in a furnace and removed once it had stopped smoking. The purpurino was ground on porphyry and mixed with gum water. Other recipes suggest Roman tin instead of Venetian, and grinding the quicksilver and tin with 'sulphur vivum' and sal ammoniac (ammonium chloride). Kunckel (1689) gives two recipes for *arum musicum* the second of which begins with a mixture of pure tin and bismuth and calls for the addition of 'salmiac'. (There follows a separate recipe for what he calls argentum musicum which is generally made with bismuth and tin.) Cennini (c. 1400, Clarke MS 590) calling this *porporina*, comments that it is a colour for manuscripts but that it has some use in panel painting. The importance of this pigment to illumination is quite clear from the fact that in Boltz's *Illuminierbuch* of 1549 he gives five different recipes.

Mosaic gold has been identified on a number of paintings and manuscripts, notably various contexts in the fifteenth century; examples include that found by Speleers on an early fifteenth century Italian panel painting attributed to Arcangelo di Cola da Camerino, by Smith *et al*. and Wallert (1997a) on works by del Cossa, Ercole de'Roberti and Liberale da Verona (late fifteenth century). Thompson and Wallert have identified it on a fourteenth century manuscript (MS Palatina 951; Thompson, 1935; Wallert, 1995b) and there are a number of examples on fifteenth century illuminated manuscripts as well as playing cards from the so-called 'Stuttgarter Kartenspiel' of *c*.1430 (Richter and Härlin, 1976). Recipes of the period for mosaic gold call for melting equal parts tin, mercury, sulfur and ammonium chloride, though according to more recent recipes (Bersch, 1901) either mercury or ammonium chloride can be used, their purpose being to control the temperature.

Use of this compound appears to have either continued or been rediscovered, perhaps from historical study since a recipe for it is contained in the late nineteenth/early twentieth century book of pigment recipes by Bersch (1901). He provides two basic methods – the 'dry' route described above as well as an inferior 'wet' route.

Synonyms and orthographic variants for mosaic gold include *porporino*, *purpurino*, *purpurinus*, *color purpurinus*, *aurum musivum*, *aurum mosaicum*, or *musif*, *musivgold* (Speleers, 1999) and *tin bronze* (*Merck Index*, 1996). Mosaic gold can also refer to an alloy of 65.3% copper and 34.7% zinc (*Merck Index*, 1996). The *Colour Index* (CI 77613) gives lead iodide as a 'golden yellow pigment used in mosaic gold'. A pigment known as chrysean was also supposedly an alternative to tin sulfide.

Tin sulfides group; Berndtite; Gold; Lead iodide; Metal pigments; *Chrysean*; *Purpurino*
Bersch (1901) 160; Boltz von Ruffach (1549/Benziger, 1913) 53–57; Cennini (c. 1400/Thompson, 1960) 93; *Colour Index* (1971) 77613; Kunckel (1689) 247; *Merck Index* (1996) 8936; Merrifield (1849) 54, 458; Needham (1974); Richter & Härlin (1976); Smith *et al*. (1981); Speleers (1999); Thompson (1935); Wallert (1991a); Wallert (1995b); Wallert (1997a)

Mosaic silver

Metal
Synonym, variant or common name

A mixed amalgam of tin and bismuth used to make a silver paint. The *Miscellanea Curiosa* of Fishwick (c. 1795–1816), for example, gives a recipe for what he calls *mosaic silver* (presumably in analogy to mosaic gold): 'Mosaic silver, or white bronze: Take 1 oz block tin – melt it on a crucible & put thereto 1 oz tartar & 1oz quicksilver. Stir these well together until they be cold, then bruize it to powder & grind fine on a stone with water & dry it.' Recipes for this *Argentum musicum* are also given in German mediaeval literature, such as Boltz's *Illuminierbuch* 1549 and then in Kunckel's *Ars Vetraria* of 1689. Later recipes can also be found in the German literature – Mierzinski (1881), for example, describes *Musivsilber* as an amalgam made of 3 parts of bismuth, 3 parts of tin and 1½ parts of mercury. He also gives the terms 'fake silver' or 'painter's silver'. Rose (1916) adds that it was also known as *Argentum musicum* and that it could be applied with egg white, oil or resins and polishing it would give a good metallic sheen. It was also known as *Malsilber*.

Metal pigments; *Mosaic gold*
Boltz von Ruffach (1549/Benziger, 1913) 57; Fishwick (1795–1816) 147; Kunckel (1689) 427–428; Mierzinski (1881) 330; Rose (1916) 352

Moss green

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*). However, according to Mayer (1991) it is synonymous with chrome green (*q.v.*).

Chrome green; *Emerald green*
Fiedler & Bayard (1997); Mayer (1991) 51

Mother-of-coal

Black
Synonym, variant or common name

See: fusain.

Fusain

Mother-of-pearl

White
Synonym, variant or common name

Mother-of-pearl is an iridescent form of the calcium carbonate mineral aragonite (and occasionally vaterite) forming on the inside of molluscan shells. It is technically referred to as nacre. Field (1835) describes the use of true mother-of-pearl as an opalescent pigment.

Aragonite; Vaterite; *Pearl white*; *Shell white*
Field (1835) 70

Mountain blue

Blue
Synonym, variant or common name

Synonym for azurite, after the German *Bergblau*.

Azurite

Mountain green

Green
Synonym, variant or common name

Sixteenth to eighteenth century literature indicates that this term was used for chrysocolla (*q.v.*); however, early literature often confused malachite and chrysocolla, both being copper minerals which came from related sources (Burmester and Resenberg, 2003). This appears, most commonly, to have been a synonym for malachite (*q.v.*) from the second half of the eighteenth century. Watin (1785), for example, describes this, with the term Hungarian green, as ‘a greenish mineral or fossil or more likely a chalk of green copper which is found in small grains, like sand in the mountains of Kernhausen in Hungary’. Lemery (1721, cf. Brachert, 2001) states that this is variously synonymous with malachite, crysocolla, Veronese green or green earth. However, various nineteenth century sources also indicate that mountain green could refer to copper-arsenic pigments; Mierzinski (1881), for example, describes this as either malachite or – with Braunschweig, neuwied, Kaiser and copper greens – as a copper acetate arsenite (that is, emerald green) lime green that contains calcium or barium sulfate.

Closely related to the terms *Berggrün* and berg green, this being a literal translation. All terms seem to have the same multiple meanings.

Chrysocolla; Malachite
Brachert (2001) 38; Burmester & Resenberg (2003); Mierzinski (1881); Watin (1773/edition of 1785) 30

Mulberry

Yellow
Synonym, variant or common name

See: fustic.

Mulhauser’s white

White
Synonym, variant or common name

See: Mulhouse white.

Mulhouse white

White
Synonym, variant or common name

Various sources list Mulhouse white (*Mülhauserweiss* and *Blanc de Mulhouse*); it appears to be lead sulfate (Corbeil *et al*., 1999). However, Brochwicz *et al*. (1993) list $2PbSO_4.Pb(OH)_2$ as Mulhauser’s white, though this is perhaps in error. This pigment was presumably associated with the city of Mulhouse, France.

Lead sulfates group
Brochwicz *et al*. (1993); Corbeil *et al*. (1999)

Mummy

Brown
Synonym, variant or common name

‘Mummy’, as Weber (1923) remarks, ‘derives its rather gruesome name from its source’. Throughout history, Egyptian mummies have been a perceived source of medication and have furnished the traders in religious relics with a ready supply of suitably aged body parts. However, despite the illegality of exporting mummies from Egypt during the sixteenth and seventeenth centuries a ready supply was available. The bodies when ground produced a brown pigment with good transparency, similar to asphalt (*q.v.*) and it had been generally assumed since mediaeval times that they were in fact preserved in bitumen. However, asphalt and bitumen were for much of history very much secondary materials in the mummification process and only became important during the Ptolemaic period, in the fourth century BC (see: David, 2000; Nissenbaum, 1992; Harrell and Lewan, 2001). The main materials for mummification were desiccating salts, particularly natron ($Na_2CO_3.10H_2O$, which also destroys fats) as preservatives. Bandages were soaked in plant-derived gums, waxes and resins and only occasionally was bitumen used (predominantly derived from the Dead Sea: Rullkoetter and Nissenbaum, 1988; Proefke and Rinehart, 1992; Harrell and Lewan, 2001).White (1986) points out that the confusion is also possible from the linguistic aspect in that ‘mumiya’ refers to wax in Persian and bitumen in Arabic. Woodcock (1996) rather disturbingly implies that many of the mummies supplied to colourmen and apothecaries may be more recent than assumed and in fact that during the sixteenth century mummies were being manufactured by unscrupulous dealers from ‘the bodies of slaves’, and these were probably made with far more bitumen than the originals.

Church (1901) wrote that mummy ‘is inferior to prepared, but superior to raw, asphalt, inasmuch as it has been submitted to a considerable degree of heat, and has thereby lost some of its volatile hydrocarbons. Moreover it is usual to grind up the bones and other parts of the mummy together, so the resulting powder has more solidity and is less fusible than the asphalt alone would be. A London colourman informs me that one Egyptian mummy furnishes sufficient material to satisfy the demands of his customers for twenty years’ (although in his 1890 edition, he says a mummy lasted only seven years; cf. Woodcock, 1996).

An early mention of mummy as a colourant occurs in Shakespeare’s *Othello*, in reference to the colour of a silk handkerchief (1602–04). It also appears that mummy was used as an oil paint as early as the close of the sixteenth century, and had identical applications to that of asphalt, namely as an oil paint and a varnish. Haydocke and de Mayerne (MS Sloane 2052; cf. Harley, 1982) both suggest its use as (ironically) a flesh tone and for shading; it was reputed to be less prone to cracking than asphalt, but was a poor drier. Palomino’s *El museo pictórico y la escala óptica* of 1715–24 says that *spalt*, a Spanish and Portuguse term for asphalt, is ‘also called mummy earth’ (Veliz, 1986).

As a pigment, it attained its greatest popularity in the mid-eighteenth to nineteenth centuries, losing appeal as the scientific interest in Egyptian archaeology grew in the late nineteenth and early twentieth centuries and public distaste with the pigment became more universal. Woodcock recounts a visit by Lawrence Alma-Tadema to Edward Burne-Jones in 1881 when the pigment and its origins were discussed (Burne-Jones was so horrified that he buried his tubes in his garden). However, it can be assumed that both artists and their contemporaries were using the pigment routinely. The artist's colourmen Roberson's stocked the pigment until the 1920s–1930s but sold very little during the twentieth century. White points out that this pigment was also called Egyptian brown.

Mummies manufactured during the historical period are made of preserved flesh, bone and asphalt whereas ancient mummies would be additionally rich in natron and plant-derived resins. Mummy was adulterated by the Roberson Company with Cappagh Brown (Woodcock, 1996) and probably with asphalt by other colourmen and artists.

The term mummy as applied to the preserved bodies and to the pigment and is derived from the Persian/Arabic word *mumia* or *mumija* meaning pitch or bitumen. In Persia, the so-called 'Mummy Mountain' was noted for it oozing black bituminous material, to which was attributed magical properties. However, according to David (2000), the term was applied to mummies because of their blackened appearance only, and the belief in mediaeval times that they too may impart magical qualities. Synonyms for mummy as a pigment include variations on *mummia* or *momia* and Egyptian brown. 'Sham mummy' was made out of bitumen and lime and mummyine was 'an extract obtained by solvents', though an extract of what is unclear (Woodcock, 1996). Doerner (1935) lists 'mummy' as being asphalt based and 'mummy brown' as burnt green earth.

Asphalt; Bitumen; *Egyptian brown*; *Spalt*
Church (1901) 235; David (2000); Doerner (1935) 89; Harley (1982) 153; Harrell & Lewan (2001); Lomazzo/Haydocke (1584/1598); MS Sloane 2052 (nd); Nissenbaum (1992); Palomino (1715–24); Proefke & Rinehart (1992); Rullkoetter & Nissenbaum (1988); Veliz (1986) 154; Weber (1923) 21; White (1986); Woodcock (1996)

MUNICH GREEN
Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

MUNICH LAKE
Red
Synonym, variant or common name

A synonym for a cochineal lake. Listed as a term in the *Colour Index* (1971) under CI Natural Red 4.

Cochineal
Colour Index (1971)

MUNJISTIN
Orange
Generic compound

Munjistin, 1,3-dihydroxyanthraquinone-2-carboxylic acid, is an anthraquinone found as a component in roots of various *Rubia*, *Relbunium* and *Morinda* species; it is therefore a major constituent of certain madder dyes (Schweppe and Winter, 1997). It is designated by the *Colour Index* as CI 75370.

Anthraquinones group; Madder
Colour Index (1971) 75370; Schweppe & Winter (1997)

MUREXIDE
Red
Synonym, variant or common name

Murexide, though a dyestuff, is described by Salter (1869) as a candidate pigment. That author describes it as 'produced by the action of ammonia on alloxan, which is itself derived from the uric acid of guano by treatment with nitric acid, and was known nearly fourty years back to stain the fingers and nails red. The first murexide sent into the market was a reddish-purple powder, dissolving in water with a fine purple tint, leaving a little residue undissolved.' It was also apparently possible to derive a series of related organo-metallic pigments, precipitating an alkaline solution of murexide with an acid to give a compound referred to as 'purpuric acid'. This in turn would react with metallic salts to form 'purpurates': lead gave a red compound, mercury purple-red to rose, silver a purple-red, strontium a dark red-brown, cobalt a 'crystalline' red, platinum a scarlet, zinc a yellow and barium a green.

Murexide is currently available from chemical supply houses as a complexing reagent, presumably because of the above properties.

Salter (1869) 169–170

MUSCOVITE
White
Generic compound

Muscovite is a sheet silicate mineral with composition $K_2Al_4[Si_6Al_2O_{20}](OH,F)_4$. It is a common member of the mica group (*q.v.*) of minerals and occurs as thin flexible cleavable hexagonal plates, as small anhedral disseminated grains or as compact scaly masses. It is colourless or white when pure but may be brown, blue, green, pink or red due to the presence of impurities such as Fe, Mg, Na, Ca, Cr, Li, Rb or Ba. Muscovite is closely related to paragonite (*q.v.*) and both minerals are known as white mica. Muscovite is named after Muscovy province (Russia) and is also known as isinglass and potash mica (Rutley, 1988; Dana, 1932). Several varieties of muscovite exist: fuchsite is a deep green variety enriched in Cr (Martin-Ramos and Rodriguez-Gallego, 1982); phengite is a variety enriched in Si, Mg and Fe; binnite is a Ba-rich variety, while rose muscovite is coloured pink by the presence of Mn; sericite, damourite and gilbertite are very fine-grained varieties forming from the hydrothermal alteration of silicate minerals. Muscovite occurs in acid igneous, low-grade metamorphic and sedimentary rocks. It is common worldwide and is often found in association with biotite, plagioclase feldspar, and quartz (*qq.v.*); it may decompose to form illite, hydromuscovite, montmorillonite and finally kaolinite (*qq.v.*; Rutley, 1988). Three polymorphs of muscovite exist, related by the stacking sequences of the internal $(Si,Al)O_4$ layers which sandwich K and Al in selected octahedral sites between them (dioctahedral mica). The most common polymorph is type $2M_1$ (a monoclinic two-layer repeating structure), with types 1M and 1M*d* (monoclinic one-layered repeating ordered and disordered structures) less common (Deer *et al.*, 1992; Bailey, 1984; Yoder and Eugster, 1955).

The *Colour Index* (1971) lists Pigment White 20/26 as naturally occurring micaceous potassium aluminium silicates such as muscovite and paragonite. A tentative suggestion has been made that fuchsite could have been used by the Chumash Indians as a rock art pigment (Scott and Hyder, 1993); it is also currently available as a specialist pigment.

Aluminium group; Feldspar group; Mica group; Sheet silicates group; Illite; Paragonite; Pyrophyllite
Bailey (1984); *Colour Index* (1971) 77019; Dana (1932) 659; Deer *et al*. (1992) 288–293; Martin-Ramos & Rodriguez-Gallego (1982); Rutley (1988) 398–399; Scott & Hyder (1993); Yoder & Eugster (1955)

MUSIVGOLD

Yellow
Synonym, variant or common name

See: mosaic gold.

MUTRIE YELLOW

Yellow
Synonym, variant or common name

According to Salter, writing in 1869, that under the name Mutrie yellow 'a lemon sulphide of cadmium has lately appeared'. It therefore seems to be a colour variant of cadmium yellow, one of the palest shades. 'Lemon cadmium' appears to have been used synonymously. Also referenced in Collier (1886).

Cadmium yellow; *Lemon cadmium*
Collier (1886); Salter (1869) 92

MYRTLE GREEN

Green
Synonym, variant or common name

Mayer (1991) lists this as another synonym for chrome green.

Chrome green
Mayer (1991) 52

N

NACARAT CARMINE

Red
Synonym, variant or common name

Heaton (1928) lists nacarat carmine as an obsolete or rarely used pigment term denoting 'the finest quality of cochineal [*q.v.*] extract'.

Cochineal
Heaton (1928) 382

NACRITE

White
Generic compound

Nacrite is an aluminium sheet silicate hydroxide mineral with composition $Al_4[Si_4O_{10}](OH)_8$, although impurities such as Fe, Mg, Ca, Na, K or Ti may be present. It is a member of the clay minerals group, belonging specifically to the kaolinite sub-group (*qq.v.*), although it is a rare member. It is polymorphous with other members kaolinite and dickite (*qq.v.*) and is composed of sheets of SiO_4 tetrahedra alternating with AlO_6 octahedra (Rutley, 1988; Blount *et al*., 1969; Zheng and Bailey, 1994). Nacrite was first described by Brongniart in 1807 and is named after the Persian and French words *nakar* and *nacre* on account of its pearly lustre (Dana, 1932). It occurs most commonly as soft white earthy and compact masses, or as pseudohexagonal tabular crystals which may be grey, yellow or pale brown due to impurities. Nacrite forms from the hydrothermal decomposition of feldspar group minerals and is commonly found close to ore deposits in association with kaolinite, dickite, mica group minerals and quartz (*qq.v.*; Rutley, 1988). It is likely to be found worldwide but confirmed localities include St Andreasberg and Freiberg District (Saxony, Germany), Groby (Leicestershire, England), St Peters Dome (Colorado, USA), St Eustache (Quebec, Canada), Piedmont (Italy), Chihuahua (Mexico) and Kasuga mine (Kagoshima Prefecture, Japan).

Although to date nacrite has not been identified in an art context, its common association with kaolinite means that its future identification is likely.

Aluminium group; Clay minerals group; Clay minerals group: Kaolinite sub-group; Feldspar group; Mica group; Sheet silicates group; Dickite; Kaolinite; Quartz
Blount *et al*. (1969); Dana (1932) 680; Rutley (1988) 410; Zheng & Bailey (1994)

NANKEEN YELLOW

Yellow
Synonym, variant or common name

Term associated with Naples yellow (*q.v.*) as listed by Wainwright *et al*. (1986).

Lead antimony oxide; *Naples yellow*
Wainwright *et al*. (1986)

NANKIN YELLOW

Yellow
Generic compound

Riffault *et al*. (1874) describe producing this pigment by drying then calcining a concentrated solution of lead nitrate which has been mixed with a small quantity of powdered peat; the peat probably acts as a reducing agent.

Riffault *et al*. (1874) 421

NANTOKITE

White
Generic compound

Nantokite is a copper chloride mineral with composition CuCl. It is named after its type locality of Nantoko (Atacama, Chile) from where it was described by Breithaupt in 1868. It occurs as soft masses of white microcrystals and granular aggregates which have precipitated in hydrothermal ore veins (Dana, 1932). Nantokite is also known from Tuscany (Italy), Broken Hill (Australia), St Just (Cornwall, England), Bisbee (Arizona, USA) and Durango (Mexico).

Nantokite is not known to have been used as a pigment, although other related copper chloride hydroxide minerals atacamite, botalackite, clinoatacamite and paratacamite (*qq.v.*) have been encountered.

Copper halides group; Atacamite; Botallackite; Clinoatacamite; Paratacamite
Dana (1932) 459

NAPHTHOL CRIMSON

Red
Synonym, variant or common name

Sonoda (1999) has identified the azo-based CI Pigment Red 170 (*Colour Index*, 1971; CI 12475) in a sample of *Liquitex* colour (Binney and Smith Inc.) labelled 'Naphthol crimson' purchased in 1997.

Azo pigments group
Colour Index (1971) 12475; Sonoda (1999)

NAPHTHOL PIGMENTS

Variable
Group term

See: azo pigments group: naphthol AS sub-group and azo pigments group: β-naphthol sub-group.

NAPHTHOL RED

Red
Synonym, variant or common name

See: azo pigments group: naphthol AS sub-group and azo pigments group: β-naphthol sub-group.

NAPHTHOL, β-PIGMENTS

Red-Orange
Group term

See: azo pigments group: β-naphthol sub-group.

NAPHTHOQUINONES GROUP*

Variable
Group term

A group of natural and synthetic dyestuffs based on the naphthoquinone structure (phenolic) have found use in the formation of lake and other pigments. Naphthoquinones are found in the leaves, blossoms, wood, bark, roots and fruit of about 20 different species. Those which are found in pigment use are: Alkannin and Alkannan in 'Alkanet' from plant species such as *Alkanna lehmannii* Tineo (formerly known as *Alkanna tinctoria* Tausch.), *Macrotomia* spp., *Onosma* spp. and juglone in 'Walnut' (*qq.v.*) from *Juglans* spp.

The naphthoquinone *shikonin* is found in the plant known as 'Bastard alkanet', *Lithospermum arvense* L.; however there is no indication that this was used for pigment production.

Quinones group; Alkanet; Alkannan; Alkannin; Juglone; Walnut

* For structure, see Quinones group entry.

NAPLES GREEN

Green
Synonym, variant or common name

The manuscript by Fishwick (1795–1816) gives a recipe for Naples green, which consisted of a combination of 'Patente [?] mineral green, Prussian blue, Dutch pink, gamboge, starch [*qq.v.*].'

Gamboge; Starch; *Dutch pink*; *Mineral green*; *Prussian blue*
Fishwick (1795–1816) 76

NAPLES YELLOW

Yellow
Synonym, variant or common name

Naples yellow refers primarily to lead antimony oxide (lead antimonate; *q.v.*), although it has been erroneously applied by authors of the nineteenth and early twentieth centuries to other lead-based yellows such as lead tin oxides (*q.v.*). Latterly, pigments other than lead antimony oxide have been substituted for products labelled Naples yellow.

The earliest use of the term is commonly attributed to Andrea Pozzo, referring to *luteolum Napolitanum* in his Latin treatise on fresco painting of 1693–1700. Use of *giallolino di Napoli* occurs shortly afterwards, such as in an Italian translation of Pozzo dating from 1733 cited by Merrifield (1849). However, the 1674 edition of the *Traité de mignature, pour apprendre aisement à peindre sans mâitre*, thought to be by Claude Boutet, predates this and mentions both massicot (probably meaning lead tin oxide) and Naples yellow. 'Naples yellow' is certainly being used in English by the early eighteenth century, the author Elsum (1704) stating that Naples yellow was a middle yellow more suited to miniature painting than oil (cf. Wainwright *et al*., 1986; see also: *OED*, 2002, 'Naples yellow' for other English eighteenth century examples). In Dutch, the *Het groot Schilderboek* of de Lairesse (1707) also mentions both massicot (*q.v.*) and Naples yellow in the same context. Numerous other examples can be given from this time forward.

Early theories, probably based on a combination of speculation and disinformation, placed the origin of Naples yellow as a natural product found around Vesuvius or a manufactured colour from Naples. Watin (1785), for example, stated that Naples yellow 'is naturally formed around the sulfur mines on Mount Vesuvius'. However, he also adds that 'There is a dissertation by M. Fougeroux de Bondaroy cited in the Mémoires de L'académie 1766 pg 303 where he states that he analysed Naples yellow because its composition as *giallolino* was a secret in Naples. He found it to be composed of ceruse, alum, salts of ammonia and antimony.' This dissertation marked the point at which the composition of Naples yellow was generally accepted to be lead antimonate although Harley (1982) states that the first to establish this fact was Passeri, who based his knowledge on the recipes of Piccolpasso (1556–59). Subsequent interpretations of the documentary evidence, combined with an ignorance of the existence of the lead tin compound, overextended the use of Naples yellow as a lead antimony oxide to most references to *giallolino* (*q.v.*) as well. In consequence this led to the mistaken belief that many examples of yellow lead-based pigments through the Renaissance and later periods were lead antimony oxide; this situation was only rectified once lead tin yellow (*q.v.*) was defined by Jacobi (1941) and later authors.

From the nineteenth century other pigments might be admixed or substituted for lead antimony oxide, such as cadmium yellow (cadmium sulfide) and lead chloride oxide (*qq.v.*). Modern paints called Naples yellow typically contain substitutes based on cadmium sulfide (or sulfide selenide) with yellow ochre or red iron oxide and a white pigment such as lead, titanium dioxide or zinc white; chromium/nickel titanium yellows and those based on (parachloro-)orthonitraniline are also used (Carlyle, 2001; Wainwright *et al*.).

For a discussion of the preparation of lead antimony oxide and the various terms that have been applied to it, see the *relevant entry*.

Cadmium sulfides and selenides group; Lead antimony oxide; Lead chloride oxide; Lead tin oxide; Massicot; *Cadmium yellow*; *Giallolino*; *Lead tin yellow*; *Lead white*; *Titanium dioxide white*; *Zinc white*
Boutet (1674); Carlyle (2001) 157; Elsum (1704) 114; Harley (1982) 98–99; Jacobi (1941); Lairesse (1707); Merrifield (1849); *OED* (2002) 'Naples yellow'; Pozzo (1693–1700); Wainwright *et al*. (1986); Watin (1773/edition of 1785) 25

NATIVE BLACK

Black
Synonym, variant or common name

Native black is largely synonymous with terms such as black ochre, coal black and mineral black (*qq.v.*), which denote, as the *Colour Index* (1971) describes, 'impure carbon of organic and mineral origin … carbonaceous earths'.

Coal; *Black ochre*; *Mineral black*
Colour Index (1971)

NATIVE GREEN

Green
Synonym, variant or common name

Field (1835) refers to native green, meaning chromium oxide (*q.v.*). The mineral form of chromium oxide, eskolaite (*q.v.*), is extremely rare (Kuovo and Vuorelainen, 1958) and it should be presumed that the term 'native green' refers to the synthetic product. In fact Field's later editor Salter (1869) explicitly states that '[oxide of chromium] is found native in an impure state as chrome ochre, but is always artificially prepared for artistic use'.

Chromium oxide; Eskolaite
Field (1835) 129; Kuovo & Vuorelainen (1958); Salter (1869) 267

NATIVE PRUSSIAN BLUE

Blue
Synonym, variant or common name

Native Prussian blue was used synonymously with terms such as blue iron earth and blue ochre (*qq.v.*). It may be equated to the mineral vivianite (*q.v.*), an iron phosphate hydrate. Salter (1869) writes: 'In name, there is also another variety of this pigment, known as Native Prussian Blue; which is really a native phosphate of iron, occurring as a blue earthy powder, or as a white powder which becomes blue by exposure.'

Vivianite; *Blue iron earth*; *Blue ochre*
Salter (1869) 207

NATROJAROSITE

Yellow
Generic compound

Natrojarosite is a sodium iron sulfate hydroxide mineral with composition $NaFe_3(SO_4)_2(OH)_6$, first described by Hillebrand and Penfield in 1902 (Dana, 1932). It is named after its composition and close relationship with jarosite (*q.v.*), with which it forms a solid solution series (Moss, 1957; Brophy and Sheridan, 1965). The two minerals are commonly found together and are often difficult to distinguish between optically. Natrojarosite is also closely related to hydronium-jarosite (*q.v.*) and to schwertmannite (Bigham *et al.*, 1994), with which it may also be found (e.g. at Pyhasalmi, Finland). Natrojarosite occurs as relatively soft yellow tabular crystals, crusts and aggregates, and forms as an alteration product of feldspar group minerals, in sulfidic soils, and mine waste deposits under acid conditions. It is known in particular from Furteit (Sardinia, Italy) and Soda Springs Valley (Nevada, USA).

Reindell and Riederer (1978) have identified natrojarosite in earth pigments from three excavations in Iran, at Shahr-i Sokhta, Tepe Hissar and Tepe Yahya. Colinart (2001) has observed jarosite or natrojarosite, or a mixture with lesser elements such as aluminium, on monuments and artefacts from Egypt, particularly from the Old Kingdom. The present authors have also found natrojarosite among pigment pots excavated at Pompeii, Italy. El Goresy *et al.* (1986) have identified the related jarosite in Egyptian wall paintings and Wallert (1995a) has identified it in Greek artefacts. Schiegl *et al.* (1992), however, have suggested that jarosite and natrojarosite identified on Egyptian monuments are caused by an advanced decomposition of an iron-bearing glass pigment with potassium and sulfur, a view rejected by others on the basis of the absence of the supposed precursor pigment and the general context.

Iron sulfates group; Hydronium-jarosite; Jarosite
Bigham *et al.* (1994); Brophy & Sheridan (1965); Colinart (2001); Dana (1932) 769; El Goresy *et al.* (1986); Moss (1957); Reindell & Riederer (1978); Schiegl *et al.* (1992); Wallert (1995a)

NATURAL ULTRAMARINE

Blue
Synonym, variant or common name

See: lazurite.

NEGRO DE BAÑO

Black
Synonym, variant or common name

A term of obscure nature used by Pacheco in his *Arte de la Pintura* of 1638 when discussing fresco painting. Meaning literally 'black for glazing', Pacheco comments: '*La sombra ordinaria es el negro de carbón, pero mi maestro, que fué muy prático en este género usaba el negro de baño el cual no se hallará en yodas partes*.' ('The usual … black is of charcoal; but my master, who was very practised in this genre, used *negro di baño*, which will not be easily found anywhere', trans. Veliz, 1986.)

Charcoal
Pacheco (1638) Bk 3, III, 52; Veliz (1986) 65

NEPHELINE

Variable
Generic compound

Nepheline, an aluminium silicate of ideal composition (Na,K) $AlSiO_4$, is a mineral which may be white, grey, brown, brownish grey, or reddish white due to the presence of impurities. The name derives from the Greek *nephele*, 'cloud', because it becomes clouded when put in strong acid. It occurs as a component of nepheline syenites (*q.v.*), which have been used as pigments.

Silicates group

NEPHELINE SYENITE

White
Common generic composite

Nepheline syenite is a light-coloured feldspathic rock composed largely of soda and potash feldspar group minerals and nepheline (*qq.v.*); some sources, however, describe it as an anhydrous sodium potassium aluminium silicate with an approximate composition $K_2O.3Na_2O.4.5Al_2O_3.20SiO_2$. Commercial deposits are mined at Nephton in Ontario, Canada (from where it was first produced in 1937), as well as Norway and Russia. Manufacture involves mining, crushing, classification and fine grinding (Guillet, 1994), so that it takes the form of an inert, crystalline, nodular powder.

For pigment applications nepheline syenite is primarily used as a filler/extender in exterior architectural paints where it is said to impart abrasion resistance, good tint retention and film durability through control of checking and cracking. A very fine grade for pigment purposes is currently marketed under the tradename Minex®. However, nepheline syenite is also used as a source for aluminium production and in ceramics, ceramics glazes and glass. It has been reviewed as a pigment by Weitz (1973).

Silicates group; Feldspar group; Nepheline
Guillet (1994) 711, 719; Weitz (1973)

NERO DI TERRA

Black
Synonym, variant or common name

Literally translated as 'earth black'. Mentioned by Borghini in his *Il Riposo* of 1584: 'The first [black] is called earth-black, a coarse and natural color, that may be used in fresco, distemper, or oil painting.' '*Il primo si chiama nero di terra, color grosso e naturale, che a fresco, a tempera, ed a olio puó servire*'; it is also mentioned in later sources such as Osborn (1845).
See: black ochre.

Borghini (1584/edition of 1787) ii; Osborn (1845) 39

NEUBERG BLUE

Blue
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77404) and Bersch (1901), this is a mixture of copper hydroxide and 'Chinese blue' (*q.v.*); a term used to denote a high quality Prussian blue.

Copper group; Hexacyanoferrate group; *Chinese blue*; *Prussian blue*
Bersch (1901) 227; *Colour Index* (1971) 77404

NEUTRAL ORANGE

Orange
Synonym, variant or common name

Salter (1869) describes this pigment – which he also calls *Penley's neutral orange* – as being compounded of yellow ochre and brown madder, while Scott Taylor's edition of Field's *Chromatography* (1885) mentions cadmium yellow and Venetian red as components (*qq.v.*); this latter composition is reiterated by Church (1901).

Brown madder; *Cadmium yellow*; *Venetian red*; *Yellow ochre*; *Penley's neutral orange*
Church (1901); Salter (1869) 253–255; Scott Taylor (1885) 121

NEUTRAL TINT

Grey
Synonym, variant or common name

Various combinations of pigments were used to produce this: Field (1835) states it was composed of 'sepia, indigo or other blues, with madder or other lakes' while the 1896 catalogue of British colourmen Winsor & Newton lists neutral tint as 'an intimate combination of Carbon Black, Ochre, and French Ultramarine' and Indigo, Cochineal lake and Carbon black for the watercolour pigment (*qq.v.*; cf. Carlyle, 2001).

Carbon-based blacks group; Cochineal; Indigo; Madder; Ochre; Sepia; *French ultramarine*
Carlyle (2001) 497–498; Field (1835)

NEUTRAL VERDIGRIS

Blue-Green
Synonym, variant or common name

Neutral verdigris, neutral copper(II) acetate monohydrate ($Cu[CH_3COO]_2.H_2O$), is deep blue-green and typically forms prismatic or platy, rhombic crystals (Scott, 2002; Kühn, 1993a). Anhydrous neutral verdigris ($Cu[CH_3COO]_2$) produces spherical aggregates of anhedral grains (Kühn, 1993a). A third neutral acetate, copper(I) acetate ($Cu[CH_3COO]$) also apparently exists.

Traditionally neutral verdigris was manufactured by dissolving basic verdigris (*q.v.*) compounds in vinegar and allowing the material to recrystallise by evaporation on wooden sticks (see Scott, 2002). This compound was also referred to as 'distilled' or 'crystallised' verdigris (*q.v.*).

Copper acetate group; *Verdigris*
Kühn (1993a); Scott (2002) 270–294

NEUWEISS

White
Synonym, variant or common name

Neuweiss, that is, new white, is a synonym for barium sulfate (*q.v.*; Feller, 1986).

Barium sulfate
Feller (1986)

NEUWIED BLUE

Blue
Synonym, variant or common name

A number of German authors (such as Gentele, 1860 and Rose, 1916) remark that *Neuwied* or *Neuwieder blue* was a variety of Bremen or lime blue (*qq.v.*). According to Zerr and Rübencamp (1906) 'When lime blue, usually sold in the form of powder, is made up into oblong rectangular lumps it is known as "Neuwied blue", no doubt with the idea of making consumers believe that it is a different article'; these authors describe lime blue as the product of the precipitation of copper sulfate by calcium hydroxide ('caustic lime'). Gentele indicates lime blue was sold as irregular lumps; Rose states that Bremen blue was supplied as a powder.

Bremen blue; *Lime blue*
Gentele (1860) 207–209; Rose (1916) 136; Zerr & Rübencamp (1906/1908) 162–164

NEUWIED GREEN

Green
Synonym, variant or common name

Carlyle (2001) notes that a number of British nineteenth century authors such as Muckley (1882), Scott Taylor (1885), Standage (1892) and Vibert (1892) all give this as copper arsenite (Scheele's green, *q.v.*); Seward (1889) records that it is precipitated onto a base. Zerr and Rübencamp (1906) provide extensive formulations giving six varieties of Neuwied green, the principal distinction from other Scheele's green and emerald green-related pigments being the inclusion of baryte and, variously, potassium tartrate, soda or potash, lime and gypsum (*qq.v.*). They also closely relate it to Brunswick green and imperial green (*qq.v.*). Mierzinski (1881) describes neuwied green, with *Braunschweig*, *Kaiser*, *Berg*, copper and mountain greens, as a copper acetate arsenite (i.e. emerald green) lime green that contains calcium or barium sulfate while Guignet (1888) described Neuwied green (along with pickle green) as Scheele's green co-precipitated with calcium sulfate.

Copper arsenite group; Baryte; Copper acetate arsenite; Copper hydroxide; Gypsum; Lime; *Brunswick green*; *Emerald green*; *Imperial green; Scheele's green*
Carlyle (2001) 494; Gentele (1860); Guignet (1888); Mierzinski (1881) 281, 285; Muckley (1882) 37; Scott Taylor (1885) 194; Seward (1889) 57; Standage (1892) 41; Vibert (1892) 170; Zerr & Rübencamp (1906/1908) 220–223

NEW BLUE

Blue
Synonym, variant or common name

Salter (1869) states that this is an artificial ultramarine (*q.v.*) 'holding a middle position between French blue and permanent blue', adding that it 'may be said to hover in tint between a rich ultramarine and cobalt [blue]'. It was still a current term for synthetic ultramarine when Heaton was compiling a list of pigment synonyms in 1928, though Mayer (1991) on the other hand states that the name originally applied to a variety of cobalt blue which contains chromium, 'a shade now termed cerulean blue chromium' (perhaps chromium cobalt aluminium oxide, *qq.v.*). Finally, it was also apparently synonymous with Prussian blue (*q.v.*).

Hexacyanoferrate group; Chromium aluminium cobalt oxide; Ultramarine; *Cerulean blue*; *Cobalt blue*; *Prussian blue*
Heaton (1928) 382; Mayer (1991) 52; Salter (1869) 216

NEW CHROME YELLOW

Yellow
Synonym, variant or common name

Listed by Kühn and Curran (1986) as synonymous with chrome yellow (*q.v.*).

Chrome yellow
Kühn & Curran (1986)

NEW RED LAKE

Red
Synonym, variant or common name

Listed as a term in the *Colour Index* (1971) under CI Natural Red 4, New red lake was a form of cochineal (*q.v.*) lake.

Cochineal
Colour Index (1971)

NEW YELLOW

Yellow
Synonym, variant or common name

According to Zerr and Rübencamp (1906), this was one of the forms of chrome yellow which contained white adjuncts (for example, baryte, china clay, diatomaceous earth and gypsum, *qq.v.*). Other related products were called Baltimore yellow, American (chrome) yellow (*qq.v.*) and Paris yellow.

Chromates group; Lead chromates group; Baryte; Gypsum; *American chrome yellow*; *Baltimore chrome yellow*; *China clay*; *Chrome yellow*; *Diatomaceous earth*
Zerr & Rübencamp (1906/1908) 149

NICKEL AZO YELLOW

Yellow
Synonym, variant or common name

See: azo pigments group: metal complex sub-group.

NICKEL BROWN

Brown
Synonym, variant or common name

A pigment very briefly described in Salter (1869) as 'A very pleasing yellowish brown is obtainable from nickel, bright and clear in its pale washes, and of some richness in oil.' There is no further information given regarding the composition.

Nickel group
Salter (1869) 358

NICKEL DIOXINE YELLOW

Yellow
Synonym, variant or common name

See: azo pigments group: metal complex sub-group.

NICKEL GROUP

Variable
Group term

Nickel occurs primarily in synthetic pigments of recent origin. Nickel forms part of the yellow pigments nickel rutile yellow ($(Ti_{0.85}Sb_{0.10}Ni_{0.05})O_2$) (Buxbaum, 1998) and barium titanate yellow ($2Ni_{0.3}Ba_{0.17}TiO_2$) as well as certain modern cobalt green (*q.v.*) pigments with approximate compositions $NiCo_{0.5}Zn_{0.5}TiO_4$ and $Li_2(Co,Ni,Zn)Ti_3O_8$. Nickel has been used in the preparation of some hexacyanoferrate group (*q.v.*) pigments. Nickel phosphate hydrate ($Ni_3(PO_4)_2.7H_2O$) is described by the *Colour Index* (1971; 77783). Further, nickel forms part of the so-called 'nickel azo yellow' pigments (for which, see: azo pigments group: metal complex sub-group). Additionally, Bieganska *et al.* (1988) describe the use of metallic flakes of nickel. A pigment of unknown composition but called nickel brown (*q.v.*) is described by Salter (1869). However, nickel also occurs as an impurity in chlorite group (*q.v.*) minerals and as a minor component in oxide form in absolite, a form of wad (*q.v.*). The mineral smaltite ($(Co,Ni,Zn)_2TiO_4$), used historically in the production of the blue cobalt-based pigment smalt (*qq.v.*), contains nickel.

Azo pigments group: Metal complex sub-group; Chlorite group; Hexacyanoferrate group; Metal pigments; Nickel phosphate hydrate; Smalt; Smaltite; Wad; *Barium titanate yellow*; *Cobalt green*; *Nickel brown*; *Nickel rutile yellow*
Bieganska *et al.* (1988); Buxbaum (1998) 100; *Colour Index* (1971) 77783; Salter (1869) 358

NICKEL PHOSPHATE HYDRATE

Yellow
Generic compound

Nickel phosphate hydrate, $Ni_3(PO_4)_2.7H_2O$, is described in the *Colour Index* (1971; 77783), though as the preparation requires heating to red heat, it is probable that the result is anhydrous. Anhydrous nickel phosphate is a pale yellow-green colour.
See: nickel yellow.

Colour Index (1971) 77783

NICKEL RUTILE YELLOW

Yellow
Synonym, variant or common name

The *Colour Index* (1971; CI 77788/Pigment Yellow 53) lists an antimony oxide-nickel oxide-titanium oxide compound prepared by calcining the oxides together at high temperature. Buxbaum (1998) describes this, calling it nickel rutile yellow, as a light lemon yellow pigment with approximate composition $(Ti_{0.85}Sb_{0.10}Ni_{0.05})O_2$. Mayer (1991) lists a nickel titanate yellow which he differentiates from nickel titanium yellow although he does not explain how they differ. Synonyms include sun yellow and titan yellow (de Keijzer, 1990).

Chromium rutile yellow; *Sun yellow*; *Titan yellow*
Buxbaum (1998) 100; *Colour Index* (1971) 77788; Keijzer (1990); Mayer (1991)

NICKEL TITANATE YELLOW

Yellow
Synonym, variant or common name

See: nickel rutile yellow.

NICKEL TITANIUM YELLOW

Yellow
Synonym, variant or common name

See: nickel rutile yellow.

NICKEL YELLOW

Yellow
Synonym, variant or common name

Formulations in several early twentieth century sources indicate that this is a nickel phosphate compound (for example, Bersch, 1901). Zerr and Rübencamp (1906) describe its preparation by 'precipitating nickel sulphate with sodium phosphate. The precipitate is pale green, turning bright yellow at a red heat.' The *Colour Index* (1971) is more specific, stating that this is nickel phosphate hydrate $Ni_3(PO_4)_2.7H_2O$, though this seems unfeasible if the material is to be heated to redness during manufacture.

Other related nickel-containing yellow pigments include antimony nickel titanium oxide and nickel-based azo-metal complexes.
See: nickel rutile yellow and azo pigments group: metal complex sub-group.

Bersch (1901) 157; *Colour Index* (1971); Zerr & Rübencamp (1906/1908)

Nickel-azo pigments

Yellow
Group term

See: azo pigments group: metal complex sub-group.

Nightshade

Green
Synonym, variant or common name

Various sources give recipes for preparing a green colour from 'morelle' or 'black nightshade'. Alcherius (1398–1411, Clarke MS 2790; cf. Merrifield, 1849), for example, states that 'to make green … boil the leaves of the Morelle, with ochre, and grind them with a stone … if you were to put saffron with the ochre the colour would be very good' (*qq.v.*). Jehan Le Begue describes (1431, Clarke MS 2790, cf. Merrifield, p. 200) 'a green colour for painting what you please. Grind white earth with the leaves of the black nightshade … Grind them both evenly together on a marble slab until they become liquid.' The Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield) also gives a recipe for a green ink based on nightshade: '*35. To make green for writing* Take the black nightshade, extract the juice, strain it, and write with it, and it will answer well. You may also do the same with the juice of rue' (*q.v.*).

About 1700 *Solanum* species exist in the world, including some of the most common garden plants such as the potato *S. tuberosum* L. and the aubergine (eggplant), *S. melongena* L. 'Black nightshade' is *Solanum nigrum* L. (not to be confused with 'deadly nightshade' *Atropa belladonna* (Solanaceae)), a European native though widely naturalised. The berries are round, about 5–9 mm across and green, turning purplish to black when ripe; immature berries and foliage are toxic, but ripe fruits are reportedly edible. It is also known as *morelle noire*. This may be the *solatrum maius* listed by Thompson (1935) as providing berries that can be used to dye eggshell blue described in a fifteenth century MS (Bodleian Library, Oxford, MS Canon Misc. 128, f. $36^{r,v}$ Clarke MS 2470).

Another *Solanum* species, *S. indiana* L., is used to give a red colour; for more information, see: solatro.

Ochre; Saffron; *Rue*; *Solatro*
Merrifield (1849) II, 666; Thompson (1935)

Nitrate green

Green
Synonym, variant or common name

Mayer (1991) describes this as a 'blue toned variety of chrome green' (*q.v.*).

Chrome green
Mayer (1991) 52

Nocera earth

Brown
Synonym, variant or common name

Given as a term used in association with Vandyke brown (*q.v.*) by Feller and Johnston-Feller (1997).

Humic earth; *Vandyke brown*
Feller & Johnston-Feller (1997)

Noir de bougie

Black
Synonym, variant or common name

See: lamp black.

Noir de fumée

Black
Synonym, variant or common name

See: lamp black.

Noir de vigne

Black
Synonym, variant or common name

See: vine black.

Nontronite

Variable
Generic compound

Nontronite is a hydrated iron sodium aluminosilicate mineral with composition $(\frac{1}{2}Ca,Na)_{0.7}Fe_6[(Si,Al)_8O_{20}](OH)_4.nH_2O$ although impurities such as Mg, Ti and Al may also be present. It is a clay mineral, belonging specifically to the smectite sub-group, and forms as continuous series with fellow members montmorillonite and beidellite (*qq.v.*), by the substitution of Ca, Mg and Al (Deer *et al.*, 1992). Nontronite is named after its type locality of Saint-Pardoux, Nontron (Dordogne, France), from where it was described by Berthier in 1827 (Dana, 1932). It commonly occurs as soft green, yellow or brown earthy cryptocrystalline masses, although bladed crystals or spherules may also be found. It forms in a variety of settings: from the weathering of basic and ultrabasic igneous rocks, in mineral veins, metamorphosed limestones, as a precipitate from hot brines, in poorly drained soils derived from volcanic ash and in recent marine sediments (Deer *et al.*, 1992). Nontronite is less common than other members of the smectite group but is found at Okhansk (Russia), Burra (South Australia), Chihuahua (Mexico), Minas Gerais (Brazil), Attica (Greece), Budleigh Salterton (Devon, England), Andreasberg (Saxony, Germany), Crestmore (California, USA) and Froland (Norway).

Nontronite has been identified in decorations of historical buildings in Lower Saxony, Germany (Funders and Möller, 1989).

Aluminium group; Clay minerals group; Clay minerals group: Smectite sub-group; Iron group; Sheet silicates group; Beidellite; Montmorillonite
Dana (1932) 684; Deer *et al.* (1992) 369–376; Funders & Möller (1989)

Nordstrandite

White
Generic compound

Nordstrandite is a triclinic aluminium hydroxide mineral with composition $Al(OH)_3$ (Deer *et al.*, 1992; Saalfeld and Jarchow, 1968; Wall *et al.*, 1962); older sources including Winchell (1931) describe it as α-$Al_2O_3.H_2O$, although there are no water molecules present within the structure. Nordstrandite was first described by Papée *et al.* (1958) and is named after R.A. von Nordstrand. It is polymorphous with gibbsite, bayerite and doyleite (*qq.v.*), and occurs as tabular or spherulitic crystals or aggregates of crystals. Nordstrandite is white when pure but may be brown, green, grey or pink when impurities such as Fe, Mn and Cr are present. It is found as a minor component, in association with gibbsite, bayerite and diaspore, in bauxite (*q.v.*) in areas of tropical weathering, where it forms from the alteration of aluminosilicate minerals (Deer *et al.*, 1992). Nordstrandite may be found in areas such as Rurutu, French Polynesia (Jamet *et al.*, 1991) and Los Pijiguaos, Venezuela (Meyer *et al.*, 2002), as well as Les Baux (France), Vogelsberg (Germany) and Lages (Brazil). Empirical studies by Violante and Huang (1993) indicate that the formation of $Al(OH)_3$ polymorphs is dependent on pH conditions and elapsed time, with bayerite forming initially, followed by a mixture of bayerite and nordstrandite, and finally gibbsite.

The synthetic form of $Al(OH)_3$, aluminium hydroxide (*q.v.*), is often encountered as a lake substrate. Its precipitation in a lake context usually results in the crystallisation of the bayerite polymorph; however, Greenwood and Earnshaw (1999) indicate that precipitation from warm alkaline solutions can result in the formation of gibbsite.

Aluminium oxides and hydroxides group; Aluminium hydroxide; Bauxite; Bayerite; Doyleite; Gibbsite
Deer *et al.* (1992); Greenwood & Earnshaw (1999); Jamet *et al.* (1991); Meyer *et al.* (2002); Papée *et al.* (1958); Saalfeld & Jarchow (1968); Violante & Huang (1993); Wall *et al.* (1962); Winchell (1931)

NOTTINGHAM WHITE

White
Synonym, variant or common name

Nottingham white is source or manufacturing variant of lead white (*q.v.*) which, according to the *Compendium* of 1808, was the cheapest, had the most body and was used for 'coarser purposes'. The *Practical Treatise on Painting in Oil Colours* (1795) in particular notes that while vinegar was normally used in the production of lead white, alegar (sour ale or malt vinegar) was used for Nottingham white. Lastly, Field (1835) states that it was prepared from flake white (*q.v.*), also observing that because of this it was greyer than the broadly equivalent London white.

Flake white; *Lead white*; *London white*
Compendium (1808); Field (1835); *Practical Treatise* (1795)

NOVACULITE

White
Synonym, variant or common name

Novaculite is a sedimentary rock widely distributed in the Ouachita Mountains of Arkansas (USA) and composed mostly of microcrystalline quartz (*q.v.*), being a recrystallised variety of chert crypto (an opaque form of cryptocrystalline silica). It is dense, hard, white to greyish black in colour. In a pigment context, Patton (1973b) defines novaculite as 'a generic name for massive and extensive geologic formations of hard, compact, homogeneous, microcrystalline silica located in the vicinity of Hot Springs, Arkansas', adding that it 'can be considered as a very finely divided or "micro" form of quartz in a bound state of subdivision. Novaculite particles are composed of loose clusters of countless silica platelets ranging between 1.0 and 10.0 μm in dimension.' It was apparently first mined in the 1800s as a block abrasive for whetstones (*novacula* is a Latin word meaning 'sharp knife' or 'razor stone'), but large reserves of a finely particulate variety were found in the 1930s and commercially exploited.

Quartz; Silica
Patton (1973b)

NOVISMUTH

White
Synonym, variant or common name

Listed as 'bismuth subnitrate', that is, a bismuth hydroxide nitrate oxide (*Merck Index*, 1996).
See: bismuth nitrates group and bismuth white.

Bismuth nitrates group; *Bismuth white*
Merck Index (1996)

NUREMBERG VIOLET

Purple
Synonym, variant or common name

Hackman (1973) lists Nuremberg violet among various synonyms for a manganese ammonium phosphate pigment ('manganese violet', *qq.v.*), though in practice it is probably one of several manganese phosphates thought to have been used as pigments. It is also known as Nürnberg violet.

Manganese phosphates group; *Manganese ammonium phosphate*; *Manganese violet*
Hackman (1973)

NÜRNBERG GREEN

Green
Synonym, variant or common name

Linke and Adam (1913) give this as a trade name for chrome green (*q.v.*) although Riffault *et al.* (1874) mention that sap green (*q.v.*) was produced in Nürnberg.

Chrome green; *Sap green*
Linke & Adam (1913) 69–70; Riffault *et al.* (1874) 534

NÜRNBERG RED

Red
Synonym, variant or common name

Watin (1785) equates Nürnberg red with Prussian red, stating that they are either a calcined earth, or, more likely, a caput mortuum or colcothar (*qq.v.*). As late as Riffault *et al.* (1874), Nürnberg red is still being given as an alternate term for Prussian red.

Caput mortuum; *Colcothar*; *Prussian red*
Riffault *et al.* (1874) 360; Watin (1773/edition of 1785) 22–23

NÜRNBERG VIOLET

Purple
Synonym, variant or common name

A term for manganese violet (various manganese phosphates, *qq.v.*).
See: Nuremberg violet.

Manganese phosphates group; *Manganese violet*; *Nuremberg violet*

O

OCHRE

Red-Orange-Yellow
Common generic composite

Ochres are variably coloured rocks and soils primarily composed of oxides and hydroxides of iron. Colours can vary through various shades of purple, red, orange and yellow. Ochres are secondary deposits occurring either as soils or 'gossans' (the weathered, highly oxidised surface outcrops of ore deposits) which have become enriched in the colour-bearing constituent, usually iron oxides or iron hydroxides. The presence of such minerals promotes a strong and permanent colour, which due to the micron-scale grain size of the particles is not reduced on grinding. Red ochres contain hematite, while yellow ochres ('limonites') contain goethite and/or jarosite group minerals (e.g. jarosite and natrojarosite) (*qq.v.*). Such ochres can be very pure, but more typically contain other minerals such as quartz, clays, gypsum, micas, feldspars, etc. (*qq.v.*). Pigments which may be classed as ochres have a worldwide distribution – 'countless localities' according to Church (1901). The precise composition and therefore colour and other working properties are very much locally specific and geologically controlled. Important producers of ochre pigments are France, Spain, Cyprus, Iran, Italy, Australia and the USA (see Buxbaum, 1998).

It is worth noting that unmodified 'ochre' *usually* refers to an iron oxide-rich earth, and importantly for a classification of pigments, should contain no manganese oxide, thus separating it from the siennas and umbers (*qq.v.*). However, other metalliferous ore bodies oxidise to earthy gossans at their surface outcrop and are also technically ochres but have less application as pigments. These less common ochres include antimony ochre (stibiconite [$Sb_2O_3(OH)_2$] rich); bismuth ochre (bismite [$Bi_2O_3.3H_2O$] rich); molybdic ochre (molybdite [MoO_3] rich); nickel ochre or nickel bloom (annabergite [$Ni_3As_2O_2.8H_2O$] rich); plumbic ochre (brown lead(IV) oxide [PbO_2] rich); telluric ochre (yellow tellurium(IV) oxide [TeO_2] rich); tungstic ochre (yellow tungsten(VI) oxide [WO_3] rich) and uranic ochre (yellow uranium(III) oxide, [U_2O_3] rich; Hackh, 1969).

Iron is the third most abundant element occurring in the earth's crust and occurs in some form in most rocks. Consequently, iron oxide and hydroxide, the most stable compounds of this incredibly stable element, dominate ochres and related deposits occurring in worldwide settings primarily associated with iron and copper ores (with which iron ores often occur). Secondary deposits, iron oxide and hydroxide-rich soils may cover large areas, these deposits are likely to be less pure than the primary ochres and are likely to contain humic matter. They accumulate above bedrock rich in iron minerals including oxides but also silicates such as the olivines, pyroxenes, amphiboles and micas and the carbonate siderite. Particulary iron oxide-rich soils are also ochres *sensu lato* and suitable for pigment manufacture. These deposits are also rich in aluminium which may substitue for iron in some compounds (bauxites are soils with very high aluminium content). Ferricretes are hematite- and goethite-rich horizons formed from the weathering of bedrock in tropical environments. They represent early stages of soil formation (palaeosols). Similar deposits occurring in temperate climates are the so-called bog iron ores (or lymnites), which accumulate in deep (glacial) valleys. The less oxidising conditions favoured by this deposit prevent the formation of hematite and they are therefore goethite and ferrihydrite rich. Iron oxide and hydroxide-rich soils are generally called podzols or krasnozems in worldwide soil classification schemes. Laterites are iron- (and aluminium-) rich soils occurring in well-drained, tropical environments. Terra rossa (red earths) typically form as soils above limestones in regions with a Mediterranean climate.

Iron may be concentrated in acid mine waters and naturally occurring groundwaters. Natural flocculents of iron(III) oxide occur when iron-rich groundwaters enter the surface environment and are rapidly oxidised. These can form relatively pure ochreous deposits in ephemeral lakes and waterways or form as either a scum or muds in wetland environments. Evidence for the use of this material as a pigment is documented in Scott *et al.* (2002).

Ochres are prepared by washing, levigation and grindings but will inevitably contain impurities. The colours can be altered by roasting, hence burnt ochres (*q.v.*). Yellow ochres will become red or brown and red ochres will become purplish or darkened (see Helwig, 1997). They are stable, non-fugitive and inert pigments in all media.

A comprehensive documentation of the identifications and occurrence of ochre in art and archaeology is well beyond the scope of this work. Some recent and key references are listed here. Ochres are the earliest used pigments and their deposits are the sites of the earliest mining activity (see Watson, 1967, 1969). Very early records of the use of ochres as pigments (perhaps for ritual and cosmetic use) have been speculated to occur as early as 300,000 b.p. (cf. Barham, 2002). More recently Barham has documented pigment use in 270,000–170,000-year-old deposits in South Africa. Both cases indicate use of pigments by hominids predating the appearance of *Homo sapiens*. The use of ochres is well documented in western European later Palaeolithic cave art (see Smith *et al*., 1999; Pomiès *et al*., 1999; Hameau *et al*., 2001; Barham, 2002 and references therein) and in rock art from aboriginal cultures in North America (see Edwards *et al*., 1998; Scott *et al*., 2002; Hyman *et al*., 1996; Stafford *et al*., 2003 and references therein), South America (Wainwright *et al*., 2002), Australasia (see Jercher *et al*., 1998; Smith and Pell, 1997;

Watchman *et al.*, 1993; Barton and Reynolds, 1985; Lee and Guggenheim, 1981) and Southern Africa (see Watts, 2002; Woodhouse, 1969).

Ochres are recognised from Egyptian art (see David *et al.*, 2001; Burgio and Clark, 2000) and from ancient Greek, Hellenistic and Roman wall paintings, sculpture and architecture. Classical use of ochre pigments is described by the contemporary authors Theophrastus (c. 315 BC), Vitruvius (first century BC) and Pliny (77 AD) and examples have been identified more recently by Riederer (1985), Stodulski *et al.* (1984), Edwards *et al.* (1998) and papers in Béarat (1997). Notably, ochres of various hues and compositions are the most commonly used pigments on icons from the Byzantine and Russian Orthodox traditions (Bikiaris *et al.*, 1999; Lelekova, 1998; Panev, 1979). Ochres are important pigments in frescos from the Late Antiquity onwards in Europe (for example, see Perez *et al.*, 1999), and appear in illuminated manuscripts from European and Asian sources (see Burgio *et al.*, 1999a; Wei-Yeh *et al.*, 1983; Kaneko, 1983). They appear in codices and as architectural and ritual pigments in pre-Hispanic South American cultures (see Ortega *et al.*, 2001) and are standard components of the palettes in European-tradition easel painting to the present day (see Townsend, 1996; Gifford, 1983; Newman *et al.*, 1980, etc.). Further identifications are listed under the entries for red ochre and yellow ochre and from the constituent iron oxide and iron hydroxide minerals.

Terminology for ochre is as wide as its use and occurrence and in fact the name often reflects the geographical location of the source. Additionally, 'ochre' exists in many traditional spellings: *ocher*, *oker*, *oaker* and so forth occur in the literature.

Historically southern Britain was a well-known source of ochres, hence English ochre which was locally called 'common brown oker' (Bristow, 1996b). As the name suggests this was a brownish colour but could be calcined to produce good red tones. A particular variety came from near Bristol ('Bristol oker' which had a good yellow colour and thus was also called Bristol yellow ochre). The Oxford area was also a well-known British source of ochres derived from the local Jurassic ironstone deposits, and this was considered the best yellow ochre available in the UK during the seventeenth and eighteenth centuries. John Smith in *The Art of Painting* (1676; cf. Bristow, 1996b) writes that 'Plain-Oker' was 'a certain concret, or stony substance, found among stiff Clays in divers parts of this Kingdom; but those parts that contain most of it, is the Shotover Hills near Oxford, from whence most of the Yellow-Oaker that is sold in England is dug out; 'tis a Colour, that with pains, will grind very fine, it bears an excellent body, and resists the weather well.' Oxford ochre was variably known as Shotover ochre or Oxford stone ochre. Heaton (1928) writes that these supplies were almost exhausted by his time, but that the poorer grades of the deposits (stone ochres) were used adulterated with chalk and baryte (*qq.v.*).

The 'second best' ochre available to British artists was imported and known as Dutch or Spruce ochre (derived from Prussian ochre 'Spruce' being an old form of 'Prussia' or 'Prussian'). Spanish brown was the name applied to low-grade, usually natural red ochres often from British sources (despite the name). Indian ochre came either from Bengal or from the Persian Gulf, but this name was also applied to synthetic pigments of the same red hue. Other deposits mentioned by Heaton (1928) are those of the Vale of Avoca (Wicklow, Ireland) and those in Pennsylvania and Georgia (which were known for their transparency). Tingry (1804) recommends the sources in the Auvergne which produced both red and yellow ochres. Tingry also lists the varieties brown ochre and *ocre de rue* (*q.v.*). Natural ochres were also known as flesh ochres, hence Weber (1923) uses the terms *ocre de chair* and *ocra di carne*.

Toch (1916) lists a whole series of ochre-variants known in the paint trade: cream ochre, grey ochre, white ochre and golden ochre. Golden ochre was, apparently, 'either French ochre or American ochre which is brightened with some chrome yellow [*q.v.*]. There are various shades of golden ochre sold, depending upon the shade of chrome yellow with which it is mixed. Some of them are perfectly orange colored, and contain as high as 12 to 15 per cent of chemically pure orange chrome yellow.'

Additionally, ochres have had widespread use as domestic and industrial paints used for both interior and exterior walls.
See: Sienna

Clay minerals group; Feldspar group; Iron oxides and hydroxides group; Mica group; Baryte; Chalk; Goethite; Gypsum; Hematite; Jarosite; Lepidocrocite; Limonite; Natrojarosite; Quartz; Sienna; Umber; *Burnt ochre*; *Chrome yellow*; *English ochre*; *Ocre de rue*; *Oxford ochre*; *Red ochre*; *Yellow ochre*
Barham (2002); Barton & Reynolds (1985); Béarat (1997); Bikiaris *et al.* (1999); Bristow (1996b) 30–33; Burgio & Clark (2000); Burgio *et al.* (1999a); Buxbaum (1998) 83; Church (1901) 138, 180–182; David *et al.* (2001); Edwards *et al.* (1998); Gifford (1983); Hackh (1969); Hameau *et al.* (2001); Heaton (1928) 165–170; Helwig (1997); Hyman *et al.* (1996); Jercher *et al.* (1998); Kaneko (1983); Lee & Guggenheim (1981); Lelekova (1998); Lumley, de (1969); Newman *et al.* (1980); Ortega *et al.* (2001); Panev (1979); Perez *et al.* (1999); Pliny (1st cent AD/Rackham, 1952) XXXV.30, 35; Pomiès *et al.* (1999); Riederer (1985); Scott *et al.* (2002); Smith & Pell (1997); Smith *et al.* (1999); Stafford *et al.* (2003); Stodulski *et al.* (1984); Theophrastus (c. 315 BC/Caley & Richards, 1956) 40, 53–56; Tingry (1804) 351; Toch (1916) 79; Townsend (1996); Vitruvius (1st cent BC/Grainger, 1934) VII.vi.2, VII.vii.1–2; Wainwright *et al.* (2002); Watchman *et al.* (1993); Watson (1967); Watson (1969); Watts (2002); Weber (1923) 56; Wei-Yeh *et al.* (1983); Woodhouse (1969)

OCRE DE RUE

Red-Brown
Synonym, variant or common name

Ocre de rue, and the synonyms *ocre de ru* and *oker de rouse*, describe an obscure variety of brown red or yellow ochre (*qq.v.*). Harley (1982) cites Peacham (1634) who recommends it for painting hair colours. Tingry (1804) lists *ochre de rue* as dark yellow and calcined *ochre de rue* as yellow. Harley suggests that the French thought the term referred to an English place name and Mérimée (1830) suggests that '*ru*' refers to *ruisseau* indicating a riverside deposit from iron.
See: oker de rouse.

Ochre; *Oker de rouse*; *Red ochre*; *Yellow ochre*
Harley (1982) 89; Mérimée (1830/trans. Taylor, 1839); Peacham (1634); Tingry (1804) 351

OIL BLACK

Black
Synonym, variant or common name

A flame carbon derived from the incomplete combustion of oil (Mayer, 1991).
See: carbon-based blacks group: flame carbons sub-group and lamp black.

Carbon-based blacks group; Carbon-based blacks group: flame carbons sub-group; *Lamp black*
Mayer (1991) 52

OIL BLUE

Blue
Synonym, variant or common name

A complex recipe for the production of oil blue is given by Bersch (1901), who states that the pigment consists of copper sulfide, Zerr and Rübencamp (1906) describing it as 'copper mono-sulphide, CuS, of a very pretty bright blue shade'. This identification is more complex than at first sight since (a) the copper(I) and copper(II) sulfides are both black and (b) the copper-sulfur system is highly complex (Scott, 2001; see: copper sulfides group). Preparation follows these lines, however: copper wire or filings are added to boiling sulfur in a flask, the copper igniting and burning. Further copper is added until only a little sulfur is left, the flask sealed and cooled. When the contents have cooled to room temperature the flask is broken open and the product boiled with potassium hydroxide solution to remove excess sulfur. It is, however, noted as a 'very sensitive' pigment.

According to Gardner *et al.* (1978), oil blue was also a synonym for Prussian blue (*q.v.*).

Copper sulfides group; Hexacyanoferrate group; *Prussian blue*
Bersch (1901) 228; Gardner *et al.* (1978); Scott (2002); Zerr & Rübencamp (1906/1908)

OIL GREEN

Green
Synonym, variant or common name

Mayer (1991) states that oil green is synonymous with two terms of variable meaning: Bremen green and chrome green (*qq.v.*).

Bremen green; *Chrome green*
Mayer (1991) 52

OKER DE LUKE

Yellow
Synonym, variant or common name

Oker de luke, or *oker de luce*, was a historical term for an ochre (*q.v.*) pigment encountered by Harley (1982) in several English sixteenth and seventeenth century documentary sources. One of these, Peacham (1634, cf. Harley) who is normally informative about word derivations, gives little information about the pigment apart from the fact that it is a yellow ochre (*q.v.*) suitable for painting hair, and Hilliard (1624) recommends it for shading yellow.

A related term – *Oker de rouse* (*q.v.*) – referred to a darker ochre tending to red or brown.

Earth pigments group; Ochre; *Oker de rouse*; *Yellow ochre*
Harley (1982) 89; Hilliard (1624/Thornton & Cain, 1981); Peacham (1634)

OKER DE ROUSE

Red-Orange-Yellow
Synonym, variant or common name

Oker de rouse was a historical term of obscure derivation for an ochre (*q.v.*) pigment encountered by Harley (1982) in various English seventeenth century documentary sources. From the context of use it seems probable that *oker de rouse* was a darker shaded ochre tending to red or brown; Hilliard (1624) for example suggests that it should be used as a shading yellow.

The term may be compared with the French *Ocre de ru* (or *rut* or *ruë*), the meaning of which is also obscure: in the seventeenth century it was suggested that this ochre came from Ruë, which was thought to be an English placename. Mérimée (1830) suggested in the nineteenth century that 'ru' was an old form of *ruisseau* and that the term therefore suggested deposits in 'brooks of ferruginous waters'. Watin (1785) also mentions *ochre de rue* or *ochre de rut*, as a colour taken from the streams in iron mines '*qui se prend aux ruisseaux de mine de fer*', saying that it will 'imitate the colour of wood and that calcination will give it a beautiful colour. He states furthermore that it 'imitates and can supplant Italian Ochre'.

Earth pigments group; Ochre; *Oker de luke*; *Yellow ochre*
Harley (1982) 89; Hilliard (1624/Thornton & Cain, 1981) 94; Mérimée (1830/trans. Taylor, 1839) 104; Watin (1773/edition of 1785) 25

OLD FUSTIC

Yellow
Synonym, variant or common name

See: fustic.

OLD GREY

Grey
Synonym, variant or common name

Old grey is given as a term for a fruitstone black by Riffault *et al.* (1874).
See: carbon-based blacks group; chars sub-group.

Riffault *et al.* (1874) 515

OLEUM WHITE

White
Synonym, variant or common name

Stated to be a then-current term for Lithopone (*q.v.*) by Heaton (1928).

Lithopone
Heaton (1928) 382

OLIGOCLASE

White
Generic compound

Oligoclase is a sodium-rich member of the feldspar group (*q.v.*) of minerals, with composition $(Na_{0.9–0.7}Ca_{0.1–0.3})(Al,Si)_4O_8$. It forms part of the plagioclase feldspar series, occurring as an intermediate composition between end members albite and anorthite (*qq.v.*); it is considered to contain 10–30% anorthite and 70–90% albite. Oligoclase was first described by Breihaupt in 1826 and occurs as well-formed crystals, anhedral grains or compact masses which are commonly white, but may be yellow, brown or grey due to weathering processes or the presence of impurities. Plagioclase feldspars are major rock forming minerals, occurring in many different rock types worldwide. Oligoclase is often found in association with quartz and orthoclase (*qq.v.*); good examples are known from Monteagle (Canada), Arendel (Norway) and Silberberg (Germany). For further information see: Dana (1932), Deer *et al.* (1992) and Rutley (1998).

Plagioclase feldspars decompose in the presence of water to clay minerals (*q.v.*) and for this reason may occur as relict minerals in artists' materials such as pottery and plasterwork; they are important relict components in kaolin (*q.v.*).

Clay minerals group; Feldspar group; Silicates group; Albite; Anorthite; Orthoclase; Quartz; *Kaolin*
Dana (1932) 547; Deer *et al.* (1992) 431–454; Rutley (1988) 417

OLIVE GREEN

Green
Synonym, variant or common name

Salter (1869) includes this, declaring it to be 'an arbitrary compound, or mixed green, of a fine deep olive colour and sober richness'. He gives the term Dewint's green as a synonym. This colour was recorded by the Russell and Abney committee in 1886 (cf. Brommelle, 1964).

Dewint's green
Brommelle (1964); Salter (1869) 330–331

OLIVE LAKE

Green
Synonym, variant or common name

Field (1835) stated that this pigment was prepared from ebony, adding (in 1841) that it was also made from 'laburnum'. However, by the latter part of the century this was no longer an organic lake but a compounded colour: quercitron lake and 'bone brown' blended with ultramarine; quercitron lake and Prussian blue; Indian yellow, umber and indigo (*qq.v.*). Finally, Reeves (in a catalogue of about 1898) stated that their *Olive green* and *Olive lake* were both made from 'an alizarin compound' (*qq.v.*; cf. Carlyle, 2001).

Alizarin; Indian yellow; Indigo; Quercitron; Ultramarine; Umber; *Bone brown*; *Ebony*; *Green lake*; *Olive green*; *Prussian blue*
Carlyle (2001) 495; Field (1835); Field (1841)

OLYMPIAN GREEN

Green
Synonym, variant or common name

Olympian green is listed as a term for malachite (*q.v.*) by Gettens and FitzHugh (1993b).

Malachite
Gettens & FitzHugh (1993b)

OPAQUE GREEN

Green
Synonym, variant or common name

Opaque green is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's green and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997)

ORANGE LAKE

Orange
Synonym, variant or common name

Recipes in *A Practical Treatise* (1795) and the *Compendium* of 1808 use 'Spanish annotto, pearl ashes and alum' to produce orange lake. Carlyle (2001) found no further mention of it in her survey of British nineteenth century documentary sources. For annatto, see: bixa.

Bixa
Carlyle (2001) 500; *Compendium* (1808); *Practical Treatise* (1795)

ORANGE LEAD

Red-Orange
Synonym, variant or common name

Carlyle, in a survey of nineteenth century British documentary sources, records that various preparations of lead(II,IV) oxide (*q.v.*) were listed among orange colours, either as red lead, orange lead or mineral orange (Carlyle, 2001). Weber (1923; cf. Kühn, 1986) states that orange lead (or orange mineral) may be used as a synonym for red lead, but that more commonly this term refers to the finest or purest red pigment produced by calcining lead white. Heaton (1928) gives orange lead as 'a generally accepted trade name in general use' at that time. Oguchi (1969) records that in Japan, when red lead is prepared from lead white it is called orange lead or orange mineral. Orange lead was reputed to have a finer texture and lighter colour than red lead; Bearn (1923) says that it was used with dyes and other materials such as lead acetate and calcium sulfate to make what was called *rouge universel* or *rouge vermilion* as well as acting as a base for synthetic dyestuffs. The terms 'orange lead' and 'orange mineral' appear to have largely overlapping meaning, occurrence and use.

Lead(II,IV) oxide; Minium; *Mineral orange*; *Red lead*
Bearn (1923); Carlyle (2001) 501; Heaton (1928) 382; Kühn (1986); Oguchi (1969); Weber (1923)

ORANGE MINERAL

Red-Orange
Synonym, variant or common name

See: orange lead.

ORANGE ORPIMENT

Orange
Synonym, variant or common name

This pigment was sold by Reeves, 1856–59, and listed in Roberson's Bought Ledger No. 3 in 1878. According to Carlyle (2001) 'Field (1835) categorized orpiment (also called realgar; [*qq.v.*]) under orange as he said it was "improperly" called red orpiment. He identified two varieties, one native, and one "factitious", but noted that they only differed in colour (the native was redder in hue).' Salter (1869) stated that orange orpiment was realgar, contained more arsenic and less sulfur than the yellow, and was often sophisticated with brickdust and yellow ochre.

Orpiment; Realgar; *Yellow ochre*
Carlyle (2001) 498, 500; Field (1835); Salter (1869) 258–259

ORANGE PASTE

Orange
Synonym, variant or common name

According to Kühn and Curran (1986), orange paste is an older term associated with basic lead chromate (lead chromate(VI) oxide, *q.v.*), as stated in their review of chrome orange and chrome red (*qq.v.*) pigments. The term 'paste' sometimes implies supply in the form of pigment thickly dispersed in some medium (for example as in paste blue and paste white lead, *qq.v.*).

Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*; *Paste blue*; *Paste white lead*
Kühn & Curran (1986)

ORANGE RUSSET

Orange
Synonym, variant or common name

Standage (1887) gives this as a synonym for 'Rubens' madder' (*q.v.*), stating 'a very rich crimson russet with a flash of orange, pure, transparent, and of madder hue between orange and purple'. There is also a recipe in one of the Roberson's recipe books (R.2.N) which is unclear but includes madder and burnt sienna (*qq.v.*; cf. Carlyle, 2001).

Madder; *Burnt sienna*; *Field's russet*; *Madder orange*; *Orange lake*; *Rubens' madder*; *Russet rubiate*
Carlyle (2001) 500; Standage (1887)

ORANGE VERMILION

Orange
Synonym, variant or common name

Described by Field (1835) as a 'sulphurette of quicksilver' (that is, mercury(II) sulfide, the composition of vermilion, *q.v.*). However, Martel (1860) identified it as 'the lighter portion of crude Vermilion, which is separated when the latter is mixed with water; the orange portion being the lightest, occupies the upper portion of the pigment deposited by the water … Some specimens of Orange Vermilion are mixtures of Vermilion and Chrome Yellow (*q.v.*).'

Mercury sulfides group; *Chrome yellow*; *Field's orange vermilion*; *Vermilion*
Field (1835) 93–94; Martel (1860) 29

ORCEIN

Blue-Purple
Generic compound

Orcein is the principal colouring component found in orchil (*q.v.*). Treatment of the lichen *Rocella tinctoria* (litmus, *q.v.*) with ammonia forms orcin which is then oxidised to form orcein, $C_{28}H_{24}N_2O_7$. This compound has been extensively studied by Hans Musso, who has produced a series of papers on the structure, chemistry and properties of orcein and its derivatives; see Musso (1956) and Musso (1960) for a review of his work.

Orcein is synthesised today from orcinol (3,5-dihydroxytoluene) by hydrogen peroxide oxidation in the presence of ammonia.

Lichens group; *Litmus*; *Orchil*
Musso (1956); Musso (1960)

ORCHIL

Blue-Purple
Synonym, variant or common name

Orchil is the dyestuff derived from lichens of the Roccellaceaea group and particularly the genus Rocelleae. Orchil and its derivative orcein (*q.v.*) have been the subject of extensive research by Hans Musso (Musso, 1956, 1960).

An extensive bibliography on orchil has been assembled by Cooksey (1997). Useful modern discussions of the historical context of orchil as a dye from ancient time to the present day are given by Perez-Llano (1944), Kok (1966), Brunello (1973) and Schweppe (1992). Diadick Casselman (2001, 2002) has reviewed the etymology and botany of European lichens in the context of historical dyestuffs. Veliz (1986) found fairly frequent mention of this pigment in Spanish treatises, suggesting that the reported proximity of sources in Malta and the Canary Islands perhaps accounted for this.

The term is spelled variously as archil, archall, -al, -el, or arcel(l) as well as orchil (or -ill), orchell, orchel, orchall, orcheall, orcall, orchal, orcheil, orselle, oricelle or orseille. It is also related to the Old French word *orchel* as well as the Italian *oricello* (*q.v.*) and Spanish *orchillo* (*OED*, 2002).
See: lichens group.

Lichens group; Orcein; *Oricello*
Brunello (1973); Cooksey (1997); Diadick Casselman (2001) 5–9; Diadick Casselman (2002); Kok (1966); Musso (1956); Musso (1960); *OED* (2002) 'Archil', 'Orchil'; Perez-Llano (1944); Schweppe (1992); Veliz (1986) 198, n. 11

ORGANO-COPPER COMPLEXES GROUP

Green
Group term

The existence and formation of transparent green pigments based on combinations of copper compounds and organic media is a field of some debate and there has long been uncertainty over whether these are so-called copper resinates, or compounds based largely on drying oils, or combinations of oil and resin. To complicate matters analogous compounds are also known to exist between copper and proteins, and from the reaction between copper compounds and beeswax. Moreover, such compounds can form spontaneously over time between copper compounds used as pigments and the media in which they are bound, raising the possibility that the material was never intentional at all. To avoid the implications of composition, recent studies have tended to use the term copper green glaze, but this does not satisfy the general need for a term since they are not necessarily used in a glazing context. Consequently they will be referred to here as belonging to a group of organo-copper complexes. This broad classification encompasses a variety of naturally derived polymeric materials containing different organic species (ligands), which coordinate to the copper *via* oxygen, nitrogen and sulfur ligands.

It is generally understood that these compounds are produced in copper resinate-type materials through the dissolution of verdigris (*q.v.*) compounds in resin and oil and that a reaction occurs creating copper salts of oxidised abietic acid ($C_{19}H_{29}COOH$). In such cases Colombini *et al.* (2001) have found that dehydroabietic, 7-oxodehydroabietic and primaradenic acids are diagnostic. It is not known whether these compounds were synthesised intentionally or whether some later, unintentional reaction has taken place, and in fact Colombini *et al.* indicate that they form both during manufacture of the pigment and during curing over several years. Analysis of these substances is difficult and requires large aliquots of the sample. Kühn (1993a) writes of transparent copper green glazes that 'the outlines of crystals of verdigris are often very difficult to recognise under the microscope and … verdigris reacts in the course of time [and becomes amorphous] with protein, oil and resin media to form transparent coppers salts of fatty acids'. Eikema Hommes (2001, 2002) thereby postulates that many glazes may therefore not be copper resinate but copper oleates or proteinates. She concludes, in agreement with Kühn, that a large percentage of resin in the pigment must be detected before a green glaze can be said to be a copper resinate. Very few examples of glazes analysed are resin rich (see van den Berg *et al.*, 2000) and therefore there is still some mystery associated with their manufacture and composition, further work clearly being required.

Woudhuysen-Keller (1995) quotes de Mayerne's recipe for making 'copper resinate'; 'Beautiful green: take two ounces of Venetian turpentine, one-and-a-half ounce of oil of turpentine, mix and add two ounces of verdigris in little pieces. Set it on hot ashes and let it boil gently.' Woudhuysen-Keller (1995) was unable to replicate this method without the addition of extra resin, and the resulting pigment, though green and glassy *en masse*, when ground in oil was not particularly intense. Woudhuysen-Keller and Woudhuysen (1998) have further experimented with dissolving basic verdigris in pine resin (colophony) to produce what they have termed ‘copper resinate I’, which could then be used, ground, in oil or varnish media. Alternatively, they found verdigris could be dissolved in a solution of hot oil and pine resin and used directly as a paint (if necessary, thinned with turpentine); this they call ‘copper resinate II’. In their reconstructions, verdigris particles were often found to be present within the copper resinate. They conclude that preparation must begin with dissolving verdigris completely in colophony and then dissolving the two in oil. Without sufficient resin, particles of undissolved verdigris will remain.

The pigment is prone to discoloration through oxidation in air (Woudhuysen-Keller and Woudhuysen, 1998). Gunn *et al.* (1999) have shown that the brown layers which form over time are oleresinous layers (copper oleates and copper proteinates), caused by the relative ease of extraction of copper(II) ions from verdigris by fatty acids, proteins and waxes present in the binding media or overlying varnishes.

Copper green glazes are known to have been adulterated or varnished with yellow lakes (including Dutch pink, turmeric, weld and aloes; *qq.v.*).

Given the uncertainty of the nature of these compounds, identification of the pigments should be treated with some trepidation. Historical analyses identifying ‘copper resinate’ without adequate confirmatory analysis are to be regarded as questionable. However, copper resinates have been identified on a number of paintings in the National Gallery, London, dating from the mid-fifteenth to late sixteenth century (see Kühn, 1993a). Sr. Daniila *et al.* (2002) have identified copper resinate on two sixteenth century Byzantine-tradition icons and Woudhuysen-Keller and Woudhuysen (1998) have identified copper resinate glazes on the *The Martyrdom of St Sebastian*, by a follower of Lorenzo di Credi. In addition copper resinate has been identified on a sixteenth century painting by Maarten van Heemskerk (Gifford, 1990) and on van Eyck’s *Mystic Lamb* alterpiece (Kockaert, 1979). Kühn (1993a) categorically identified copper resinate on Vermeer’s *Maid Handing a Letter to her Mistress*, and Arnold Böcklin’s *Triton and Nereide*.

Scott *et al.* (2003) have identified an olive green pigment on a Graeco-Roman cartonnage fragment, which appears to be verdigris dissolved in a protein-based glue. It is uncertain whether this sample of copper proteinate (so far unique for this period) was deliberately or accidently prepared. However, the fact that brush fibres are present suggests it was a viscous paint, which implies that it may well have been intentionally prepared.

Copper resinate is also known as transparent copper green. Historical terms for the pigment are not recorded; it was probably considered as verdigris or verdigris glaze; Birelli (1601; cf. Eikema Hommes, 2002), for example, writes of a glaze ‘green like an emerald’.

Copper acetate group; Aloe; Turmeric; Weld; *Dutch pink*; *Verdigris*
Berg *et al.* (2000); Birelli (1601); Colombini *et al.* (2001); Daniila *et al.* (2002); Eikema Hommes (2001); Eikema Hommes (2002); Gifford (1990); Gunn *et al.* (1999); Kockaert (1979); Kühn (1993a); Scott (2002) 294–298; Scott *et al.* (2003); Woudhuysen-Keller & Woudhuysen (1998); Woudhuysen-Keller (1995)

ORGANO-IRON GROUP

Variable
Group term

Iron(II) oxalate (or oxalite), humboldtine ($Fe[C_2O_4].2H_2O$) is often found in association with the calcium oxalates, whewellite and weddellite (*qq.v.*). Iron(II) oxalate has been mentioned by Salter (1869) as the compound forming a pigment he calls iron yellow. Hemoglobin is also an organo-iron compound; for fuller discussion of this compound, see: hemoglobin.

Iron group; Porphyrins group; Hemoglobin; Humboldtine; Iron(II) oxalate; Weddellite; Whewellite; *Iron yellow*
Salter (1869)

ORICELLO

Purple
Synonym, variant or common name

Oricello is apparently a purple lichen dyestuff used as a dye or for underpainting gold. According to the Bolognese MS: ‘*174. To make purple Oricello*. Oricello has a purple colour. Boil some water, when it is hot liquefy some oricello in it, rub it hard and press through a strainer … do two or three times … put a piece of saffron [*q.v.*] and a piece of gum in an egg shell and warm it on the coals. – do 2 or 3 times … next day, strain … distemper, lay it upon paper and write … [grind gum ammoniac with vermilion [*q.v.*] and ley and write upon the oricello … take leaf of gold … etc.]’ (fifteenth century, Clarke MS 160; cf. Merrifield, 1849). See also: orchil.

Lichens group; Saffron; *Orchil*; *Vermilion*
Merrifield (1849) 474

ORIENT YELLOW

Yellow
Synonym, variant or common name

Described as ‘an opaque variety of Cadmium Yellow, similar in quality to Aurora Yellow [*qq.v.*]; but of a much deeper hue’ in a Winsor & Newton catalogue of 1896 (cf. Carlyle, 2001). Salter (1869) praises it very highly, stating that it is ‘an entirely new preparation of absolute permanence, and perfectly unexceptionable in all respects’ and, while not exactly explaining what it is, does imply that he does not believe it to be a cadmium yellow (‘Being more transparent than cadmiums and less obtrusive’). The term was still current in the early twentieth century (Heaton, 1928)

Cadmium group; *Aurora yellow*; *Cadmium yellow*
Carlyle (2001) 524–525; Heaton (1928) 382; Salter (1869) 110–111

ORIGINAL GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

ORNACHA

Yellow
Synonym, variant or common name

Ornacha (or *hornaza*) is a term found in Spanish treatises for a dark yellow pigment. Veliz (1986) links this to a term for glassmakers’ furnaces – *hornillo* – and thereby to the *giallo di vetro* described by Borghini (1584), which is currently thought to be lead tin yellow (lead tin and lead tin silicon oxides; *qq.v.*).

Lead tin oxide; Lead tin silicon oxide; *Giallo di vetro*; *Hornaza*; *Lead tin yellow*
Borghini (1584/edition of 1787); Veliz (1986) 198, n.9

OROPIMENTE

Yellow
Synonym, variant or common name

The term *oropimente* is to be found in Spanish treatises (see Veliz, 1986), being intermediate between the original Latin *auripigmentum* and the modern term orpiment (*q.v.*).

Orpiment
Veliz (1986)

OROPIMENTE QUEMADO

Red
Synonym, variant or common name

Quemado means 'burnt' and *oropimente quemado* refers to artificially produced realgar (*q.v.*). The term is to be found in seventeenth century Spanish treatises (see Veliz, 1986).
See: oropimente.

Realgar
Veliz (1986)

ORPIMENT

Yellow
Generic compound

Orpiment is a yellow to greenish yellow sulfide of arsenic (As_2S_3), containing 60% arsenic. Both orpiment and the related mineral realgar (*q.v.*) often occur together as massive encrusting or granular deposits (crystals occur rarely). Other arsenic sulfide minerals are often found associated with orpiment and realgar including pararealgar (AsS), duranusite (As_4S), alacranite (α-AsS), dimorphite (As_4S_3) and uzonite (As_4S_5) (*qq.v.*). The main occurrence of these phases is in the oxidised portions of arsenic veins (Heinrich and Eadington, 1986). Both minerals are also often found in association with cinnabar (*q.v.*) and antimony deposits (see Bancroft *et al.*, 1991) and as sublimates from volcanoes, particularly from Vesuvius and the Phlegrian Fields around the Bay of Naples and the volcanoes of the Aeolian Islands (see Garavelli and Vurro, 1994). Important deposits are found in association with hot springs worldwide and Chinese deposits of this variety are well known (see Zhang *et al.*, 1993). China was an important exporter of naturally occurring orpiment to the west during the nineteenth century, hence the name Chinese yellow (Harley, 1982). The unpleasant nature of the minerals and their derived pigments was well known (for example, Hilliard, 1624); not only are the fumes poisonous but they also smell foul and this decreased the popularity of orpiment with many artists. Furthermore, orpiment reacts with copper and lead-based pigments (Weber, 1923; FitzHugh, 1997) and was therefore avoided in this context and most treatises warned against mixing these colours. However, Harley (1982) remarks that orpiment is often listed among pigments suitable for heraldic blazonry, possibly because it could be used in isolation in such cases.

Despite its unpleasantness and the fact that many artists would not touch it, the colour of orpiment produced a splendid shade of yellow; 'the most beautiful colour we have' (Roberts, 1809; cf. Harley, 1982). As a pigment, natural orpiment gives a yellow which is a 'very brilliant colour' (Terry, 1893) and Yü (1955) quotes a Chinese proverb, 'from just four taels of orpiment comes a thousand taels of gold leaf'.

Orpiment has been manufactured certainly since the Early Renaissance. In *Il Libro dell'Arte*, Cennini (c. 1400, Clarke MS 590) is apparently unaware that naturally occurring deposits exist. Harley (1982) states that the natural and synthetic varieties were not differentiated in pre-eighteenth century English texts. Dossie (1764) and de Masoul (1797) give instructions on the manufacture of artificial orpiment, 'King's yellow or pure orpiment', which must be prepared by mixing sulfur and arsenic by sublimation. Historical methods of manufacture of orpiment and realgar are summarised by Wallert (1984) and can be generally subdivided into 'dry-process' methods (involving heating) and 'wet-process' methods (involving precipitation). Synthetic orpiments may often contain the impurity arsenolite (As_2O_3, *q.v.*, used as a raw material for the manufacture of orpiment). Harley (1982) suggests that synthetic orpiment was more widely used than the naturally occurring mineral, and this was the Chinese yellow imported from the deposits in Hunan Province (Zhang *et al.*, 1993; Yü, 1955).

On the whole, orpiment in both natural and synthetic forms was used as a pure pigment. However, examples of adulteration to extend the pigment or improve its physical properties are not uncommon. Colinart (2001) notes that in some ancient Egyptian contexts it is adulterated by mixing with yellow ochre (*q.v.*) and notes that on papyri it has degraded to white arsenic oxide (As_2O_3). This phenomena has also been noted in orpiment painted in glue medium (White, quoted in FitzHugh, 1997) and on Nepalese manuscripts (Trier, 1972). Another case of adulteration is mentioned by Boltz (1549) who suggests mixing it with saffron (*q.v.*) to make it 'prettier'. Additionally the authors have recognised it in Rubens' *Massacre of the Innocents*. Orpiment-based pigments from twentieth century Persian miniatures have been found occurring with portlandite ($Ca[OH]_2$; *q.v.*) a mineral which could feasibly occur in association with volcanogenic orpiment.

Early known uses of orpiment as a pigment occur in Middle and New Kingdom Egypt (sixteenth to eleventh centuries BC) as painted decoration on wooden coffins and stelae and as a cosmetic (Colinart, 2001). Because of its bright colour, the pigment was popular for use on mediaeval manuscripts and it has been identified from the Book of Kells (Meehan, 1994). Derbyshire and Withnall (1999) have identified orpiment on Elizabethan miniatures. FitzHugh (1997) reviews the widespread use of orpiment in western and eastern art until the end of the nineteenth century, when it was largely phased out due to its toxicity.

Apart from the reactions with copper- and lead-based pigments (particularly lead white and verdigris; *qq.v.*), orpiment is also considered to be unsuitable for use on frescos as was noted by Roman authors and Cennino Cennini in the early fifteenth century ('it turns black on exposure to air'). Orpiment was known as a poor drier but this could be improved, according to de Mayerne (BL MS Sloane 2052; cf. Harley, 1982) by 'grinding it in oil previously boiled with litharge' (*q.v.*). Ground glass was also added as a potential drier (Haydocke, 1598; cf. Harley 1982).

The main and acknowledged problem with the pigment was its toxicity. Cennini writes 'Beware of soiling your mouth with it, lest you suffer personal injury.' Orpiment was in fact also used to protect manuscripts from the deprivations of insects and has been recorded as a post-excavation treatment on Egyptian papyri by Olsson *et al.* (2001).

The name orpiment is originally derived from the Latin *auripigmentum*, literally 'gold paint' and this term is used by both Pliny (77 AD) and Vitruvius (first century BC); the latter notes that it was derived from the Pontus in Northern Anatolia. Theophrastus (c.315 BC) and other Greek authors give the name *arsenikon* from which the modern 'arsenic' is derived. Ancient sources quoted by Merrifield (1849) use the Spanish terms *jalde* and *oropimente*. The term *Arzicon* or *Arsicon* is also mentioned in the fifteenth century manuscript of Jehan le Begue (Clarke MS 2790); Merrifield presumes that this is a corruption of arsenikon and wisely notes the opportunity for confusion here with the unrelated dye arzica (*q.v.*; Merrifield, 1849). By the sixteenth century, Agricola (1556) was using '*operment*' to describe the natural mineral variety. Eighteenth century texts (Dossie, 1764; de Massoul, 1797) refer to King's yellow; this name is possibly derived from mediaeval Arabic alchemical texts which describe orpiment and realgar as the 'two Kings' (Crosland, 1962) and is therefore more likely to refer to synthetic orpiment. Terry (1893) refers to King's yellow and trisulfide of arsenic as alternative names for orpiment, citing Hungary and the Harz Mountains as sources. He adds that the finest quality 'golden orpiment' comes from Persia. Weber (1923) continues to use King's yellow (and *Koenigsgelb*), *Jaune royal* and Arsenic yellow as synonyms for orpiment. Modern names used to describe the pigment include *Gelbe Arsenblende* and *Arsenic sulfuré jaune* although these are synthetic products (FitzHugh, 1997).

Arsenic sulfides group; Alacranite; Arsenic sulfide, orpiment type; Arsenolite; Cinnabar; Dimorphite; Duranusite; Litharge; Pararealgar; Portlandite; Realgar; Saffron; Uzonite; *Arsenic Yellow*; *King's Yellow*; *Orange orpiment*; *Verdigris*; *Yellow arsenic*; *Yellow ochre*

Agricola (1556/trans. Hoover & Hoover, 1950) 111, 222; Bancroft *et al.* (1991); Boltz (1549); Cennini (c. 1400/Thompson, 1960) 28–29; Colinart (2001); Crosland (1962) 36; Derbyshire & Withnall (1999); Dossie (1764) I-97, 105; FitzHugh (1997); Garavelli & Vurro (1994); Harley (1982) 93–94; Heinrich & Eadington (1986); Hilliard (1624/Thornton & Cain, 1981) 88; Massoul (1797); Meehan (1994) 86–88; Merrifield (1849) cliv, clxvii; Olsson (2001); Pliny (1st cent AD/Rackham, 1952) XXXV.xii.30; Roberts (1809); Terry (1893) 280; Theophrastus (c. 315 BC/Caley & Richards, 1956) 51; Trier (1972); Vitruvius (1st cent BC/Grainger, 1934) VII.vii.5; Wallert (1984); Weber (1923) 96; Yü (1955/trans. Silbergold & McNair, 1988) 44; Zhang *et al.* (1993)

ORPIMENT, DRY-PROCESS

Yellow
Generic compound

See: orpiment and arsenic sulfide, orpiment type.

ORPIMENT, WET-PROCESS

Yellow
Generic compound

See: orpiment and arsenic sulfide, orpiment type.

ORR'S ZINC WHITE

White
Synonym, variant or common name

John Bryson Orr developed and patented a process for the manufacture of the pigment known as 'Orr's Zinc White' (patent 517 of 1874), which had a novel manufacturing process that included calcination of the basic ingredients. Orr was born in 1840 in Blantyre, Lanarkshire, Scotland, the son of a dyer. He was apprenticed to the firm of Lewis, McLellan and Co., Oil and Colourmen and Drysalters in Glasgow, where he also studied chemistry at the Andersonian College (now the University of Strathclyde). In 1872 Orr set up a factory for the manufacture of lithopone (*q.v.*). Orr's 1874 invention produced a lightfast product and in time became a basic pigment for the paint industry. In 1898 Orr expanded into industrial development at the Vine Works, Widnes, Lancashire, England. Widnes was a prime location for the manufacture of a product that grew to over a quarter of a million tons annually. In 1930 the company was merged with the Imperial Smelting Corporation Ltd, of which Orr was a director until his death in 1933.

Zinc oxide; *Lithopone*; *Zinc white*

ORTHOCHRYSOTILE

White
Generic compound

Orthochrysotile is one of the polymorphs of the magnesium-rich silicate mineral chrysotile (*q.v.*), along with parachrysotile and clinochrysotile (*qq.v.*). It belongs to the serpentine group (*q.v.*) of minerals and has the chemical composition $Mg_3Si_2O_5(OH)_4$ (Wicks and O'Hanley, 1988). It is usually found as white, brown, green or grey fibres in hydrothermally altered ultrabasic rocks such as those found in Cornwall (England) and Cyprus.

Magnesium group; Serpentine group; Silicates group; Chrysotile; Clinochrysotile; Parachrysotile
Wicks & O'Hanley (1988)

ORTHOCLASE

White
Generic compound

A member of the feldspar group (*q.v.*), orthoclase is a potassium-rich aluminosilicate mineral with composition $KAlSi_3O_8$. It forms a solid solution series with albite (*q.v.*) and may contain up to 20% of the albite component ($NaAlSi_3O_8$), as well as impurities such as Ba, Fe^{3+}, Na, Li and Sr. Orthoclase occurs as white prismatic or tabular crystals, with a distinct cleavage, or as aggregates and grains which may be coloured pink, green or yellow due to impurities or inclusions. It is an alkali feldspar, polymorphous with microcline (*q.v.*) and sanadine, which form under different rates of cooling. The structure of orthoclase has been discussed in detail by Prince *et al.* (1973) and Smith and Brown (1988). Orthoclase occurs in alkali granites, in metamorphic rocks and in the sedimentary rocks derived from them, and is often found with quartz, muscovite, biotite and amphibole group (*qq.v.*) minerals. It was described by Breithaupt in 1823 and is named from the Greek words *ortho* and *klas*, meaning 'straight' and 'fracture' in allusion to the cleavage angle of the mineral. Orthoclase is found in areas such as Mogok (Burma), Kangerdlugssuaq (Greenland), Selkingen (Switzerland), Elba (Italy) and Cornwall (England) and breaks down by hydrothermal alteration or weathering to form clay minerals (*q.v.*; Ribbe, 1983; Deer *et al.*, 1992; Rutley, 1988; Dana 1932). It may be encountered as a relict mineral in kaolin and ochres (*qq.v.*), used as artists' materials.

Amphibole group; Clay minerals group; Feldspar group; Silicates group; Albite; Biotite; Microcline; Muscovite; Ochre; Quartz; *Kaolin*
Dana (1932) 536; Deer *et al.* (1992) 396–430; Prince *et al.* (1973); Ribbe (1983); Rutley (1988) 418; Smith & Brown (1988)

ORTHONITROANILINE ORANGE

Orange
Synonym, variant or common name

Orthonitroaniline orange is a β-napthol azo pigment, a positional isomer of so-called 'Para red' (CI 12070/Pigment Red 1; *q.v.*). It is listed by the *Colour Index* (1971) as CI 12060/Pigment Orange 2. Herbst and Hunger (1997) specifically note its use in artists' colours.
See: azo pigments group: β-naphthol sub-group.

Azo pigments group: β-Naphthol sub-group; *Dinitroaniline orange*; *Para red*
Colour Index (1971) 12060, 12070; Herbst & Hunger (1997) 277

Oster

Purple
Synonym, variant or common name

See: ostrum.

Ostrum

Purple
Synonym, variant or common name

In classical times '*purpurissum*', purple, was a difficult to produce (and therefore highly prized) colour. The best and most pure purple was made from certain shellfish which were collected offshore from Tyre in Phoenicia and elsewhere in the Mediterranean, and thus gave name to the colour as Tyrian purple (*q.v.*), which Vitruvius (first century BC) calls *ostrum*. Vitruvius tells us that there was a variation in colour from blueish through to reddish purples depending upon where the shells were collected. *Ostrum's* prohibitive expense and use primarily for imperial trappings meant that it was rarely used in painting. However, Vitruvius recommends that if it is used it should be mixed with honey to prevent it drying out too quickly. *Ostrum* was probably used mainly for dyeing cloth. In fact Pliny (77 AD) says that a purple lake pigment was made by soaking purple cloth in water with chalk (*q.v.*; see the entry: cimatura). Alternative organic purples were made by mixing crushed chalk with plant dyes such as madder and woad (*qq.v.*). Heraclius (tenth–thirteenth century) also records '*Oster autem, cuius sanguinem qui pro colore purpurae temperatur … optimum in insola Cipri habentur … circumcisiae fuerint lacrimas in purpurem colorem emittunt*' ('The oster also, the blood of which is used for a purple colour … best are found in the island of Cyprus … cut them round, pound them, will give out drop of a purple colour … called oster' (tr. Merrifield, 1849)).

For a fuller discussion, see: Tyrian purple.

Indigoid group; Chalk; Dibromoindigo; Madder; *Tyrian purple*; *Woad*
Heraclius/Romano (10–13th cent/1996) III, liv; Merrifield (1849) I, 250; Pliny (1st cent AD/Rackham, 1952) XXXV.xxvi; Vitruvius (1st cent BC/Grainger, 1934) VII.xii.3

Ottemannite

Red
Generic compound

Ottemannite is tin sulfide mineral with composition β-Sn_2S_3. It occurs as red or red-grey crystals with metallic lustre. It was first found at Cerro Rico Mountain, Bolivia and is also found at Maria Teresa mine, Bolivia and Pirquitas mine, Argentina (Paar *et al.*, 2001). Ottemannite occurs in veins associated with volcanism and is usually found in association with other sulfide minerals such as marcasite, sphalerite and wurtzite (*qq.v.*). It is also related to the minerals berndtite, SnS_2, and herzenbergite, SnS (*qq.v.*). Mosaic gold (*q.v.*; Speleers, 1999), a synthetic tin sulfide pigment, is considered to take the hexagonal berndtite crystal structure; ottemanite is a higher temperature orthorhombic form.

Ottemannite has been identified on Francesco del Cossa's *S. Vincent Ferrer* by Smith *et al.* (1981).

Tin sulfides group; Berndtite; Herzenbergite; Marcasite; Sphalerite; Wurtzite; *Mosaic gold*
Paar *et al.* (2001); Smith *et al.* (1981); Speleers (1999)

Oxford ochre

Yellow
Synonym, variant or common name

A variety of yellow ochre (*q.v.*). Harley (1982) found various seventeenth century authors referring to 'English ochre', one of the earliest being Norgate (early seventeenth century). However, John Smith (1676) remarks that most comes from Shotover Hills near Oxford, England; this is therefore the origin also of 'Oxford ochre' a term which was only introduced in the nineteenth century. Salter (1869) describes it as 'semi-opaque, of a warm yellow colour and soft argillaceous texture, absorbent of water and oil'.

Ochre; *Yellow ochre*
Harley (1982) 89–90; Norgate/Thornton & McCain (early 17th C./1981); Salter (1869) 109; Smith (1676)

Oxide of chromium

Green
Synonym, variant or common name

See: chromium oxide.

Oxyacanthine

White
Generic compound

The colourless basic compound oxyacanthine, 6,6′,7-trimethoxy-2,2′-dimethyloxyacanthan-12′-ol, is a major component of the dye extracted from the root of *Berberis vulgaris* L. (Schweppe, 1992).
See: berberis.

Schweppe (1992) 440, 445

Oyster shell white

White
Synonym, variant or common name

Oyster shells were used as a white pigment in Japan, locally called *gofun* (*q.v.*). Further, according to Hall (1973) 'Oyster shell pigment, a fossiliferous form of limestone (like chalk), is a natural calcium carbonate that is finely ground for pigment use.'
See: shell white.

Calcium carbonates group; *Gofun*; *Shell white*
Hall (1973) 109

Ozark white

White
Synonym, variant or common name

According to Toch (1916), ozark white was a mixture of zinc oxide and lead sulfate. The product was highly controlled so that the proportions – approximately 60% zinc oxide and 40% lead sulfate – varied less than 2%. To manufacture this pigment, ore (unspecified) was mechanically mixed, analysed and the proportions adjusted if necessary before 'being mixed with the proper proportion of coal and antifluxing material (crushed silicious rock or mine screenings), is charged into furnaces […which are…] then sealed, allowing the temperature to rise to about 2300°F [1260°C], at which point it is held until the zinc and lead pass off together in the form of fume, which is conducted by means of suction fans through pipe-lines for a distance of about 500 feet'. Toch identifies this as a superior version of what he calls 'Standard Zinc Lead White'.
See: Freeman's white and zinc lead white.

Lead sulfates group; Zinc oxide; *Freeman's white*; *Zinc lead white*
Toch (1916) 39–41

P

Pabonazo

Red-Purple
Synonym, variant or common name

Pabonazo (*paonazo, pavonazo, paghonazo*), along with *violetto* and *morello* (from the the Latin for mulberry, *morum*) were used as terms to denote a purple colour. This may have been produced from kermes or cochineal insects and the preparation as a pigment by a process called *cimatura* (*qq.v.*). On the other hand this is also a term identified by Veliz (1986) as a carmine-red mineral pigment used in fresco. Carducho, in his *Diálogos de la Pintura* of 1633, specifies that there was an 'English' pabonazo and a 'salt' pabonazo; assuming that this was probably an earth pigment, pabonazo might then be an English ochre (*q.v.*). Salt pabonazo on the other hand seems to be equivalent to the '*pagonazzo di sale*' mentioned by Borghini (1584). Lomazzo (1584) further relates this term to '*morello di sale*' (at the same time drawing a distinction from '*morello di ferro*' and 'burnt Roman vitriol'), which Haydocke in his 1598 translation of Lomazzo describes as a 'rust of iron and salt'. Finally Merrifield (1849) discusses at some length the meaning of this term, suggesting that '*morello di sale*' was 'the sediment which subsides from rock-salt when it is purified', additionally linking it to the German term '*morellen salz*'.

The Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield) gives three contrasting recipes for *pavonazzo*, an orthographic variant term that seemingly refers to the same purple-red colour but which could be produced from distinct sources. In the first two formulations a plant extract is prepared: '*To make pavonazzo with the juice of herbs* Take thick pieces of [old] linen cloth … take roche alum and dissolve in boiling water and let cool. Soak rags in this water, wet well and dry in the shade; then take the juice of the plant gilosia [Merrifield: Erba gilosia, the Amaranthus Tricolor] and wet the linen rags many times in this juice, between each time let them dry in the shade. Keep them in a place open to the air … and when you wish to use the colour take a little piece of that linen, and put it to soak in a shell with gum water, and let it stand for the space of an hour; then press it out and paint with it […]. *To make a pavonazzo colour* Take blue flowers which grow in the corn when it blooms, and extract the juice, and then do as before directed for the other purple made with the pieces of linen, and it is done.' In the second, thermal alteration of an ochre is described: '*To make a pavonazzo colour*, *perfect for painting on walls* take yellow ochre, clean from all other mixtures, and put it into a vessel which will stand the fire, and set the vase with the ochre to bake in a brick or glass furnace; and know, that if you put it at the top of the furnace it will become of a red colour like vermilion. And if you put the vase at the bottom of the furnace in a place where it will have more heat, it will become of a fine pavonazzo colour, and you must let the vase remain in the furnace from the time that the fire is first lighted, until the furnace is emptied, when it will be done.' This appears to refer to a variant of iron oxide formed by thermal conversion of iron hydroxides.

Iron oxides and hydroxides group; Cochineal; Kermes; Lac ochre; *Cimatura*
Borghini (1584/edition of 1787) 174; Carducho (1633); Lomazzo/Haydocke (1584/1598); Merrifield (1849) clxxxvi–viii; Veliz (1986) 198, n 8

Pagonazzo di sale

Red
Synonym, variant or common name

See: pabonazo.

Paille de mil

Red
Synonym, variant or common name

Salter (1869) lists this, giving also the alternate term African cochineal. He is unspecific about the exact nature of it, unsure even that it derives from a cochineal-type insect (*q.v.*).

Cochineal; *African cochineal*
Salter (1869) 170–171

Paint green

Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997)

Palladian red

Red
Synonym, variant or common name

Seward (1889) apparently identifies chrome red (*q.v.*) in this pigment.

Chromates group; Lead chromate(VI) oxide; *Chrome red*
Seward (1889)

Palladian scarlet

Red
Synonym, variant or common name

Seward (1889) apparently identifies chrome red (*q.v.*) in this pigment.

Chromates group; Lead chromate(VI) oxide; *Chrome red*
Seward (1889)

PALLADIUM AMMONIUM CHLORIDE

Red
Generic compound

See: palladium red.

PALLADIUM AND PLATINUM GROUP

Variable
Group term

Two pigments belong to this general group, both are halides: a palladium ammonium chloride ('ammonia-perchloride of palladium' or 'palladium red') and potassium hexachloroplatinate(IV), $K_2[PtCl_6]$ (also known as potassium chloroplatinate), which may be associated with the rare pigment known historically as 'platina yellow'.

Salter (1869) also mentions a 'platinum blue' of unknown composition.

Palladium ammonium chloride; Potassium hexachloroplatinate(IV); *Palladium red*; *Platina yellow*; *Platinum blue*; *Potassium chloroplatinate*
Salter (1869)

PALLADIUM RED

Red
Synonym, variant or common name

The *Colour Index* (1971) lists an 'ammonia-perchloride of palladium' (CI 77790), stating that palladium red is a synonym. It would seem to be closely allied chemically to potassium hexachloroplatinate(IV).

Palladium and platinum group; Potassium hexachloroplatinate(IV)
Colour Index (1971) 77790

PALMATINE

Yellow
Generic compound

Palmatine, 5,6-dihydro-2,3,9,10-tetramethoxydibenzo[a.g]quinolizinium, a basic dyestuff, is, along with tetrahydropalmatine, the most widely distributed Berberis alkaloid. It is extracted from the rootbark of *Berberis vulgaris* L. and *Phellodendron amurense* Rupr. (Schweppe, 1992; *Merck Index*, 1996)

Berberis; Phellodendron
Merck Index (1996) 7126; Schweppe (1992) 444

PALYGORSKITE

White
Generic compound

Palygorskite is a hydrated magnesium aluminosilicate mineral with composition $(Mg,Al)_2[Si_4O_{10}](OH).4H_2O$, although Fe and K are often present as impurities. It belongs to the clay minerals group and is the principal member of the palygorskite sub-group (*qq.v.*; Bradley, 1940; Christ *et al*., 1969). It forms a series with sepiolite (*q.v.*), the pure Mg variety of the palygorskite clays. Palygorskite was first described by Savchenkov in 1862 from Palygorskaya (Ural Mountains, Russia) after which it is named; it is also known as attapulgite, after reported occurrences of the mineral at Attapulgus (Georgia, USA). Palygorskite occurs as soft earthy masses, fibrous aggregates or laths which are white when pure but which may be grey, pale blue, green or yellow when impurities are present. It forms most commonly from the hydrothermal alteration of magnesium silicate minerals and is found in igneous rocks, limestones, sediments and soils, often in association with sepiolite, talc, calcite, chlorite group minerals, dolomite, quartz and montmorillonite (*qq.v.*). Palygorskite is common worldwide and occurs at localities such as Enderby (Leicestershire, England), Tafraout (Morocco), Broken Hill (New South Wales, Australia), Field (British Columbia, Canada), Ariege (France), Tsumeb (Otavi, Namibia), Chihuahua (Mexico), Boudinar (Egypt) and Pima County (Arizona, USA). 'Mountain leather' is a fibrous felted form of palygorskite which consists of an entangled mass of fibrous crystals, giving the appearance and texture of fabric; calcite crystals are commonly found attached to the fibres.

Palygorskite and indigo are the principal components of Maya blue (*qq.v.*; Olphen, 1966; Littman, 1980, 1982; Torres, 1988). Mines for the clay have been described by Arnold and Bohor (1975) and the pigment in its geological context has been discussed and characterised by Isphording *et al*. (1998), José-Yacamán *et al*. (1996) and Polette *et al*. (2002).

Aluminium group; Chlorite group; Clay minerals group; Clay minerals group: palygorskite sub-group; Magnesium group; Sheet silicates group; Calcite; Dolomite; Indigo; Limestone; Maya blue; Montmorillonite; Quartz; Sepiolite; Talc
Arnold & Bohor (1975); Bradley (1940); Christ *et al*. (1969); Isphording *et al*. (1998); José-Yacamán *et al*. (1996); Littman (1980); Littman (1982); Olphen (1966); Polette *et al*. (2002); Torres (1988)

PANDIUS

Red
Synonym, variant or common name

Colour recipes for *pandius* are given in the mediaeval collection of recipes, the *Mappae Clavicula*, the term referring to a number of complex mixtures often including madder (*q.v.*) but sometimes other colours (Phillips, 1847; cf. Smith and Hawthorne, 1974, and Schweppe and Winter, 1997).

Madder
Phillips (1847); Schweppe & Winter (1997); Smith & Hawthorne (1974)

PANNETIER'S GREEN

Green
Synonym, variant or common name

Pannetier's green is a synonym for a chromium oxide hydrate pigment, viridian (*q.v.*), described as a 'sesquioxide of chromium prepared in a particular manner' by Riffault *et al*. (1874). The name derives from a Parisian colour maker who, along with his assistant Binet, first prepared it about 1838 (Church, 1901).

Chromium group; Chromium oxide hydrate; *Viridian*
Church (1901); Riffault *et al*. (1874) 563

PANSY GREEN

Green
Synonym, variant or common name

Pansy green is mentioned by Harley (1982) as a green dye made from the petals of violets.
See: iris green and sap green.

Harley (1982) 86

PAPER BLACK

Black
Synonym, variant or common name

According to the *Compendium* (1808; cf. Carlyle, 2001) this was 'burnt paper, ground finely'. Various authors in fact mention this pigment, including Borghini (1584) and later nineteenth century followers. Osborn (1845), for example, rather tiredly remarks that paper black is 'Of the nature of Vine-black; but much more

easy to grind. It is, however, tedious and wearisome to make; and though excellent, we are so rich in blacks'.
See: carbon-based blacks group, chars sub-group.

Carbon-based blacks group: chars sub-group
Borghini (1584/edition of 1787); Carlyle (2001) 469–470; *Compendium* (1808); Osborn (1845) 36–37

PAPER GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

PARA RED

Red
Synonym, variant or common name

The pigment known as para red is diazotised 2-chloro-4-nitroaniline combined with β-naphthol; it is a positional isomer of ortho-nitroaniline orange, both compounds containing an NO_2 substitution. The pigment was an early introduction, in 1885; however according to Herbst and Hunger (1997), because of a variety of deficiencies it has lost most of its significance as a pigment. Listed by the *Colour Index* (1971) as CI 12070/Pigment Red 1, para red has also been known under a variety of other names such as para toner and signal red; according to Heaton (1928), signal red was a 'variety of vermilionette' (*q.v.*). Two other closely related pigments with the common name 'para' designation are chlorinated para red (*Colour Index* CI 12085/Pigment Red 4) and parachlor red (CI 12090/Pigment Red 6); these are positional isomers of one another, both containing NO_2 and Cl substitutions (Keijzer, 1999).
See: azo pigments group: β-naphthol sub-group.

Azo pigments group: β-Naphthol sub-group; *Vermilionette*
Colour Index (1971) 12070; Heaton (1928) 384; Herbst & Hunger (1997) 279; Keijzer (1999)

PARACHLOR RED

Red
Synonym, variant or common name

See: para red.

PARACHRYSOTILE

White
Generic compound

Parachrysotile, along with orthochrysotile (*q.v.*), are the two orthorhombic polymorphs of the silicate mineral chrysotile (*q.v.*). They belong to the serpentine group (*q.v.*) of minerals and have the chemical composition $Mg_3Si_2O_5(OH)_4$ (Wicks and O'Hanley, 1998). Parachrysotile is also polymorphous with the monoclinic form clinochrysotile (*q.v.*) and has been found as white, red, green and yellow fibres in hydrothermally altered ultrabasic rocks such as those found in Cornwall (England) and Cyprus.

Magnesium group; Serpentine group; Silicates group; Chrysotile; Clinochrysotile; Orthochrysotile
Wicks & O'Hanley (1988)

PARAETONIUM WHITE

White
Synonym, variant or common name

In a description of natural colours, Vitruvius (first century BC) states that: 'Paraetonium white gets its name from the place where it is dug up.' Paraetonium is modern Mersa Matruh, NW Egypt. Pliny (77 AD) states that other localities producing similar material were on Crete and near Cyrene (now Shahhat, Libya); this latter locality is possibly a source for what is called in modern times tripoli, a form of diatomaceous silica. Wallert (1995a) has, however, made a tentative suggestion that Paraetonium refers to deposits of the lead carbonate mineral cerussite (*q.v.*).

Cerussite; *Tripoli*
Pliny (1st cent AD/Rackham, 1952) XXXV.xviii; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.3; Wallert (1995a)

PARAGONITE

White
Generic compound

Paragonite is a sodium aluminosilicate mineral with composition $Na_2Al_4[Si_6Al_2O_{20}](OH)_4$, although minor Ca, K, Mg and Fe may also be present. It belongs to the mica group of minerals and is closely related to muscovite (*qq.v.*), which contains potassium instead of sodium; only very limited solid solution exists between these two minerals and they are both known as 'white mica'. Paragonite is white when pure but may be pale yellow or green when impurities are present. It occurs as relatively soft scaly aggregates, fibrous masses, or thin cleavable platy crystals. The cleavage is related to the sheet-like structure of the mineral which consists of layers of $(Si,Al)O_4$ tetrahedra separated by Na and Al in octahedral sites (it is a dioctahedral mica as only selected octahedral sites are filled). Paragonite is found widespread, in many metamorphic rocks, hydrothermal veins and fine-grained sedimentary rocks. It often occurs in association with muscovite, quartz, actinolite, calcite and chlorite group (*qq.v.*) minerals and is known from localities such as Monte Campiano (Switzerland), Borgofrance (Piedmont, Italy), Miass (Ilmen Mountains, Russia), Broken Hill (New South Wales, Australia), Telemark (Norway) and Rhiw (Wales). See Rutley (1988), Deer *et al.* (1992) and Bailey (1984) for further discussion of this mineral.

The *Colour Index* (1971) describes Pigment White 20/26 as naturally occurring micaceous potassium aluminium silicates such as paragonite and muscovite.

Aluminium group; Chlorite group; Mica group; Sheet silicates group; Actinolite; Calcite; Muscovite; Quartz; Talc
Bailey (1984); *Colour Index* (1971) 77019; Deer *et al.* (1992) 294–295; Rutley (1988) 400

PARALAURIONITE

White
Generic compound

Paralaurionite is a monoclinic lead chloride hydroxide mineral with composition PbCl(OH). It is polymorphous with laurionite (*q.v.*), the orthorhombic form, and occurs most commonly as small white or colourless tabular or prismatic crystals, although pale yellow or green-yellow crystals may be encountered (Merlino *et al.*, 1993). It precipitates in the same environment as laurionite, as a secondary mineral forming in slag heaps associated with smelting activities. Paralaurionite is found at Laurion (Attica, Greece), from where it is named and has also been found at other mine locations in Cornwall (England), Tiger (Arizona) and Saxony (Germany).

Although the natural form of paralaurionite is not known as a pigment, its synthetic analogue, lead chloride hydroxide (*q.v.*), has been identified in a pigment context.

Lead group; Lead halides group; Laurionite; Lead chloride hydroxide
Merlino *et al.* (1993)

PARAREALGAR

Red-Orange
Generic compound

Compositionally pararealgar is an arsenic sulfide mineral (AsS), a polymorph of realgar which varies in colour from bright yellow to orange-yellow to orange-brown (Roberts *et al.*, 1980; cf. FitzHugh, 1997). It occurs in association with orpiment and realgar (*qq.v.*) and the latter is known to undergo light-induced conversion to pararealgar (Trentelman *et al.*, 1996).

Pararealgar has been found on a thirteenth century BC Egyptian papyri by Burgio and Clark (2000) where it is believed to occur as a degradation of realgar (orpiment was also present). It has also been identified, for example, by Green (1995) in Egyptian artefacts and on a sixteenth/seventeenth century European painting by Corbeil and Helwig (1995). Moreno *et al.* (1998) have also observed pararealgar on Tintoretto's *The Dreams of Men* (Detroit Institute of Art, USA).

Arsenic sulfides group; Alacranite; Dimorphite; Duranusite; Orpiment; Realgar; Uzonite
Burgio & Clark (2000); Corbeil & Helwig (1995); FitzHugh (1997); Green (1995); Moreno *et al.* (1998); Roberts *et al.* (1980); Trentelman *et al.* (1996)

PARATACAMITE

Green
Generic compound

Paratacamite is a copper hydroxide mineral, $Cu_2(OH)_3Cl$. It is one of four polymorphs along with atacamite, clinoatacamite and botallackite (*qq.v.*). It is named after its crystallographic relationship with atacamite, which itself is named after its type locality in the Atacam Desert, Chile. Paratacamite is found in association with atacamite and botallackite at Botallack mine, St Just in Cornwall, England. It is one of the secondary minerals which forms in the oxidising zone around copper deposits, and its structure is only stabilised by the presence of cations such as zinc replacing copper. The pure copper form generally adopts the more stable monoclinic clinoatacamite form. Zinc-containing paratacamite has also been termed 'anarakite' after its discovery by Adib and Otteman (1972) in the Kali-Kafi mine, Anarak Province, Iran. Atacamite and paratacamite have similar thermodynamic properties and may both form under closely related conditions. Sharkey and Lewin (1971) also determined that atacamite may recrystallise to paratacamite in aqueous solution at ambient conditions.

Riederer (1977a) found paratacamite as a green pigment used in the temple of Aphaia at Aegina, Greece. Daniel (1987), in the analysis of 21 reliefs and 13 sculptures of the Old Kingdom in the Louvre's Department of Egyptian Antiquities, found the green pigments to be either malachite (*q.v.*) or paratacamite. Gettens and Stout (1958) found paratacamite in wall paintings in the chapel of Kariye Çamii, Istanbul. Delbourgo (1980) identified paratacamite (and atacamite) in eighth century Buddhist wall paintings at Dunhuang. Kerber *et al.* (1972) have observed alteration of azurite (*q.v.*) to atacamite and paratacamite in Austrian murals dating from the thirteenth to the fifteenth centuries. Dei *et al.* (1998) have also found that paratacamite can be formed from azurite after certain conservation treatments.

However, it should be noted that Scott (2002) suggests that most references to paratacamite ought now be termed clinoatacamite where the pure copper member has been found. Additionally there are a number of other copper chloride minerals which occur in both natural and synthetic analogues (see entry for copper halides group for further information).

Copper group; Copper halides group; Atacamite; Azurite; Botallackite; Clinoatacamite; Malachite
Adib & Otteman (1972); Daniel (1987); Dei *et al.* (1998); Delbourgo (1980); Gettens & Stout (1958); Kerber *et al.* (1972); Riederer (1977a); Scott (2002); Sharkey & Lewin (1971)

PARIS BLUE

Blue
Synonym, variant or common name

Paris blue, along with Berlin blue and Prussian blue (*qq.v.*), can be found in German literature sources of the nineteenth and early twentieth centuries. The relationship between the three terms is somewhat complex; for more information, see: Berlin blue. In addition to describing Paris blue as 'a synonym for the violet-tinted kind of Prussian blue', Terry (1893) describes three compositions based on calcined mixtures of (a) sulfur, sodium carbonate, sodium silicate and sodium aluminate, (b) china clay, sodium sulfate, sodium carbonate, sulfur and charcoal, and (c) sodium carbonate, orpiment, 'gelatinous alumina hydrate', clay and sulfur; these appear likely to form ultramarine-related compounds (*q.v.*).

Hexacyanoferrate group; Ultramarine; *Berlin blue*; *Prussian blue*
Terry (1893) 68–69

PARIS GREEN

Green
Synonym, variant or common name

According to Fiedler and Bayard (1997), Paris green was synonymous with emerald green (*q.v.*; copper acetate arsenite). However, Zerr and Rübencamp (1906) list it as a mixture of 50–60 parts emerald green and 40–50 parts imperial green, imperial green (*q.v.*) being an emerald green-derived compound. Heaton (1928) also lists Paris green as a then-current term for a variety of emerald green. Terry (1893) comments that the term was particularly used in America.

Arsenic group; Copper group; *Emerald green*; *Imperial green*
Fiedler & Bayard (1997); Heaton (1928) 383; Terry (1893) 132; Zerr & Rübencamp (1906/1908) 212

PARIS RED

Red
Synonym, variant or common name

Ploss (1962) cites the fifteenth century German Amberger MS (Clarke MS 15) and the Nürnburg manuscript (Clarke MS 2320) which give recipes for Paris red which involve the use of scarlet dyed wool *abrrasura di scarletto* to make *Parizrot* or *Paresrot* (see discussion for *vloken* in entry for *madder* and also the entry: *cimatura*); he also states that from other early German manuscripts this colour appears to be from Brasilwood (*q.v.*). However, later sources give Paris red as a synonym for lead(II,IV) oxide (that is, 'red lead' or 'minium'; for example, Zerr and Rübencamp, 1906).

Brazilwood; Lead(II,IV) oxide; Madder; *Cimatura*
Ploss (1962) 53, 113; Zerr & Rübencamp (1906/1908) 257

PARIS WHITE

White
Synonym, variant or common name

Paris white was considered to be a high quality chalk (*q.v.*; for example, Terry, 1893). Heaton (1928) also indicates that this is the finest grade of chalk.

Chalk
Heaton (1928) 106; Terry (1893) 246

PARIS YELLOW

Yellow
Synonym, variant or common name

According to Zerr and Rübencamp (1906) Paris yellow was one of the forms of chrome yellow which contained white adjuncts such as baryte, china clay, diatomaceous earth and/or gypsum (*qq.v.*). Kühn and Curran (1986) also document this as a form of chrome yellow, additionally noting other related products under the terms new yellow, Baltimore yellow and American (chrome) yellow.

Lead chromates group; Baryte; Gypsum: *Baltimore chrome yellow*; *China clay*; *Chrome yellow*; *Diatomaceous earth*
Kühn & Curran (1986); Zerr & Rübencamp (1906/1908) 149

PARISIAN LAKE

Red
Synonym, variant or common name

Parisian lake is considered by Schweppe and Roosen-Runge (1986) to be a cochineal lake prepared by extraction of the dye with alum solution followed by precipitation with soda. Along with similar terms such as Florentine, Viennese, Venetian lake, it was probably fanciful in derivation.
See: cochineal.

Cochineal
Schweppe & Roosen-Runge (1986)

PARROT GREEN

Green
Synonym, variant or common name

According to Zerr and Rübencamp (1906), parrot greens were produced during the manufacture of emerald green (*q.v.*; copper acetate arsenite) by treating the washed emerald green in the precipitating tank ‘with a cold solution of sugar of lead of varying amount according as a more bluish or yellowish shade is required. This is slowly precipitated with the corresponding quantity of potassium bichromate in cold solution by stirring’. Additionally, commercial products are indicated to have been derived from emerald green with a proportion of baryte (0–50 parts to 100 of emerald green) and 10–20 parts ‘pale chrome yellow’ (*qq.v.*). (These authors also report several other emerald green derivatives or by-products, namely soda green, lime-arsenic green, imperial and neuwied greens (*q.v.*).) On the other hand the 1909 edition of Gentele’s *Lehrbuch der Farbenfabrikation* uses the name parrot green (and Mitis green) to designate a mixture of copper arsenite and copper acetate arsenite.

Two samples labelled ‘*minraalgroen*’ are in the nineteenth century Dutch Hafkenscheid Collection along with another labelled ‘*papegaaigroen*’ (‘parrot green’). Analysis of these has shown that they consist of artificial copper-arsenic compounds, tentatively identified as a ‘copper formo-arsenite’ (copper formate arsenite, *q.v.*) (Pey, 1987).

Copper arsenite group; Copper formate arsenite; *Chrome yellow*; *Emerald green*; *Mineral green*; *Mitis green*; *Neuwied green*
Gentele (1860) 262–263; Pey (1987); Zerr & Rübencamp (1906/1908) 219

PARSLEY

Green
Synonym, variant or common name

The juice of plants of the *Petroselinum* species, for example, *P. crispum* (Miller) A.W. Hill., has been described as producing a green pigment when combined with green earth (*q.v.*). The main dyestuffs produced are the flavonoids apigenin and luteolin. Merrifield (1849) gives two recipes for green from parsley; an example is that from *Experimenta de Coloribus* (1431, Clarke MS 2790) which describes how ‘to make a very deep and beautiful green, take the herb rue, or parsley, when fresh and mix it with a little verdigris (*q.v.*), and grind it upon a stone’.
See also: appian green and iris green.

Apigenin; Green earth; Luteolin; *Appian green*; *Iris green*; *Verdigris*
Merrifield (1849) 66

PASTA VERDE

Green
Synonym, variant or common name

See: paste green.

PASTE BLUE

Blue
Synonym, variant or common name

A form of Prussian blue (*q.v.*) supplied ‘in pulp form, without drying, for paper staining and the preparation of water paints’ (Heaton, 1928).

Prussian blue
Heaton (1928) 160

PASTE GREEN

Green
Synonym, variant or common name

A form of sap green is described in the Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849): ‘*31. How pasta verde is made*. Take the grains or berries of the buckthorn [*q.v.*] when they are quite ripe, and this will be about the end of September; let them soften for 7–8 days in a vase with water in which roche alum has been dissolved in the proportion of 1 oz of alum to 6 of the berries, and boil it well until nearly half the water is consumed; then cool it, strain through a linen cloth, put the part that is strained into pigs’ bladders, and dry them in the sun or smoke; and this is called “pasta di vesicha” ’.

Fan Chengda of the Chinese Song dynasty writes in his *Gui hai yu heng zhi* that ‘Mineral green comes from along the You River [… and …] is called malachite [*q.v.*]. There is also a type fragmented like clods of earth that is called paste green’ (cf. Yü, 1955).

Malachite; *Buckthorn*; *Sap green*
Merrifield (1849) II, 665; Yü (1955/trans. Silbergold & McNair 1988) 8

PASTE WHITE LEAD

White
Synonym, variant or common name

According to Heaton (1928), lead white (*q.v.*) was frequently ground in linseed oil by the pigment manufacturer rather than being supplied 'dry' to others; this was known as 'paste white lead'. The reasons seem to be due to health and safety issues. Typical composition (for example, from the British Engineering Standards Association, 1926, cf. Heaton) was 91–94% lead white and 6–9% linseed oil.

Lead carbonate hydroxide; *Lead white*
Heaton (1928) 80–81

Pastel

Blue
Synonym, variant or common name

This was the term used in early French literature to describe the best type of woad dye paste (*q.v.*; Bayer, 1970; cf. Schweppe, 1997) and eventually came to mean the plant itself in French. The term meaning a sort of crayon came about as woad paste was mixed with calcium carbonate and gum and formed into a stick for drawing (Balfour Paul, 1998).

Indigo; *Woad*
Balfour Paul (1998) 258; Bayer (1970); Schweppe (1997)

Patent green

Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*), though it would seem to relate wholly to the 'improved' low-alkali version of Scheele's green produced by Parker in 1812 and patented by him. Parker proposed his product for a number of applications including house and ship painting, claiming that it would be less affected by salt water (Parker, 1812).

Emerald green; *Scheele's green*
Fiedler & Bayard (1997); Parker (1812)

Patent yellow

Yellow
Synonym, variant or common name

This is a synonymous term given by Heaton (1928) for Turner's yellow
See: lead chloride oxide.

Heaton (1928) 383

Pattinson's white

White
Synonym, variant or common name

Salter (1869) describes this pigment as an unusual form of lead white (*q.v.*), stating: 'the whites of lead are carbonates of that metal with two exceptions:- Flemish white or the sulphate, and Pattison's white or the oxychloride'. He further describes the preparation from 'a mixture of chloride and oxide of lead, formed by precipitating a solution of chloride of lead with soda, potash, lime, or baryta, in the caustic or hydrated state'.

The pigment is named after Hugh Lee Pattinson (1796–1858), an English metallurgical chemist who patented a process to desilverise and purify lead in 1833 (British Patent 6497). According to Thorpe's *Dictionary of Applied Chemistry* (1946), the value of Pattinson's process as a means of purifying lead was shown by the fact that lead used for making lead white was frequently 'Pattinsonised', even though the amount of silver present was too small to repay the cost of recovery.

Alternate spellings of the name encountered by Carlyle (2001) are 'Pattison' and 'Patterson'. Zerr and Rübencamp (1906) describe 'Pattinson's white lead' as $PbCl_2.PbO$, made by rapid precipitation of a hot concentrated solution of lead chloride with caustic lime. The pigment is listed (as 'lead oxychloride') by Heaton in the early twentieth century, though as an obsolete or rarely used one.

Lead chloride oxide; *Lead white*
Carlyle (2001) 516; Heaton (1928) 383; Salter (1869) 67–68, 73–74; Zerr & Rübencamp (1906/1908) 134–136

Paul Veronese green

Green
Synonym, variant or common name

Veronese green appears in France to have originally referred to emerald green (*q.v.*). When describing the latter, Martel noted in 1860 that 'By the French it is called Paul Veronese Green.' Salter, ten years later, stated that French Veronese green was 'often adulterated with arsenic to an enormous extent, which interferes with its transparency, mars its beauty, and renders it of course rankly poisonous'.

Copper arsenite group; Copper acetate arsenite; *Emerald green*
Martel (1860) 28; Salter (1869) 268

Pavonazzo

Red-Purple
Synonym, variant or common name

See: pabonazo.

Payen's blue

Blue
Synonym, variant or common name

According to Bersch (1901), Payen's Mountain blue is a mixture of copper hydroxide and calcium carbonate. It was said to be prepared by adding calcium chloride to a solution of copper sulfate, then adding dilute calcium hydroxide solution to give a green copper chloride precipitate. A potassium carbonate/calcium hydroxide solution was then added to decompose the copper chloride and then co-precipitate copper hydroxide and calcium carbonate. It was supplied as a paste. It is also listed by the *Colour Index* (1971) under CI 77404.

The German author Rose (1916) also refers to Payen (1823), stating that he developed a method of producing cobalt blue (*q.v.*) by evaporating a mixture of the solutions of ammonia alum and cobalt nitrate, then calcining the resulting mixture.

Calcium carbonates group; Copper oxides and hydroxides group; *Cobalt blue*
Bersch (1901) 228; *Colour Index* (1971) 77404; Rose (1916) 286

Payne's grey

Grey
Synonym, variant or common name

Payne's grey (or 'gray') was similar to the product known as neutral tint, but with differing proportions of the compound pigments (typically indigo or ultramarine, a carbon-based black and sepia, ochre or a red lake, *qq.v.*). It is listed in various nineteenth century sources such as Salter (1869). Heaton (1928) includes it among a list of by then obsolete or rarely used terms; he gives the composition as a mixture of 'black, ultramarine and ochre'.

Carbon-based blacks group; Indigo; Ochre; Sepia; Ultramarine; *Neutral tint*
Heaton (1928) 383; Salter (1869) 378–379

PEACH BLACK

Black
Synonym, variant or common name

Chars of various fruitstones have been used as pigments, notably those formed from peach, cherry and almond stones as well as nut shells (Winter, 1983). This was often called Peachstone black.
See: carbon-based blacks group: chars sub-group.

Carbon-based blacks group: chars sub-group
Winter (1983)

PEARL SPAR

White
Synonym, variant or common name

See: dolomite.

PEARL WHITE

White
Synonym, variant or common name

Dossie (1764) states that this is 'the powder of pearls, or the finer parts of oister shells'; actual pearls were apparently usually too expensive and no better than oyster shells. He also provides a method of preparation: 'take the oisters as they are found on the sea-coast, calcined by the sun; or otherwise to dry fresh ones by the fire till they will powder easily, (avoiding, however, carefully such heat as may in the least burn them, or change their colour;) to scrape off from these shells all the outward or other parts that may not be of the most perfect whiteness; and to levigate them well with water on the stone, and wash the powder over till thoroughly fine'. Field (1835) states that 'There are two pigments of this denomination: one falsely so-called, prepared from bismuth, which turns black in sulphuretted hydrogen gas or any impure air, and used as a cosmetic; the other, prepared from the waste of pearls and mother-of-pearl, which is exquisitely white, and of good body in water, but of little force in oil or varnish; it combines however with all other colours, without injuring the most delicate, and is itself perfectly permanent and innoxious:- witness Cleopatra's potation of pearls.' Less poetically, Salter (1869) gives pearl white as 'an insoluble basic nitrate of bismuth, a pearly white powder of loose texture' adding that 'Another preparation under this name, and now obsolete we believe as a pigment, was obtained from mother-of-pearl.' Heaton (1928) lists pearl white as an obsolete or rarely used pigment based on 'bismuth oxychloride'.
See: bismuth white, bismuth chloride oxide, bismuth nitrates group, magistery of bismuth and shell white.

Bismuth nitrates group; Calcium carbonates group; Bismuth chloride oxide; *Bismuth white*; *Magistery of bismuth*; *Mother-of-pearl*; *Shell white*
Dossie (1764) I-137; Field (1835) 70; Heaton (1928) 383; Salter (1869) 78–79

PEAT

Brown
Generic compound

Peat is waterlogged, organic-rich soil. Decomposition of peats forms humic earths (*q.v.*). Fossilisation of peat horizons leads to extreme compaction and over geological time and elevated temperatures lignites (low grade coals) form and, eventually, bituminous and anthracitic coals (*qq.v.*). Pigments associated with peat, but more particularly with humic earths and lignites, are discussed under entries for these substances and also under Vandyke brown.

Earth pigments group; Hydrocarbons group; Coal; Humic earth; *Vandyke brown*

PEGANUM HARMALA

Red
Synonym, variant or common name

According to Salter (1869), *Peganum harmala* 'The seeds of which afford a red colour, has been investigated by the French, but described as inferior to existing reds both in brilliancy and stability.' Seeds of *Peganum harmala* L. (Zygophyllaceae), 'Syrian rue', yield a dye ('Turkish red' or 'Syrian red') long used in textiles that contains β-carboline alkaloids, mostly harmine, as well as harmaline, harmalol, harman, peganine, isopeganine, dipegene, vasicinone and deoxyvasicinone.

Salter (1869) 171

PÉLIGOT BLUE

Blue
Synonym, variant or common name

The pigment Péligot blue, named after its inventor the French chemist Eugène-Melchior Péligot (1811–92), was, according to Riffault *et al.* (1874), a 'blue hydrated oxide of copper'. The recipe given by those authors – where copper sulphate is treated with an excess of ammonia and then precipitated by potassium or sodium carbonate – has been duplicated by Scott (2002), who found it produced a mixture of two basic copper(II) sulfates, synthetic analogues of brochantite (copper sulfate hydroxide) and posnjakite (copper sulfate hydroxide hydrate; *qq.v.*). Terry (1893) also discusses this pigment, providing a similar recipe to that above (except for precipitation by ammonia) as well as two others – the first by adding excess water to 'a slightly ammoniacal solution of copper nitrate', the second by calcining silica (73 parts), copper oxide (16 parts), lime (8 parts) and soda (3 parts) at 'a temperature not much exceeding 800°F' (about 420 to 430°C).

Péligot blue first appeared on the market as a pigment around 1858 (Scott).

Copper sulfates group; Brochantite; Posnjakite
Riffault *et al.* (1874) 261; Scott (2002) 166; Terry (1893) 41

PENLEY'S NEUTRAL ORANGE

Yellow-Orange
Synonym, variant or common name

A term given by Salter (1869) as a form of neutral orange.
See: neutral orange.

Neutral orange
Salter (1869) 253–255

PENNANTITE

Green
Generic compound

Pennantite is a manganese-rich aluminosilicate mineral, with ideal composition $Mn_{10}Al_2[(Si,Al)_8O_{20}](OH)_{16}$, which belongs to the chlorite group (*q.v.*). The manganese content varies widely as the mineral forms solid solution series with other members of the chlorite group; impurities such as Mg, Li, Zn, Cr and Ti may also be present. Pennantite was first described by Smith *et al.* in 1946 and is named after the Welsh mineralogist T. Pennant

(1726–98). It forms as an alteration product of manganese minerals and may also occur in low-grade metamorphic rocks. Pennantite has similar properties to the other chlorites, occurring as flexible tabular crystals, foliaceous masses and aggregates; these are generally green but may be red-orange as the composition varies (Bailey, 1988; Deer *et al*., 1992). Pennantite is known from localities such as the Benallt mine (Wales), Ushkatyn (Kazakhstan; see Kayupova, 1965) and Varmland (Sweden). In order to simplify the nomenclature of the chlorites, it has been suggested (as reported by Deer *et al*., 1992) that the term pennantite be applied to any manganese-rich chlorite, with the terms clinochlore and chamosite (*qq.v.*) used to refer to Mg- and Fe-rich varieties.

Chlorite group; Earth pigments group; Silicates group; Chamosite; Clinochlore
Bailey (1988); Deer *et al*. (1992) 333; Kayupova (1965); Smith *et al*. (1946)

PEORI

Yellow
Synonym, variant or common name

See: piuri and Indian yellow.

PERICLASE

White
Generic compound

Periclase is a white magnesium oxide mineral with ideal composition MgO, although impurities of iron, manganese or zinc may be present. It is also known as native magnesia and iron-bearing (5–10% FeO) samples may be called ferripericlase. Periclase was first described by Scacchi in 1840 from Monte Somma (Vesuvius, Italy) and is a comparatively rare mineral. It occurs as white cubes and octahedra, as granular aggregates, or as disseminated grains; iron-rich samples are commonly yellow-brown. Periclase forms during the contact metamorphism of dolomite-bearing rocks and Mg-rich limestones by the dissolution of dolomite and the associated formation of calcite (*qq.v.*) and carbon dioxide. It readily alters to brucite in the presence of water and subsequently to hydromagnesite (*qq.v.*). Periclase is thus often found in association with these minerals, as well as forsterite and the serpentine group (*qq.v.*) of minerals (such as at Monte Somma, Vesuvius, Italy; Crestmore, California, USA; Varmland, Sweden; Saxony, Germany). See Dana (1932), Deer *et al*. (1992) and Rutley (1988) for further discussion of this mineral.

‘Magnesia’ has been identified by Newton and Sharp (1987) in certain plasters, introduced with the dolomite used. The synthetic analogue for periclase, magnesium oxide, generally manufactured from limestone starting materials is used as a paint extender.

Magnesium group; Serpentine group; Brucite; Calcite; Dolomite; Forsterite; Hydromagnesite
Dana (1932) 479; Deer *et al*. (1992) 532–533; Newton & Sharp (1987); Rutley (1988) 259

PÉRIGORD ORANGE

Orange
Synonym, variant or common name

This is an ochre (*q.v.*) from Thiviers in Périgord, also called *gres de Périgord.* This was a potter’s colour recommended by Burton (1907) for painting in fresco and tempera. A sample of this has been found in a paintbox of J. Southall (1861–1904; Dunkerton, 1980).

Ochre
Burton (1907); Dunkerton (1980)

PERINONE PIGMENTS

Red-Orange
Synonym, variant or common name

The perinones, which are polycyclic pigments, are obtained from naphthalene-1,4,5,8-tetracarboxylic acid or its monoanhydride. The earliest commercial product was a yellowish red vat dye, a mixture of two isomers, which was discovered in 1924 by Eckert and Greune at Hoechst AG; it was not until 1950 that these compounds found recognition as pigments, with similar properties to perylene pigments (*q.v.*). At present, only the two isomers mentioned and their mixture are used commercially, providing orange to bordeaux shades (Herbst and Hunger, 1997). They are listed in the *Colour Index* (1971) as CI 71105/Pigment Orange 43 (‘Perinone Orange’) and 71100/Pigment Red 194; the former has found widespread use in paints, the latter less so.
See: polycyclic pigments group: perylene/perinone sub-group.

Polycyclic pigments group: Perylene/Perinone sub-group
Colour Index (1971) 71100, 71105; Herbst & Hunger (1997) 485–489

PERKIN’S MAUVE

Purple
Synonym, variant or common name

See: mauve.

PERMALBA

White
Synonym, variant or common name

Permalba is a trade name of the firm of F. Weber in the United States for a range of prepared artists’ paints. Originating in 1853 as Scholz and Co., the company evolved through a series of partnerships to become F. Weber and Co. in 1887 under Frederick Weber. ‘Original Permalba White’ was first formulated in 1921, being described as ‘a nontoxic, opaque, white oil paint with smooth working qualities’. Heaton (1928) lists Permalba as a then-current term for a pigment composed of titanium white (*q.v.*).

Titanium white
Heaton (1928) 383

PERMANENT BLUE

Blue
Synonym, variant or common name

Standage, writing in 1887, identifies this as ‘a pale ultramarine [*q.v.*] with cobalt hue’. The term was still current when Heaton compiled his list of pigment synonyms in 1928. Mayer (1991), however, says it is also applicable to an ‘organic pigment’ without specifying which.

Ultramarine
Heaton (1928) 383; Mayer (1991) 53; Standage (1887)

PERMANENT CARMINE

Red
Synonym, variant or common name

According to Mayer (1991), this is a common name for a naphthol AS-D azo pigment.
See: azo pigments group: naphthol AS sub-group.

Azo pigments group: Naphthol AS sub-group
Mayer (1991) 53

PERMANENT CRIMSON

Red
Synonym, variant or common name

Carlyle (2001) notes that different nineteenth century artists' colourmen recorded this pigment to be either derived from alizarin or a variety of rose madder (*qq.v.*).

Alizarin; Madder; *Rose madder*
Carlyle (2001) 506

PERMANENT GREEN

Green
Synonym, variant or common name

Eibner (1909) noted that *permanentgrün* and *Viktoriagrün* (both German terms) were mixed colours comprised of hydrated chromium oxide (viridian) with zinc yellow and sometimes barium sulfate (*qq.v.*). This produces a less saturated and more opaque colour which is more stable than viridian and in French was also called *verts solides* (Coffignier, 1924). Coffignier groups this under the term Victoria green (*q.v.*). Newman (1997) states that this term today more commonly applies to mixtures based on phthalocyanine green.

Sonoda (1999) has identified two azo compounds – CI Pigment Yellows 1 and 3 (CI 11680/11710) – in a sample of Winsor & Newton 'Griffin' colour labelled 'Permanent green light' purchased in 1986.

Azo pigments group; Phthalocyanine group; Barium sulphate; *Victoria green*; *Viridian*; *Zinc yellow*
Coffignier (1924) 457; *Colour Index* (1971) 11680/11710; Eibner (1909); Newman (1997); Sonoda (1999)

PERMANENT MAUVE

Purple
Synonym, variant or common name

Although permanent mauve is most frequently treated as manganese phosphate, the terminology is actually somewhat more confused. Carlyle (2001) found that Winsor & Newton listed both permanent violet and permanent mauve in 1892, stating in their 1896 catalogue that the former was 'phosphate of manganese'. However, about 1898, Reeves list permanent mauve as synonymous with permanent violet and that it was made with 'a combination of alizarin' (*q.v.*). Moreover, according to Standage (1883), permanent mauve was 'a violet toned variety of French ultramarine' (*q.v.*). Therefore the presence of alizarin (possibly as a lake) and synthetic ultramarine may also be anticipated. This term, along with permanent violet, was still current when Heaton compiled a list of pigment terms and compositions in 1928, both being listed there simply as manganese phosphate.

Manganese phosphates group; Alizarin; Ultramarine
Carlyle (2001) 159, 503; Heaton (1928) 383; Standage (1883)

PERMANENT VIOLET

Purple
Synonym, variant or common name

See: permanent mauve.

PERMANENT WHITE

White
Synonym, variant or common name

Permanent white might refer to a number of pigments other than those based on lead: synthetic barium sulfate or titanium dioxide, for example. Carlyle (2001) found a Winsor & Newton catalogue of 1896 indicated that this was zinc white in oil and the finer version known as Chinese white (*qq.v.*) in watercolour. However, Salter (1869) gives this as a synonym for his constant white, stated to be both the mineral baryte and its synthetic analogue barium sulfate (*qq.v.*).

Barium sulfate; Baryte; *Chinese white*; *Constant white*; *Titanium dioxide white*; *Zinc white*
Carlyle (2001) 514, 516; Salter (1869) 65

PERMANENT YELLOW

Yellow
Synonym, variant or common name

A term associated with a several yellow inorganic pigments. The review of chromate pigments by Kühn and Curran (1986) lists permanent yellow as a synonym for zinc yellow, whereas Heaton (1928) lists it as a then-current term for a pigment based on 'barium chrome' (barium chromate, *qq.v.*). According to a *Composition of Pigments* list given in a Winsor & Newton catalogue of 1896, permanent yellow was a preparation of 'Chromate of Barium and Zinc White' (cf. Carlyle, 2001).

Zinc chromates group; Barium chromate(VI); *Zinc white*; *Zinc yellow*
Carlyle (2001) 526; Heaton (1928) 383; Kühn & Curran (1986)

PERMANENTGRÜN

Green
Synonym, variant or common name

See: permanent green.

PERSIAN BERRIES

Yellow
Synonym, variant or common name

This term is generically applied to lake pigments based on dye derived from *Rhamnus* species (*q.v.*), presumably from those indigenous to the former area of Persia. Bristow (1996b) cites the records of the English firm of Berger where 'Turkey berries' (from İzmir – formerly Smyrna – or Aleppo) and 'Persian berries' were used for production of Dutch pink and brown pink (*qq.v.*); he tentatively identifies the plant source as *R. sacatalis*, *R. amygdalinus* and/or *R. oleiodes*.

Flavonoids group; Rhamnus; *Brown pink*; *Dutch pink*; *Yellow lake*
Bristow (1996b)

PERSIAN BLACK

Black
Synonym, variant or common name

According to Brommelle (1964), an artist reported using Persian black to the Russell and Abney committee in 1886. Its composition appears to be unknown.

Brommelle (1964)

PERSIAN GREEN

Green
Synonym, variant or common name

According to Zerr and Rübencamp (1906), Persian green was a mixture of 75 parts emerald green, 45 parts imperial green, 20–30 parts baryte and 10–20 parts 'pale chrome yellow' (*qq.v.*).

Baryte; *Chrome yellow*; *Emerald green*; *Imperial green*
Zerr & Rübencamp (1906/1908) 222

PERSIAN GULF OXIDE

Red
Synonym, variant or common name

See: Persian red.

PERSIAN RED

Red
Synonym, variant or common name

This term should probably refer to a natural red ochre (ochres coloured primarily by hematite; *qq.v.*) derived from commercially important deposits which exist near the Persian Gulf. Mayer (1991) considers that the term was used for a natural ochre, however it was subsequently also applied to a synthetic iron oxide pigment (Buxbaum, 1998). Standage (1887) notes: 'Beside the Persian red obtained from ochres, there is another which is a chromate of lead' and Heaton (1928) lists Persian red as a then-current term for a 'chrome red' (*q.v.*). This is essentially reiterated by Schiek (1973), though he lists Persian red among older names for chrome orange, while the *Merck Index* (1996) lists it as a synonym for lead chromate(VI) oxide (*qq.v.*). Kühn and Curran (1986) also list Persian red as an older term for basic lead chromate (lead chromate(VI) oxide) in their discussion of chrome red and chrome orange pigments.

Hematite; Lead chromate(VI) oxide; Ochre; *Chrome orange*; *Chrome red*; *Red ochre*
Buxbaum (1998) 84; Heaton (1928) 383; Kühn & Curran (1986); Mayer (1991) 53; *Merck Index* (1996); Schiek (1973); Standage (1887)

PERYLENE PIGMENTS

Red
Synonym, variant or common name

Perylene vat pigments are nearly all *N,N'*-substituted perylene-3,4,9,10-tetracarboxylic diimides (Allan Fisher, 1973). They are encompassed by *Colour Index* (1971) reference numbers 71129, 71130, 71135, 71140 and 71145, with colour descriptions ranging from red and scarlet through vermilion and bordeaux shades. CI 71129 and 71130 were discovered by Kardos in 1912–13, 71135 and 71140 by Friedlander in 1919; however, perylene pigments were not generally utilised until after 1950 (Herbst and Hunger, 1997). Mayer (1991) lists perylene maroon and de Keijzer (1988) lists perylene orange as used in artists' pigments. See: polycyclic pigments group: perylene/perinone sub-group.

Polycyclic pigments group: Perylene/Perinone sub-group
Allan Fisher (1973); *Colour Index* (1971) 71129, 71130, 71135, 71140, 71145; Herbst & Hunger (1997) 476–484; Keijzer (1988); Mayer (1991) 53

PHELLODENDRINE

Yellow
Generic compound

Phellodendrine is a basic dyestuff extracted from the wood of *Phellodendron amurense* Rupr. (Schweppe, 1992).

Phellodendron
Schweppe (1992) 442

PHELLODENDRON

Yellow
Common generic composite

The 'Amur cork tree', *Phellodendron amurense* Rupr. (Rutaceae), which contains high levels of berberine as well as phellodendrine, magnoflorine and palmatine has been noted by several authors, notably Gibbs and Seddon (1998), in the context of colouring pages of the Diamond Sutra from Dunhuang, China. This dyestuff has also been identified by Shimoyama *et al.* (1995) in *Ukiyo-e* prints. Additionally called *huangbo* as well as yellow wood in Beijing, according to Yü (1955).

Berberine; Magnoflorine; Palmatine; Phellodendrine
Gibbs & Seddon (1998); Shimoyama *et al.* (1995); Yü (1955/trans. Silbergold & McNair, 1988) 14

PHLOGOPITE

White
Generic compound

Phlogopite is a potassium, ferro-magnesian aluminosilicate mineral with ideal composition $K_2(Mg,Fe)_6[(Si_6Al_2)O_{20}](OH,F)_4$. It was described by Breithaupt in 1841 and belongs to the mica group, forming a series with biotite (*qq.v.*), the iron-rich member; phlogopite refers to Mg-rich specimens. It occurs as scaly aggregates or pseudohexagonal tabular crystals which cleave into thin lamellae. It is commonly brown-red, but varies from almost colourless to green or dark brown due to variations in the Mg:Fe ratio. Phlogopite is less common than biotite but is found in many basic igneous, metamorphic and hydrothermally altered rocks worldwide, often in association with diopside, calcite, augite, dolomite, magnetite and epidote (*qq.v.*). It may also be decomposed to form montmorillonite or vermiculite (*qq.v.*). Phlogopite is known from areas such as Badakshan (Afghanistan), Antwerp (New Jersey, USA), Lake Baikal (Russia), Valais (Switzerland), Kimberley (Western Australia), São Paulo (Brazil), Ariege (France) and Falmouth (England). Several polymorphs of phlogopite exist, caused by different stacking sequences of the internal $(Si,Al)O_4$ layers, separated by complete layers of K, Mg and Fe cations (a trioctahedral mica): the single repeating layered structure (1M monoclinic) is the most common, although two-layered monoclinic (2M), three-layered triclinic (3T) and one-layered disordered (1M*d*) structures are also known. This mineral is further described by Deer *et al.* (1992), Rutley (1988), Bailey (1984) and Rayner (1974).

The *Colour Index* (1971) mentions naturally occurring micaceous potassium aluminium silicates in the description of Pigment White 20/26.

Aluminium group; Iron group; Magnesium group; Mica group; Sheet silicates group; Augite; Biotite; Calcite; Diopside; Dolomite; Epidote; Magnetite; Montmorillonite; Vermiculite
Bailey (1984); Breithaupt (1841); *Colour Index* (1971) 77019; Deer *et al.* (1992) 298–307; Rayner (1974); Rutley (1988) 400–401

PHOENICOCHROITE

Red
Generic compound

Phoenicochroite is a relatively soft red lead chromate(VI) oxide mineral with composition $PbCrO_4.PbO$. It was first described by Williams *et al.* (1970) and is closely related to crocoite (*q.v.*), with which it is often found. It is a rare mineral, associated with deposits of lead ore and found at only a few localities worldwide including the Beresovsk gold mines (Russia), Strathclyde (Scotland), Tonopah, (Arizona, USA), Saxony (Germany) and Dundas (Tamania).

Burnstock *et al.* (2003) in their recent examination of yellow chromium-based pigments from archival sources, identified phoenicochroite in several pigment samples, either on its own or in combination with crocoite, often extended with a small amount of quartz, gypsum or cerussite (*qq.v.*). This is most likely to be the synthetic form, lead chromate(VI) oxide (*q.v.*). This formulation is one of the compositions given for chrome orange and chrome red pigments, the other being lead chromate hydroxide (*qq.v.*), $PbCrO_4.Pb(OH)_2$ (for example, Heaton, 1928; Schiek, 1973; Kühn & Curran, 1986).

Chromates group; Lead chromates group; Cerussite; Crocoite; Gypsum; Lead chromate hydroxide; Lead chromate(VI) oxide; Quartz; *Chrome orange*; *Chrome red*
Burnstock *et al*. (2003); Heaton (1928) 380; Kühn & Curran (1986); Schiek (1973); Williams *et al*. (1970)

PHOSGENITE

White
Generic compound

Phosgenite is a lead chloride carbonate mineral of composition $Pb_2(CO_3)Cl_2$ with a variable colour (white, grey, brownish yellow, greenish white, or pinkish white due to the presence of impurities (Rutley, 1988)). It is often found in association with cerussite laurionite (*qq.v.*).

Satoh *et al*. (1994) identified laurionite and phosgenite in a fifteenth to fourteenth century BC glass kohl bottle from Al-Tur, South Sinai, Egypt. Walter (1999) has demonstrated how laurionite and phosgenite can be produced using wet chemistry to form white powders which were added to other products to make Egyptian cosmetics.

Lead carbonates group; Lead halides group; Cerussite; Laurionite
Rutley (1988) 308–309; Satoh *et al*. (1994); Walter (1999)

PHTHALOCHROME GREEN

Green
Synonym, variant or common name

According to Buxbaum (1998), phthalochrome green is a composite pigment based on a chrome yellow and a phthalocyanine blue (*qq.v.*).

Phthalocyanine group; *Chrome yellow*
Buxbaum (1998) 94

PHTHALOCYANINE BLUE

Blue
Synonym, variant or common name

See: phthalocyanine group.

PHTHALOCYANINE GREEN

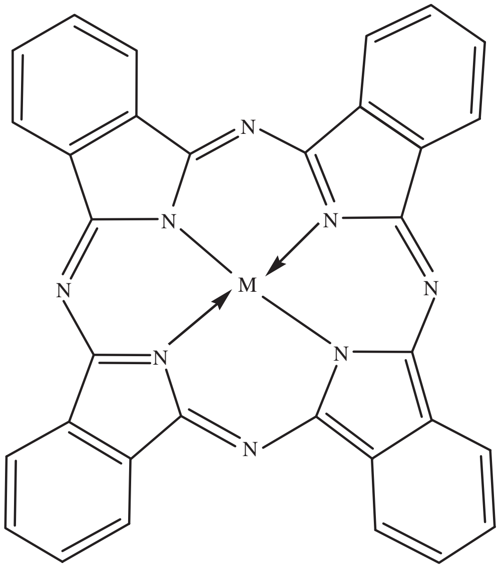
Green
Synonym, variant or common name

See: phthalocyanine group.

PHTHALOCYANINE GROUP

Blue-Green
Group term

The phthalocyanines (‘Pcs’) form a large group of synthetic organic macromolecules widely used as pigments from the third decade of the twentieth century. Pcs, as macrocyclic ligand complexes, are classed alongside the porphyrins (a group including chlorophyll and hemoglobin, *qq.v.*) with which they have much in common including the core porphine structure. In common with the other porphyrins the central void can chelate a metal atom while other substitutions may take place around the periphery; for phthalocyanines the principal metal ion is copper, the peripheral substituents chlorine and bromine.



M = copper, or hydrogen for the metal free form

As a result of the structure of phthalocyanine many substitutions can be achieved and at least 70 metal phthalocyanines have been prepared; further, as a result of the 16 reactive sites on the four benzene units, over 5000 further compounds have also been made. Polymorphism has been widely recognised in these compounds with the discovery of α, β, γ, δ, π, ρ, R and ε-crystal forms of copper and other metal phthalocyanines; however, few of these have found substantial use as pigments. In older literature ‘Pc’ is generally used to designate phthalocyanine with, in addition, the metal used as a prefix – for example, ‘Cu Pc’; metal-free Pcs may be given as ‘H_2 Pc’ or just ‘Pc’. However, to reflect the complexity of substitution a more complex nomenclature is now used in the scientific literature: a-$(L)_n$MPc-$n\&p$-S, where *a*, L and M are, respectively, axial (a) ligands (L) (such as Cl^-; HO^-; O^-; F^-; C_nO^-; $(C_n)_3SiO^-$) attached to central cation (M), Pc is phthalocyanine (or NPc, naphthophthalocyanine), *n&p* are the number and position of the ring substituents (with t = tetra, op = octa-peripheral and onp = octa-nonperipheral) and S is the benzo-substituent. Non-peripheral substitution can greatly influence the energy levels of the molecular orbital and hence the absorption spectrum. For example, electron-donating groups such as alkoxy moieties (for example, CuPc-*onp*-OC_n) cause a bathochromic (red) shift whereas peripheral substitution generally has little effect (Kobayashi *et al*., 1994; McKeown, 1998).

Phthalocyanines constitute one of the earliest classes of synthetic N_4 macromolecules prepared, being generally obtained by the interaction of phthalonitrile with metal halides. Synthesis is described, for example, by Baumann *et al*. (1956) and Sanielevici *et al*. (1961); modern pigmentary production is given by Herbst and Hunger (1997).

The phthalocyanine literature is consistent in describing two early putative Pc syntheses: in 1907, Braun and Tcherniac at the South Metropolitan Gas Co. in London found a blue substance after heating *o*-cyanobenzamide which was probably Pc, and during 1927 Diesbach and von der Weid at the University of Fribourg, in attempting to make nitriles of benzene by reacting *o*-dibromobenzene with cuprous cyanide, obtained a blue product which was probably Cu Pc. However, it was an accidental discovery in 1928 at the Grangemouth works of Scottish Dyes Ltd during the preparation of phthalimide from phthalic anhydride and ammonia of a blue impurity (probably Fe Pc) which directly led to the recognition and devlopment of Pcs. The first Pc patent (BP 322,169) was to Dandridge, Drescher and Thomas of Scottish Dyes in 1929, while investigations over the period 1929–33/4 by R.P. Linstead at the University of London determined the structure of Pc. The term 'phthalocyanine' (from Greek, *naptha* (rock oil) and *cyanine* (dark blue)) was first coined by Linstead in 1933. ICI announced the pigment in 1935 (*New York Times,* 25 Nov. 1935) as 'Monastral fast blue'. IG Farbenindustrie began to produce Cu Pc in 1936 at Ludwigshafen while Du Pont followed suit at Deepwater Point, NJ, in the late 1930s. Commercial manufacturing methods of Pc and Cu Pc as well as methods for eliminating crystallisation and flocculation of the pigment form have evolved. In addition, partially and fully chlorinated Cu Pcs and associated manufacturing methods were developed.

Associated terms for this compound used in a pigment context include Monastral (ICI trade name) and Winsor blue/green (trade names of artists' paints used by the British colourmen Winsor & Newton). Other terms encountered were amor green, astral blue/green, helio blue/green, hogar blue, intense blue and thalo blue/green. Of the commercially important phthalocyanines, the primary *Colour Index* (1971) designations are CI 74160/ Pigment Blue 15, sub-classes 15:1 to 15:6 covering the various common species used as pigments; 15 is an unstabilised (against crystal modification), non-halogenated copper phthalocyanine with the α-crystal modification, 15:1 is the same but with 0.5–1 chlorine substitutions, 15:2 is a non-flocculating version of 15:1, 15:3 is an unsubstituted β-copper phthalocyanine and 15:4 a non-flocculating version of that; 15:6 is a stabilised, unsubstituted ε-modification form. CI 74100/Pigment Blue 16 designates the metal-free phthalocyanine and CI 74160:2/Pigment Blue 75 is a cobalt phthalocyanine. CI 74260/Pigment Green 7 describes a copper phthalocyanine with 14–15 chlorine substitutions, CI 74265/Pigment Green 36 is likewise a copper phthalocyanine, but with 4–9 bromine and 8–2 chlorine substitutions.

Despite the assertion that by 1981 phthalocyanine pigments accounted for 90–95% of all blue and green pigments used by the UK paint and printing ink industries (British Colour Makers' Association, 1981), very few identifications of these pigments have been reported from paintings. Burgio and Clark (2000) have, however, noted the presence of blue and green phthalocyanine pigments on painted papyri purporting to be thirteenth century BC Egyptian, but now considered modern.

Extensive discussions of Pc chemistry, uses and analysis are given in the texts by Cook (1993), Lever (1965), McKeown (1998), Moser and Thomas (1983) and Wanser (1985). Thomas (1990) provides a convenient summary of the voluminous literature on Pcs.

Copper group; Polycyclic pigments group; Porphyrins group; Chlorophyll; Hemoglobin
Baumann *et al.* (1956); Braun & Tcherniac (1907); British Colour Makers' Association (1981); Burgio & Clark (2000); *Colour Index* (1971) 74100, 74160, 74260, 74265; Cook (1993); Dandridge *et al.* (1928); Diesbach & Weid (1927); Herbst & Hunger (1997) 426–439; Kobayashi *et al.* (1994); Lever (1965); McKeown (1998); Moser & Thomas (1983); Sanielevici *et al.* (1961); Thomas (1990); Wanser (1985)

PHYLLOSILICATES
Variable
Group term

See: sheet silicates group.

PICKLE GREEN
Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either scheele's and/or emerald green (*qq.v.*), the term probably indicating a shade variant. Guignet (1888), for example, described pickle green (along with Neuwied green) as Scheele's green co-precipitated with calcium sulfate (*qq.v.*).

Calcium sulfates group; *Emerald green*; *Neuwied green*; *Scheele's green*
Fiedler & Bayard (1997); Guignet (1888) 144–148

PICRIC ACID GREEN
Green
Synonym, variant or common name

According to Riffault *et al.* (1784), this was a mixture of picric acid and indigo carmine (*q.v.*).

Indigo carmine
Riffault *et al.* (1874) 537

PIGMENT GREEN B
Green
Synonym, variant or common name

According to Inman (1973), Pigment green B is prepared via the water-soluble bisulfite addition complex of 1-nitroso-2-naphthol, which is subsequently decomposed with alkali in the presence of iron(II) sulfate. A brown-yellow nickel analogue is also known. The compound was first described in 1885 by Hoffman though it was not until 1921 that a procedure appeared which yielded it in a form suitable for pigment use. Commercial exploitation apparently peaked in the 1950s through use in aqueous interior paints and before phthalocyanine pigments superseded it.

Inman (1973)

PINE SOOT BLACK
Black
Synonym, variant or common name

Mayer (1991) describes this as 'a Chinese lampblack, pure carbon'. See: lamp black.

Lamp black
Mayer (1991) 54

PINK
Yellow
Synonym, variant or common name

A yellow 'lake' pigment based on one of a number of naturally occurring yellow dyestuffs such as those derived from *Quercus* and *Rhamnus* species (*q.v.*). There is no explanation of the derivation of the word pink which came into use in the early sixteenth century referring to a yellow colour; however, there is speculation that due to the colour, it is derived from the German *pinkeln* translated in a dictionary of 1798 (Adelung and Schwann, 1798) as 'to piss, to make water'. Pink was rarely used as a term standing alone by the second half of the eighteenth century and was generally qualified with an adjective; brown pink, Dutch pink, French pink and Italian pink (*qq.v*). The use of this term as applied to a light red appears to occur in the middle of the seventeenth century, see: rose pink (Harley, 1982).

Flavonoids group; Quercitron; Rhamnus; *Brown pink*; *Dutch pink*; *Italian pink*; *Rose pink*; *Stil de grain*
Adelung and Schwann (1798); Harley (1982) 109–111

PINK MADDER

Red
Synonym, variant or common name

Salter records that by the time he was writing in 1869 pink madder, a lighter variety of rose madder (*q.v.*) which had been used by miniature painters, was now obsolete and both pink and rose madder were the same. The term is also mentioned in Field (1835).

Madder; *Rose madder*
Field (1835) 97; Salter (1869) 144–145

PINK SAUCERS

Red
Synonym, variant or common name

Field (1835) lists a number of related terms including rouge, rouge vegetale, Chinese rouge and pink saucers, all of which he says were prepared from safflower (*q.v.*).

Safflower; *Saucer colour*
Field (1835) 101

PIPE CLAY

White
Synonym, variant or common name

The term pipe clay is frequently treated as synonymous with kaolin (*q.v.*). However, tobacco pipes are manufactured from the sepiolite clay mineral (*q.v.*) known as 'meerschaum' (sea-foam). This hardened clay is derived from lake deposits, the best known of which are in Eskisehir, Turkey.

Spencer (1914) writes of Australian Aboriginal use: 'Painting the surface with pigments, those used being pipe clay, red ochre of at least two kinds, yellow ochre, and charcoal (*qq.v.*). This painting may take place on human bodies, on implements and weapons of various kinds, on sacred objects, and on rocks and bark.'

Carbon-based blacks group: chars sub-group; clay minerals group; Sepiolite; *Kaolin*; *Red ochre*; *Yellow ochre*
Spencer (1914) 408

PITCHBLENDE

Black
Generic compound

Pitchblende is a black, grey or brown uranium-bearing compound which commonly occurs as individual grains or with massive or botryoidal form; it is also found as coloform gels or crusts in veins. Pitchblende has a sub-metallic, greasy or dull lustre and often has an earthy texture. Its composition is given as UO_2, although is usually partly oxidised to U_3O_8 (uranyl uranate) and often contains small amounts of additional heavy elements such as thorium, zirconium and lead, resulting in a variety of names according to composition (e.g. cleveite, broggerite, gummite). It may also contain gaseous material such as helium, argon and nitrogen. Pure UO_2 is known as uraninite (*q.v.*) and has a much denser and harder form. The streak of pitchblende is black with a green or brown tinge often present probably due to the presence of the uranyl uranate component. Pitchblende is found in low temperature veins in rocks (e.g. Salamanca Province, Spain; Erzebirge, Germany; Minas-Gerais, Brazil; Sanbaqi and Huangao deposit, SE China; Cigar Lake deposit, Saskatchewan, Canada; Mika, NE Nigeria) and replacement deposits as well as some high temperature igneous (pegmatitic) rocks (Rutley, 1998).

Uranium green (*q.v.*), which may be U_3O_8 (CI 77919), is supposed to have been used as a pigment; it is described by Salter (1869) as 'an oxide of a deep dull green colour, inclining to olive, and nearly black when in lumps. A durable but unattractive preparation.' Pitchblende may be the source of uranium for many uranium-based pigments such as uranium brown, green, orange, red and yellow (*qq.v.*).

Uranium group; Uraninite; *Uranium brown*; *Uranium green*; *Uranium orange*; *Uranium red*; *Uranium yellow*
Colour Index (1971) 77919; Rutley (1988) 273–274; Salter (1869) 291

PIURI

Yellow
Synonym, variant or common name

Historical Indian term for the pigment known as Indian yellow (*q.v.*). There were numerous orthographic and other variants such as *peori*, *purree*, *pioury*, *purrea Arabica*, *Hardwari peori*, *peri rung*, *peoli* and *Monghyr puri* (Baer *et al*., 1986).

Indian yellow
Baer *et al*. (1986)

PLACITAS GREEN

Green
Synonym, variant or common name

In a discussion of pigments used by New Mexico *santeros* ('saint makers'), Carrillo (1998) mentions that 'Green pigments were likely made by the mixing of vegetable yellows with indigo or even Prussian blue, or they were derived from imports such as verdigris or of a local source such as an earthen green [*qq.v.*] from Placitas, New Mexico. Rio Grande Pueblo craftsmen may have also used this color for painting dance paraphernalia.' Carrillo also states that he 'named the green Santiago green, in honor of his uncle, Jimmy Trujillo, who pointed out the green earth in 1990'.

A fuller discussion of Placitas green is given by Toomey (1996).

Green earth; Indigo; *Prussian blue*; *Verdigris*
Carrillo (1998); Toomey (1996)

PLANCHÉITE

Blue
Generic compound

Planchéite, also known as bisbeeite, is a copper silicate hydroxide hydrate mineral with composition $Cu_8Si_8O_{22}(OH)_4.H_2O$. It was first described by Lacroix in 1908 and is named after the French explorer J. Planché who discovered it in Congo, Africa. Planchéite occurs as blue or blue-green acicular or fibrous crystals, or as botryoidal masses (Dana, 1932; Evans and Mrose, 1977). It forms as a rare secondary mineral in the weathering zones of copper ore deposits, where it is found with chrysocolla, dioptase, malachite and tenorite (*qq.v.*). It is known from localities such as Mindouli (Congo), La Rioja (Argentina), Caldbeck Fells (Cumbria, England), Bisbee (Arizona, USA) and Otavi (Tsumeb, Namibia).

Planchéite has been discussed by Rouchon *et al*. (1990) in the context of pigments from Karnak, Egypt.

Copper silicate group; Chrysocolla; Dioptase; Malachite; Tenorite
Dana (1932) 687; Evans & Mrose (1977); Rouchon *et al*. (1990)

PLASTER OF PARIS

White
Synonym, variant or common name

Plaster of Paris is the common name for gypsum-based plaster, made by calcining gypsum (*q.v.*; $CaSO_4.2H_2O$) at temperatures of a minimum of 90°C, but usually to temperatures of 150–165°C to produce hydrates with the formulae $CaSO_4.0.6H_2O$ and $CaSO_4.0.5H_2O$ which are then reconstituted by slaking with water and then curing (drying) to re-form gypsum (Bezou *et al.*, 1995; Manning, 1995). Heating to temperatures above 200°C produces β-$CaSO_4$ or anhydrite, which is a stable phase.

Plaster of Paris was used as a white ground in Renaissance painting and called *gesso* (Cennini, c. 1400, Clarke MS 590). Evidence suggests it was also used in wall painting technique: 'The quality of the plaster of Paris, is to bind the Colours together' writes Sanderson (1658; cf. *OED*, 2002).

Plaster of Paris was introduced into north-western Europe in the thirteenth century although it was used as a base for wall paintings and as a lubricant in ancient Egypt (Lucas, 1962). The name is derived from the main historical quarry sources in Montmartre, Paris. The *Oxford English Dictionary* gives the first known use of the term in c. 1462, and it was certainly in routine use from the fifteenth century onwards.
See: calcium sulfates group.

Calcium sulfates group; Gypsum
Bezou *et al.* (1995); Cennini (c. 1400/Thompson, 1960) 70–74; Lucas (1962); Manning (1995) 155; *OED* (2002) 'plaster of Paris'; Sanderson (1658)

PLATINA YELLOW

Yellow
Synonym, variant or common name

The early use and meaning of this term is somewhat confused, with the precise relationship to lemon yellow (*q.v.*) being unclear. Field (1835), who promoted the pigment, gives platina yellow as being synonymous with lemon yellow; however, Bachhoffner (1837), writing shortly afterwards, remarks that: 'This pigment [i.e. lemon yellow, which he identifies as barium chromate, *q.v.*] has lately been introduced to the notice of artists by Mr. Field; some mistake appears, however, to have arisen with respect to its composition, many artists considering it to be a compound of the metal platina', thus indicating a different pigment made from platinum. These pigments were therefore probably distinct, at first, although other, cheaper, pigments were substituted later on. Carlyle (2001), on the other hand, says: 'Judging from its history and the expense associated with using the actual metal, it is most likely that the platina yellow of the colourmen was simply a deep tint of one of the chrome yellows.'

In all probability the 'true' platina yellow is likely to have been potassium hexachloroplatinate(IV), a compound which forms as orange-yellow crystals or a yellow powder.

Salter (1869) uses the term platinum yellow.

Barium chromate(VI); Potassium hexachloroplatinate(IV); *Lemon yellow*
Bachhoffner (1837); Carlyle (2001) 519, 521–523; Field (1835); Salter (1869) 121–122

PLATINUM BLUE

Blue
Synonym, variant or common name

Platinum blue is mentioned in the 1869 Salter edition of Field's *Chromatography.* He states that 'With mercurous nitrate, the platinocyanide of potassium forms a thick smalt blue, and the platinidcyanide a dark blue precipitate. The compound is a mixture of platino- or platinidcyanide of mercury and mercurous nitrate.'

Palladium and platinum group
Salter (1869) 233

PLATINUM YELLOW

Yellow
Synonym, variant or common name

See: platina yellow.

PLATT OF INDIGO

Blue
Synonym, variant or common name

See: blue of England.

PLATTNERITE

Black-Brown
Generic compound

Plattnerite is a lead(IV) oxide mineral with composition PbO_2, named after the German metallurgist K.F. Plattner (1800–58). It occurs as black sub-metallic botryoidal masses, nodules and crusts or as prismatic crystals and forms by the oxidation of lead ore deposits in areas such as Leadhills (Scotland), Laurion (Attiki, Greece), Durango (Mexico), Tsumeb (Namibia) and Bisbee (Arizona, USA), Rutley (1988).

It appears that plattnerite has not been used specifically as a pigment, rather that it occurs as an alteration product of other lead-based pigments. For example, Gettens (1938b) suggested that the darkening of wall painting samples from central China, Kizil (Chinese Turkestan) and Afghanistan was caused by brown lead(IV) oxide formation; FitzHugh (1986) reports on the positive identification of plattnerite as the cause of the darkening of red lead on a wall painting fragment from Kizil (Chinese Turkestan), and mentions the formation of black lead(IV) oxide on thirteenth to seventeenth century Swiss wall paintings. Moffatt *et al.* (1989) and Wainwright *et al.* (1997) have noted plattnerite among pigments in fragments of wall paintings from Mogao grottoes at Dunhuang and the Bingling Temple grottoes near Lanzhou, Gansu Province, China; it is probable, however, that this represents an alteration product of lead(II,IV) oxide (minium; *q.v.*). Dneprovskaya (1992) also found plattnerite among pigments from mural paintings of the twelfth and thirteenth centuries in the grotto monasteries of Bertubani and Udabno, Republic of Georgia; in this case it was thought to be due to bacteriological oxidation of lead white (*q.v.*). Lead white and minium altered to plattnerite has been noted in frescos at Basilica Superiore di San Francesco in Assisi, Italy (Santamaria and Santopadre, 2001). Using Raman microscopy, Andalò *et al.* (2001) reported the presence of lead(IV) oxide (plattnerite), formed from the oxidation of lead white used with brown ochre pigments on the *Trionfo d'Amore*, attributed to Botticelli; however, Smith *et al.* (2001) suggest that the analysis is more indicative of massicot (*q.v.*), produced by laser induced degradation of the pigment.

Lead group; Lead oxides and hydroxides group; Lead(II,IV) oxide; Lead(IV) oxide; Massicot minium; *Lead white*
Andalò *et al.* (2001); Dneprovskaya (1992); FitzHugh (1986); Gettens (1938b); Moffatt *et al.* (1989); Santamaria & Santopadre (2001); Smith *et al.* (2001); Wainwright *et al.* (1997)

PLESSY'S GREEN

Green
Synonym, variant or common name

See: Arnaudon's chrome green.

Plumbago
Black
Synonym, variant or common name

Plumbago is a historical term for graphite (*q.v.*).

Graphite

Plumbonacrite
White
Generic compound

Plumbonacrite is a rare basic lead carbonate mineral with composition $Pb_{10}(CO_3)_6O(OH)_6$. Named for its composition and pearly lustre, it was first described by Heddle in 1889 from Wanlockhead (Scotland); it has also been reported to occur at Tiger (Arizona, USA). Plumbonacrite is not well characterised as a mineral and is considered to be a metastable phase, converting readily to hydrocerussite and cerussite (*qq.v.*; Haacke and Williams, 1981). It forms as a secondary mineral via the weathering of lead deposits and as a corrosion product of lead objects, forming as an intermediate phase of lead and lead oxide carbonitisation, as noted by Olby (1966). The structure of synthetic plumbonacrite has been characterised recently by Krivovichev and Burns (2000), who give the composition as $Pb_5O(OH)_2(CO_3)_3$.

Lead carbonates group; Lead oxides and hydroxides group; Cerussite; Hydro-cerussite
Haacke & Williams (1981); Krivovichev & Burns (2000); Olby (1966)

Plygal
Yellow
Synonym, variant or common name

Term found in German-language treatises in contexts where otherwise *giallolino* or massicot (*qq.v.*) are used. *Plygal* may be therefore translated as *blei-gelb* or 'lead-yellow'. While it is not mentioned at all in some German treatises such as the *Strasburg MS* (Clarke MS 2000) and the *Kunstbuchlein,* this term may be noted in texts such as Valentin Boltz von Ruffach's *Illuminierbuch* (1549). Later editions of this work spell the word *bleigelb*, but unfortunately for the present discussion the relevant passage is not very revealing about the pigment itself and the authors are unaware of another German source of this period that is any more so. In a copy of a later edition of the *Illuminierbuch* published at Erfurt in 1661, now in the British Library, there is a manuscript gloss; against *Bleygelb* are two handwritten translations (in different hands) providing translation as *massicot* and *lootgeel*. The latter is the only occurrence of that term in such a context known to the authors. Bound with this edition of Boltz von Ruffach's book is a copy of the Gerhard ter Brugge/Willhelm Goeree *Illuminir- Oder Erleuchterey Kunst*, published in Hamburg in 1677. This too contains manuscript notes, and in a colour list that gives Masticot there is the handwritten comment '*oder bleygelb*'. From an examination of dated entries at the end of the bound book, these comments must have been added some time in the late seventeenth century. Of similar importance is the de Mayerne (BL MS Sloane 2052), where samples of watercolours include two specimens labelled both 'Masticot' and 'English bleigelb', thus leaving us in no doubt as to the equivalence (Eastaugh, 1988)

Thompson (1935) has also found the term plygal in a fifteenth century German manuscript now in the Bayerische Staatsbibliothek in Munich (MS germ. 822, Clarke MS 2220), and comments elsewhere that plygal was a term frequently encountered in similar manuscripts.

Massicot; *Giallolino*
BL MS Sloanne 2052; Boltz von Ruffach (1549/Benziger, 1913) 71, 99; Boltz von Ruffach (1661); Eastaugh (1988); Goeree (1670); *Strasburg MS* (15th cent/tr. Borradaile, 1966); Thompson (1935)

Polianite
Black
Generic compound

See: pyrolusite.

Polychloro copper phthalocyanine
Green
Generic compound

See: phthalocyanines group.

Polycyclic pigments group
Variable
Group term

A wide range of both historically significant and modern commercially important pigments can be classed as polycyclic. All contain condensed aromatic or heterocyclic ring systems in contradistinction to the other principal modern range of organic pigments, the azo pigments group (*q.v.*), which are based instead around the $-\mathrm{N}{=}\mathrm{N}-$ linkage; in fact Herbst and Hunger (1997) explictly state in their definition that polycyclic pigments are precisely those organics which are *not* azo compounds. While in the present publication some of the following groups are categorised separately, classes that are normally covered under the general heading of polycyclic pigments include: phthalocyanines; quinacridones; perylenes and perinones; diketopyrrolo pyrroles ('DPP' pigments); thioindigoids; the anthraquinone-related anthanthrones, anthrapyrimidines, flavanthrones, indanthrones and pyranthrones; dioxazines; triarylcarboniums; quinophthalones. In addition, under this definition one might include the important group of naturally occurring flavonoid and porphyrin compounds; the former typically constitute yellow to brown dyestuffs, the latter include chlorophyll and hemoglobin.

Various compounds belonging to this general group are currently produced in large volume; others, such as anthraquinone, flavonoid and indigoid compounds, are also of historical importance. Of the synthetic polycyclic pigments, the first to reach commercial importance are probably those based on triphenylmethane, a technology discovered in 1914; among these the nitroso-b-naphthole iron complex known as pigment green, first synthesised in 1921, achieved significance as an inexpensive green pigment prior to the introduction of the phthalocyanine pigments in the 1930s. Other more recent commercial products include perylene pigments, dioxazine (carbazole violet), quinacridone pigments (from 1958) and, recently, DPP pigments.
See: anthraquinones group, flavonoids group, phthalocyanines group and porphyrins group.

Anthraquinones group; Azo pigments group; Flavonoids group; Phthalocyanine group; Porphyrins group; Chlorophyll; Hemoglobin; *Pigment green*
Herbst & Hunger (1997) 423

Polycyclic pigments group: anthanthrone sub-group
Red
Group term

The anthanthrones are classed as polycarbocyclic anthraquinone pigments. Anthanthrone itself consists of two connected anthraquinone structures; unsubstituted the compound exhibits an orange colour, though this is too weak tinctorially to be useful as a pigment. However, halogenation has formed the commercially important 4,10-dibromoanthanthrone, CI 59300/ Pigment Red 168 (*Colour Index*, 1971); this was first synthesised as a vat dye in 1913. The superior properties of this pigment mean that it has found applications in a wide range of contexts (Herbst and Hunger, 1997).

Anthraquinones group; Polycyclic pigments group
Colour Index (1971) 59300; Herbst & Hunger (1997) 525–527

POLYCYCLIC PIGMENTS GROUP: ANTHRAPYRIMIDINE SUB-GROUP

Yellow
Group term

The anthrapyrimidine sub-group of the polycyclic pigments are heterocyclic anthraquinones. 1,9-anthrapyrimidine, which is not used commercially, is the parent structure for this group; this, and its substituted derivatives, are obtained by condensation of 1-aminoanthraquinone. The principal member is anthrapyrimidine yellow, CI 68420/Pigment Yellow 108 (*Colour Index*, 1971), a compound mainly used in paints (Herbst and Hunger, 1997).

Anthraquinones group; Polycyclic pigments group
Colour Index (1971) 68420; Herbst & Hunger (1997) 512–514

POLYCYCLIC PIGMENTS GROUP: DIKETOPYRROLO PYRROLE SUB-GROUP

Red-Orange
Group term

A recent class of pigments, discovered in the early 1980s, these are based on the 1,4-diketopyrrolo(3,4c)pyrrole system. This structure consists of a skeleton of two anellated five-membered rings each of which contains a carbonamide moiety. Commercial examples are CI Pigment Oranges 71 and 73, and Pigment Reds 254, 255, 264 and 272 (*Colour Index*, 1971). Principal applications are currently in the industrial coatings and plastics markets rather than paints (Herbst and Hunger, 1997).

Polycyclic pigments group
Colour Index (1971); Herbst & Hunger (1997) 489–496

POLYCYCLIC PIGMENTS GROUP: DIOXAZINE SUB-GROUP

Purple
Group term

The dioxazine molecule is derived from triphenodioxazine, a linear system of five anellated rings. Two violet pigments from this group are of commercial significance, CI Pigment Violets 23 and 37 (*Colour Index*, 1971); the former is also known as *Carbazole violet*. The main applications are coatings, plastics and inks rather than paints. Pigment Violet 23 is also used to shade phthalocyanine pigments, to counteract the yellowish cast of titanium dioxide whites and to shade carbon-based blacks (*qq.v.*) that have a brownish cast (Herbst and Hunger, 1997).

Carbon-based blacks group; Phthalocyanines group; Polycyclic pigments group; *Titanium dioxide white*
Colour Index (1971); Herbst & Hunger (1997) 10, 530–537

POLYCYCLIC PIGMENTS GROUP: FLAVANTHRONE/ INDANTHRONE SUB-GROUP

Variable
Group term

The closely related flavanthrones and indanthrones are heterocyclic anthraquinones, both of which were first synthesised by R. Bohn in 1901. They are also vat dyes, capable of reduction to a leuco form.

Vat dyes of the highest quality have derived their name from indanthrone, a blue compound originally known as indanthrene blue. This compound, CI 69800/Pigment Blue 60 (*Colour Index*, 1971), has been used for a considerable period of time. Indanthrone exists in four crystal modifications: α- and β-forms, which are greenish and reddish blue, a reddish γ-form and a δ-form of no colouristic or commercial significance; the α-form is the most stable and therefore most suited to pigmentary use. Indanthrone is widely used in a variety of applications including paints. Chlorinated indanthrones have also found some limited commercial interest, notably 3,3′-dichloroindanthrone (CI 69825/Pigment Blue 64), though these forms no longer appear to be produced.

The only commercially employed flavanthrone pigment is flavanthrone yellow, CI 70600/Pigment Yellow 24. Commercially available types are a reddish yellow colour and are a speciality product used for paints; its high transparency means that it is also used in metallic finishes, typically with aluminium pigments. Further, because of high lightfastness, this pigment is specifically noted as being used in artists' paints (Herbst and Hunger, 1997).

Anthraquinones group; Polycyclic pigments group; *Indanthrene blue*
Colour Index (1971) 69800/69825/70600; Herbst & Hunger (1997) 514–521

POLYCYCLIC PIGMENTS GROUP: ISOVIOLANTHRONE SUB-GROUP

Blue-Purple
Group term

Isoviolanthrone is described as a 'highly anellated polycyclic quinone system', essentially two benzanthrone molecules joined asymmetrically. This compound was first synthesised in 1907 and has long been known as a vat dye. However, it is the dichloroderivative which is best known as a pigment, affording the reddish violet colour known as isoviolanthrone violet, CI Pigment Violet 31 (*Colour Index*, 1971; Wich, 1973; Herbst and Hunger, 1997).

Polycyclic pigments group
Colour Index (1971); Herbst & Hunger (1997) 527–530; Wich (1973) 651–666

POLYCYCLIC PIGMENTS GROUP: PERYLENE/ PERINONE SUB-GROUP

Variable
Group term

Perylene and perinone pigments are closely related chemically and are manufactured by essentially the same route. Perylenes are diimide derivatives of perylene-3,4,9,10-tetracarboxylic acid, while perinones are derivatives of naphthalene-1,4,5,8-tetracarboxylic acid (Herbst and Hunger, 1997).

The earliest member of the perylenes was described in 1912, but it was not until 1950 that perylene compounds found use as pigments; commercial types are the Pigment Reds 123, 149, 178, 179, 190 and 224, and Pigment Violet 29. Similarly, the earliest perinone introduced commercially was discovered in 1924. The earliest product was a yellowish red vat dye, a mixture of *cis* and *trans* isomers, which was discovered in 1924 by Eckert and Greune at Hoechst AG. Again it was not until 1950 that these compounds found recognition as pigments. At present, only the two isomers and their mixture are used commercially, providing orange to Bordeaux shades. They are listed in the *Colour Index* (1971) as CI 71105/Pigment Orange 43 ('Perinone Orange') and CI 71100/Pigment Red 194; the former has found widespread use in paints, the latter less so.

Polycyclic pigments group
Colour Index (1971) 71100/71105; Herbst & Hunger (1997) 475–489

POLYCYCLIC PIGMENTS GROUP: PYRANTHRONE SUB-GROUP

Red-Orange
Group term

Pyranthrone pigments are derivatives of the pyranthrone structure, itself related to the flavanthrone structure (see: polycyclic pigments group: flavanthrone sub-group), but with nitrogen atoms replaced by CH groups. They are also classed as polycarbocyclic anthraquinone pigments. The unsubstituted structure has been manufactured until relatively recently as CI 59700/Pigment Orange 40. Other products are bromo-, chloro- and bromo/chloro-derivatives; Pigment Orange 51 is the 2,10-dichloro-derivative, CI 59710/Pigment Red 216 is a tribromo-derivative and Pigment Red 226 is a dibromo-4,6-dichloro-derivative (Herbst and Hunger, 1997; *Colour Index*, 1971).

Anthraquinones group; Polycyclic pigments group
Colour Index (1971) 59700, 59710; Herbst & Hunger (1997) 521–525

POLYCYCLIC PIGMENTS GROUP: QUINACRIDONE SUB-GROUP

Variable
Group term

Quinacridone pigments are dioxotetrahydroquinolinoacridine compounds, typically five-ring polycyclic systems. The molecule consists of a central benzene ring bridged to two six-membered aromatic rings by 4-pyridone rings; both linear and angular molecules can be formed, though it is the former which gives rise to viable pigments. Commercial examples include the β- and γ-crystal modifications of CI 46500/Pigment Violet 19, the CI Pigment Reds 122 (a 2,9-dimethylquinacridone), 192, 202, 206, 207 and 209, Pigment Oranges 48 and 49 and Pigment Violet 42; Pigment Red 206 and the orange and violet pigments are so-called 'quinacridone quinone' pigments (Herbst and Hunger, 1997; *Colour Index*, 1971).

Polycyclic pigments group
Colour Index (1971) 46500; Herbst & Hunger (1997) 454–474

POLYCYCLIC PIGMENTS GROUP: QUINOPHTHALONE SUB-GROUP

Red-Orange-Yellow
Group term

Quinophthalone was first synthesised by E. Jacobsen in 1882 by fusing phthalic anhydride with quinoline bases derived from coal tar. Derivatives of quinophthalone carrying sulfonic or carboxylic acid groups provide anionic dyes, those with basic side chains such as quaternary nitrogen produce cationic dyes. However, quinophthalones are too soluble in various media to be used for normal applications and therefore pigments are produced by creating other modifications, notably halogenation. Of these the chlorine-substituted quinophthalone CI 56300/Pigment Yellow 138 is that with the greatest commercial significance, its excellent stability in a number of respects ensuring its use in various contexts including paints. Quinophthalones generally provide yellow to red shades (Herbst and Hunger, 1997; *Colour Index*, 1971).

Polycyclic pigments group
Colour Index (1971) 56300; Herbst & Hunger (1997) 538–541

POLYCYCLIC PIGMENTS GROUP: THIOINDIGOID SUB-GROUP

Red
Group term

The Thioindigoid group are closely related in structure to indigo (*q.v.*), but with sulfur in place of the nitrogen in the five-member rings. Thioindigo, the unsubstituted parent structure, was discovered by Friedländer in 1905, but it is of little technical or commercial importance. More significant have been the chlorinated and/or methylated derivatives, which became recognised as pigments in the 1950s; a range of colours from red violet and maroon to brown could be achieved. However, most thioindigoid pigments are no longer manufactured, leaving only two of any remaining significance – the red-violet CI 73312/Pigment Red 88 (the 4,4′,7,7′-tetrachlorothioindigo) and the bluish red CI 73360/Pigment Red 181; in fact, of these, only the former retains much demand for paints (Herbst and Hunger, 1997; *Colour Index*, 1971).

Indigoid group; Polycyclic pigments group; Indigo
Colour Index (1971) 73312/73360; Herbst & Hunger (1997) 496–502

POLYCYCLIC PIGMENTS GROUP: TRIARYLCARBONIUM SUB-GROUP

Variable
Group term

The triarylcarbonium group of pigments unsurprisingly share the triarylcarbonium structure, though at least two of the aryl moieties carry amino groups. The compounds are consequently basic and therefore capable of reacting with acids to form insoluble salts, the form in which these compounds can be and are employed as pigments. Two types of insoluble triarylcarbonium compounds are used industrially as pigments; so-called 'alkali blue' types are inner salts of sulfonic acids, while the other group are salts of complex inorganic anions of heteropolyacids.

Alkali blue compounds are tri(amino)phenylmethane derivatives based on parafuchsine or pararosaniline with one to three methyl substituents, the most commercially significant types being diarylated and triarylated rosanilines. Typical examples are CI 42770:1/Pigment Blue 18, CI 42750/Pigment Blue 19, CI 42800/Pigment Blue 56 and CI 42765:1/Pigment Blue 61. However, their properties are such that they are primarily used for inks rather than paints.

The second group of compounds, dye salts formed with complex anions, has achieved much greater significance. As early as 1913 cationic dyes were being precipitated with a heteropolyacid, phosphotungstic acid; this, phosphomolybdic and phosphotungstomolybdic acid have subsequently led to important commercial products, particularly in the 1920s and 1930s.

Additionally, shortages in the availability of tungsten and molybdenum in Germany during the 1930s led to the development of analogues with copper ferrocyanide (copper hexacyanoferrate) as the anion. Pigments are now commonly referred to not only by their *Colour Index* (1971) designation, but also by an added abbreviation according to the respective heteropolyacid: PM or PMA for phosphomolybdic acid, PT or PTA for phosphotungstic acid, PTM or PTMA for phosphotungstomolybdic acid, SM or SMA for silicomolybdic acid and CF for copper ferrocyanide. Specific varieties are too numerous to detail here; however, again most are used principally for inks rather than paints (Herbst and Hunger, 1997; *Colour Index*, 1971).

Polycyclic pigments group
Colour Index (1971) 42750, 42765, 42770, 42800; Herbst & Hunger (1997) 541–567

POMPEIAN BLUE

Blue
Synonym, variant or common name

Synonym for the synthetic calcium copper silicate Egyptian blue (*qq.v.*) listed by Mayer (1991), who notes that this term was also used for 'certain impermanent synthetic lakes that resemble Egyptian blue in hue'.

Calcium copper silicate; *Egyptian blue*
Mayer (1991) 54

POMPEIAN RED

Red
Synonym, variant or common name

Heaton (1928) lists Pompeian red as a then-current term for a light Indian red (*q.v.*); he in turn defines Indian red as an 'oxide of iron highly calcined'.

Indian red
Heaton (1928) 383

PONOLITH

White
Synonym, variant or common name

Ponolith is listed by Heaton (1928) as a then-current term for a product composed of lithopone (*q.v.*).

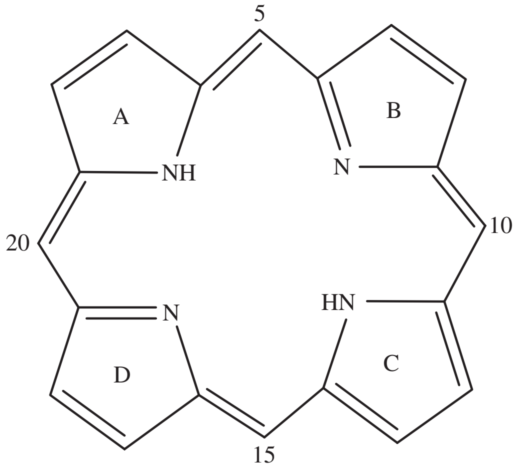
Lithopone
Heaton (1928) 383

PORPHYRINS GROUP

Variable
Group term

The porphyrins are a group of compounds found in all living matter which form the basis of, for example, the respiratory pigments in animals and plants, as well as structures such as that which underlies the phthalocyanines. Porphyrins and other closely related tetrapyrrolic pigments occur widely in nature, and they play very important roles in various biological processes. Heme (the iron(II) protoporphyrin-IX complex) is the prosthetic group in hemoglobins and myoglobins, which are responsible for oxygen transport and storage in living tissues. Reduction of one of the pyrrole units on the porphyrin ring leads to a class of porphyrin derivatives called chlorins; chlorophylls, found abundantly in green plants, belong to this category.

The basic structure of porphyrin (the porphine structure) consists of four pyrrole units linked by four methine bridges, lying in a planar arrangement; the porphyrin macrocycle thus forms an aromatic system containing 22 p electrons. In the various derived porphyrins, side chains and rings are substituted for the hydrogens in the porphine pyrrole rings. Additonally, the structure can effectively chelate metal ions in the central cavity – magnesium in chlorophyll, iron in hemoglobin and copper in phthalocyanines, though it will receive others.



For more information on specific members of this group, see: chlorophyll, blood and hemoglobin, and the phthalocyanines group.

Phthalocyanine group; Blood; Chlorophyll; Hemoglobin

PORPORINO

Yellow
Synonym, variant or common name

See: tin(IV) sulfide and mosaic gold.

PORTLANDITE

White
Generic compound

Portlandite is a calcium hydroxide mineral with composition $Ca(OH)_2$. It occurs as relatively soft, white, platy, hexagonal crystals and compact masses that have a pearly luster. It was first described by Tilley in 1934 and is named after its occurrence in Portland cement. It is a common component of man-made lime mortars and plasters (for example, see Moropoulou *et al.*, 1995), but occurs naturally in Kalahari (South Africa), Buskerud (Norway), Bavaria (Germany) and Vesuvius (Italy), forming particularly by fumarole deposition or by the decomposition of feldspar group minerals in kaolin (*qq.v.*) samples, as described by Peng *et al.* (1995).

Although normally white in colour, FitzHugh (1997) has reported finding portlandite among some twentieth century Persian yellow pigments. Two samples, probably both deriving from the Kasivin quarry, were found to contain portlandite, calcite and quartz (determined by X-ray diffraction) and traces of orpiment (determined by light microscopy). FitzHugh further cites in this context Minguzzi (1937), who reported that portlandite occurred as a yellow powder in fumaroles on Vesuvius.

Calcium oxides and hydroxides group; Feldspar group; Calcite; Calcium hydroxide; Kaolin; Orpiment; Quartz
FitzHugh (1997); Minguzzi (1937); Moropoulou *et al.* (1995); Peng *et al.* (1995); Tilley (1934)

POSNJAKITE

Green
Generic compound

Posnjakite is a copper(II) sulfate hydroxide hydrate mineral with composition $Cu_4(SO_4)(OH)_6.H_2O$, essentially a hydrated form of brochantite (*q.v.*). It is closely related to – and almost indistinguishable from – both langite (*q.v.*) and wroewulfeite, which contain more water. Posnjakite was first formally described by Komkov and Nefedov in 1967 and is named after the US geochemist E.W. Posnjak (1888–1949). It occurs as small blue tabular crystals or thin vitreous crusts with an internal sheet-like structure (Mellini and Merlino, 1979) and forms as a secondary mineral from the weathering of copper ore deposits. It is known from areas such as Saxony (Germany), Alsace (France), Buskerud (Norway), Attica (Greece), Mont St Hilaire (Quebec, Canada), Talinsk (Kazahkstan) and Broken Hill (New South Wales, Australia). Authors such as Nassau *et al.* (1987) and Scott (2002) have discussed the formation of posnjakite as a degradation product of copper. Krätschmer *et al.* (2002) have shown that in low-sulfur environments, the decomposition of copper occurs by the initial formation of cuprite (*q.v.*), followed by posnjakite, which forms as a precursor to brochantite. Empirical experiments by Fitzgerald *et al.* (1998) also show that posnjakite forms as a precipitate from cuprite in contact with rainwater.

Posnjakite, or its synthetic analogue, has been found on mediaeval playing cards (Richter and Härlin, 1976), paintings by Jan van Scorel (Asperen de Boer, 1977) and Lucas van Leyden (Hermesdorf *et al.*, 1979). Occurrence on sixteenth century Russian frescos has been reported by Naumova *et al.* (1990) and on a work by Bronzino (Grenberg *et al.*, 1992; Naumova and Pisareva, 1994). Spring (2000) has also noted this pigment on three Netherlandish paintings of the 1520s to 1530s, where she calls it 'green copper sulphate'. Further identifications have been made by a group of French researchers (Martin and Eveno, 1992; Martin *et al.*, 1995) who also discuss the issues regarding whether the material is of natural or synthetic origin. However, Spring points out that the array of associated minerals in material analysed from a painting by Ysenbrandt makes it almost certainly of natural origin, while a recipe for the synthetic preparation of posnjakite is to be found in an early nineteenth century treatise on paint preparation (Hochheimer, 1803; cf. Naumova and Pisareva).

Copper oxides and hydroxides group; Copper sulfates group; Brochantite; Cuprite; Langite
Asperen de Boer (1977); Fitzgerald *et al.* (1998); Grenberg *et al.* (1992); Hermesdorf *et al.* (1979) 407, n.144; Hochheimer (1803); Krätschmer *et al.* (2002); Martin & Eveno (1992); Martin *et al.* (1995); Mellini & Merlino (1979); Nassau *et al.* (1987); Naumova & Pisareva (1994); Naumova *et al.* (1990); Richter & Härlin (1976); Richter (1988); Scott (2002) 230; Spring (2000)

POTASSIUM CHLOROPLATINATE

Yellow
Synonym, variant or common name

See: potassium hexachloroplatinate(IV) and platina yellow.

POTASSIUM COPPER CHLORIDE

Blue-Green
Generic compound

Riederer (1982) has identified a potassium copper chloride among ancient pigments. A potassium copper chloride mineral, mitscherlichite (*q.v.*), also exists.

Copper group; Copper halides group; Mitscherlichite
Riederer (1982)

POTASSIUM HEXACHLOROPLATINATE(IV)

Yellow
Generic compound

Potassium hexachloroplatinate(IV), $K_2[PtCl_6]$, forms as orange-yellow crystals or a yellow powder. The structure of this compound, a coordination complex, has been discussed by Williams *et al.* (1973). Potassium hexachloroplatinate(IV) is associated with the pigment known historically as platina yellow (*q.v.*).

Palladium and platinum group; *Platina yellow*
Williams *et al.* (1973)

POTASSIUM HEXANITROCOBALT(III)

Yellow
Generic compound

Commonly known as cobalt yellow or aureolin, this is either a potassium or a sodium substituted potassium cobalt nitrite. Although generally described in the literature as tripotassium hexanitrocobalt(III) ($K_3Co(NO_2)_6.nH_2O$), a related compound, dipotassium monosodium hexanitrocobalt(III) ($K_2NaCo(NO_2)_6.nH_2O$) has also been documented, notably in the book by Church (1890). Gates (1995), however, has recently shown that a more reasonable formulation of the constitution of this pigment is $K_{3-x}Na_x[Co(NO_2)_6].nH_2O$. The compound was first synthesised by N.W. Fischer in Breslau, in 1831.

For more information on the history and terminology, see: cobalt yellow. This pigment has been recently reviewed by Cornman (1986).

Cobalt group; *Aureolin*; *Cobalt yellow*
Church (1890); Cornman (1986); Gates (1995)

POTASSIUM SODIUM HEXANITROCOBALT(III)

Yellow
Generic compound

See: potassium hexanitrocobalt(III).

POTASSIUM TITANATE

White
Generic compound

The earliest patents on the preparation of pigmentary potassium titanate, $(K_2O)_{1/x}(TiO_2)_4$ (where $x > 1$ due to leaching during preparation), were granted in 1958. It was introduced as a commercial pigment in 1965, production ceasing in 1972. It was primarily used in the paper industry, mainly because of the effects which could be achieved that resulted from the highly acicular (needle-like) morphology of the particles. Potassium titanate is formed by reacting titanium(IV) oxide with a combination of potassium salts at elevated temperatures (in the range 570–950°C).

The pigment has been reviewed by Riches (1973). Laver (1997) also mentions potassium titanate in her review of titanium dioxide pigments, as a possible form of titanium white (*q.v.*). The compound is sometimes known as PKT ('pigmentary potassium titanate').

Titanium group; *Titanium white*
Laver (1997); Riches (1973)

POTTER'S PINK

Red
Synonym, variant or common name

Potter's pink was manufactured from tin oxide roasted with chalk and small amounts of chromium oxide (*qq.v.*) to produce a range of pink shaded pigments. It is also known as mineral lake and tin pink (Mayer, 1991). Burton (1907) states that this is the name given by the Society of Painters in Tempera to a potter's colour first prepared in the early nineteenth century.

A sample called potter's pink was found by Dunkerton (1980) in the paint box belonging to Joseph Southall (1861–1944). The collection of pigments from the British colourmen C. Roberson and Co. Ltd now held at the Hamilton Kerr Institute, Cambridge, UK, contains a jar labelled 'Potts Pink' (ref. HKI M. 250–1994).

Chalk; Chromium oxide
Burton (1907); Dunkerton (1980); Mayer (1991) 54

POUSSIN YELLOW

Yellow
Synonym, variant or common name

Name recently proposed by Roy and Berrie (1998) along with Roman yellow for a lead antimony tin oxide known to have been used in Rome in the seventeenth century and by Nicolas Poussin in particular.

Lead antimony oxide
Roy & Berrie (1998)

POWDER BLUE

Blue
Synonym, variant or common name

According to the *Oxford English Dictionary* (2002) this was 'Powdered smalt [*q.v.*] esp. for use in the laundry'. Cited examples of context extend from the mid-seventeenth to early nineteenth centuries including evident use as a pigment.

Smalt
OED (2002) 'Powder-blue'

POWDER GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

POWDER OF ALGAROTH

Yellow
Synonym, variant or common name

See: antimony chloride oxide.

POZZUOLI BLUE

Blue
Synonym, variant or common name

A modern transliteration of the pigment *Puteolanum*, which is described by the classical author Pliny (77 AD). Pozzuoli – historically, Puteoli is some 13 km west of Naples. Founded c. 520 BC by Samian Greeks from Cumae, it came under Roman control by the end of the fourth century BC and was made a citizen colony in 194 BC becoming famous as Rome's port of entry for eastern trade, handling notably mosaics, pottery and perfumes. The shops were rich and the city was surrounded by handsome villas. According to Vitruvius (first century BC), a man called Vestorius founded a factory in Puteoli to manufacture what we may identify as Egyptian blue (*q.v.*).

Calcium copper silicate; *Egyptian blue*
Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii.161–163; Vitruvius (1st cent BC/Grainger, 1934) VII.xi.1

POZZUOLI RED

Red
Synonym, variant or common name

According to Mayer (1991) this was originally a species of red earth produced at Pozzuoli (ancient Puteoli, see the entry for Pozzuoli blue), a type of clay which set when wetted; additionally synthetic iron oxides and a 'native earth of a peculiar rosy shade' have supposedly been sold under this name.

Pozzuoli blue; *Red ochre*
Mayer (1991) 54

PRECIPITATED CARBON

Black
Synonym, variant or common name

Bachhoffner (1837) speculatively suggests the production of 'precipitated' carbon, describing an elaborate process involving the production of 'bi-carburetted hydrogen gas', then admitting chlorine gas and igniting the mixture. However, Carlyle (2001) failed to find any other mention of it in her extensive studies of the nineteenth century British literature.

Carbon-based blacks group
Bachhoffner (1837) 49; Carlyle (2001) 469

PRETO DE FRANDES

Black-Brown
Synonym, variant or common name

Literally flemish black. According to Veliz (1986), it is probable that this is a transparent brown/black pigment such as those known in northern Europe as Vandyke brown (*q.v.*).

Vandyke brown
Veliz (1986) 3

PRETO LAPIS

Black
Synonym, variant or common name

A term found in the early seventeenth century Portuguese treatise by Nunes (1615); Veliz (1986) considers that it probably refers to a pigment based on graphite or coal (*qq.v.*).

Coal; Graphite
Nunes (1615); Veliz (1986) 5, 8

PRIDERITE YELLOW

Yellow
Synonym, variant or common name

See: barium titanate yellow.

PRIMING GREEN

Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's green and/or emerald green (*qq.v.*), the term deriving from its application as a paint primer.

Emerald green; *Scheele's green*
Fiedler & Bayard (1997)

PRIMROSE AUREOLIN

Yellow
Synonym, variant or common name

Shade variant of aureolin sold, according to Carlyle (2001), by Winsor & Newton from 1889, as well as Reeves. Heaton (1928) still lists it as a current term when he was writing, stating it to be a 'pale variety of aureolin'.
See: cobalt yellow.

Potassium hexanitrocobalt(III); *Aureolin*; *Cobalt yellow*
Carlyle (2001) 262, 526; Heaton (1928) 383

PRIMROSE CHROME

Yellow
Synonym, variant or common name

Heaton (1928) lists primrose chrome as a current term when he was writing, stating it to be a 'very pale tint of Chrome' (that is, a pale lead chromate).

Lead chromates group
Heaton (1928) 383

PRIMROSE YELLOW

Yellow
Synonym, variant or common name

According to a *Composition of Pigments* list given in a Winsor & Newton catalogue of 1896, primrose yellow was a combination of the 'Chromates of Zinc and Barium' (cf. Carlyle, 2001). Heaton (1928) also includes primrose yellow among then-current terms, defining it as 'zinc chrome'. Kühn and Curran (1986), citing Remington (1944), indicate that of the three shades of zinc yellow (*q.v.*) being produced by the Scottish chemist Murdock, one was known as pale primrose.

Zinc chromates group; Barium chromate(VI); *Zinc yellow*
Carlyle (2001) 526, 536; Heaton (1928) 383; Kühn & Curran (1986); Remington (1944) 116

PRINCE'S METALLIC BROWN

Brown
Synonym, variant or common name

A commercial product described by Toch (1916) along with 'Princess Mineral Brown' as being derived from an ore mined in the US. Toch describes the ore as 'a carbonate, [which] lies between the upper Silurian and lower Devonian. It is a massive material of bluish gray color when mined, and resembles limestone, although it contains a very low percentage of lime … The ore is hauled to the kilns, where it is roasted, which drives of the carbon dioxid [sic] and converts it into the sesqui-oxid [sic].' The original manufacturer was Robert Prince of New York, USA, who became interested in a slate quarry in Carbon County, Pennsylvania.

Toch (1916) 75–76

PRINCESS MINERAL BROWN

Brown
Synonym, variant or common name

See: prince's metallic brown.

PROANTHOCYANIDINS GROUP

Variable
Group term

Proanthocyanidins ('PAs') are, with the hydrolysable tannins, one of the two principal classes of tannins. They are oligomers or polymers of flavonoid units (i.e. flavan-3-ol) linked by carbon-carbon bonds not susceptible to cleavage by hydrolysis. PAs are more often called *condensed tannins* due to their condensed chemical structure. However, hydrolysable tannins also undergo condensation reactions so that the term 'condensed tannin' is potentially confusing.

For a fuller discussion see the entry under tannins group.

Hydrolysable tannins group; Tannins group

PROCESS WHITE

White
Synonym, variant or common name

Heaton (1928) lists process white as a then-current term for a product based on *blanc fixe* (that is, a synthetic precipitated barium sulfate, *qq.v.*).

Barium sulfate; *Blanc fixe*
Heaton (1928) 383

PROUT'S BROWN

Brown
Synonym, variant or common name

Under the general heading of indelible brown ink, Salter (1869) describes 'a beautiful transparent brown for water-colour artists, known as Liquid Prout's Brown'. It was seemingly named for the English artist Samuel Prout (1783–1852). Salter implies that it was based on bistre or sepia (*qq.v.*), but with less binding medium than the indelible ink.

Bistre; Sepia
Salter (1869) 345–346

PRUSSIAN BLACK

Black-Brown
Synonym, variant or common name

This is calcined Prussian blue (*q.v.*). Normally a brown pigment, it could be heated further to give a black (Carlyle, 2001). Bouvier (1827) gives a detailed description of the preparation, which involved taking 'good, ordinary blue; not the English' (tr. Osborn, 1845), putting it into a specially made lidded iron box that was then sealed and covered with clay and brought to red heat in a fire.

Supposedly there was also a wet process involving mixing 'a dilute solution of cupric sulphate and ferrous sulphate, in proper proportions … with a quantity of ferrocyanide of potassium, not in excess' (Salter, 1869), though clearly this is giving one of the copper hexacyanoferrate(II) pigments: copper dipotassium hexacyanoferrate(II) or dicopper hexacyanoferrate(II) hydrate. Terry (1893) also discriminates between Prussian black (calcined Prussian blue) and Prussiate black, 'the carbonaceous residue from making yellow prussiate of potash'.

Copper hexacyanoferrate(II); *Prussian brown*; *Prussian blue*
Bouvier (1827) 79–80; Carlyle (2001) 199, 467; Osborn (1845) 60; Salter (1869) 408; Terry (1893) 26

PRUSSIAN BLUE

Blue
Synonym, variant or common name

Prussian blue is a term which might reasonably be considered applicable to any of the blue hexacyanoferrate(II) pigments (compounds based around $[Fe(II)(CN)_6]^{4-}$) which also contain Fe(III); it has been reported that a series of Fe(III) compounds is possible, variations on a composition of M(I)Fe(III)[Fe(II)$(CN)_6$].$n H_2O$, where M can be K, Na or NH_4 and n = 14–16 (Berrie, 1997), though aspects of the structure remain obscure (the entry *Hexacyanoferrate group* contains a fuller discussion of the chemistry).

The early history of Prussian blue has been extensively recorded and discussed, the best account being that of Harley (1982). Rejecting the often-quoted date of 1704 for the fortuitous discovery, she suggests that a conjectured date between 1704 and 1707 is more reasonable, also noting various early authors who discuss this give c. 1710. However, the key element to the story concerns a colour-maker, Diesbach, and an alchemist, Dippel, both of whom were recorded as working in Berlin. Harley goes on: 'The chance manufacture of the pigment resulted indirectly from Dippel's production of an animal oil which was distilled over some potash which was then treated as waste. Diesbach, who used to make Florence lake from cochineal, alum, English vitriol (ferrous sulphate) and a fixed alkali, ran short of alkali and asked Dippel for some of the potash which he saw had been thrown away. He was allowed to use it, and, after he had proceeded by his usual method, the lake appeared to be very pale. When he attempted to concentrate it, it turned purple and then deep blue. Diesbach returned to Dippel for an explanation and was told that the potash was tainted with animal matter.' Details of the manufacture remained secret until they were published in England in *Philisophical Transactions*; Harley summarises the complex methodology: 'To an alkali calcined with bullock's blood, dissolved and brought to boiling point, a solution of alum and ferrous sulphate was added while also boiling. During the effervescence which followed the mixture turned green, and, after it had been allowed to stand, it was strained. The residual greenish precipitate turned blue as soon as spirit of salt (hydrochloric acid) was poured on it.' Production must have been taken up quickly, enthusiastically and widely, since by 1764 Dossie was writing that 'The common Prussian blue, found in the shops, which is prepared almost wholly at present by ignorant and sordid people, and sold at very low prices, can be very little depended upon in paintings of consequence.'

Given the complex chemistry, it is hardly surprising that there is not only deep confusion, but also a spread of terminology according to what the composition or method of production was supposed to be. Church (1901), for example, describes 'at least three different though closely allied chemical compounds': (a) soluble Prussian blue was a 'potassio-ferric ferrocyanide', (b) insoluble Prussian blue and (c) Turnbull (or Gmelin's) blue. However, Church also considered that so-called English and French Prussian blues were sufficiently distinct to give different browns on calcination.

The intensity of colour with Prussian blue meant that other pigments were frequently added or the pigment adulterated. With regard to adulterants, Martel (1860) wrote 'That manufactured in Berlin contains alumina; but English and French Prussian blue generally contain alumina only as an adulteration.' Church also lists plaster of Paris and zinc white as adulterants, while Salter (1869) lists alumina, starch, chalk and iron oxide as present in cheaper varieties and Standage (1887; cf. Carlyle, 2001) mentions 'Ochres and other earths, mineral matters, chalk, pipeclay, sulphate of lime and baryta; sometimes starch coloured blue with iodine.' The English colourmen's firm Berger added alum until 1834 when it was realised that this ingredient was unnecessary and had only been used as it had been thought essential for the precipitation of the pigment, probably with reference to its role in lake pigments (Carew-Reid, 1997). German sources indicate that the term Paris blue (*q.v.*) was applied to this darker product. Riffault *et al.* (1874) describe Antwerp and Mineral blues as mixtures of Prussian blue with alumina, magnesia and zinc oxide.

Numerous synonyms and related terms are known and examples include: American blue, ammonium Prussian blue, Antwerp blue, ariabel dark blue, Berlin blue, bronze blue, celestial blue, Chinese blue, cobalt Prussian blue, cyanine, Erlangen blue, French blue, gas blue, Haarlem blue, Hamburg blue, iron blue, lacquer blue, Leitch's blue, Manox iron blue, Marie-Louise blue, Milori blue, mineral blue, Monthier's blue, new blue, oil blue, oriental blue, Paris blue, paste blue, Persian blue, potash blue, Radiogradase, Saxon blue, soluble blue, steel blue, toning blue, Turnbull's blue, Vossen blue and Williamson's blue (Gardner *et al*., 1987; Berrie). Bersch (1901) supplies a number of German terms including *Sächsischblau, neublau, oelblau, wasserblau, mineralblau, Erlangerblau, Zwickauerblau, waschblau, Louisenblau, Raymondblau*. Placenames do not necessarily imply a place of origin (for example, 'Persian blue'), though some probably were. Other terms indicate particular varieties, such as ammonium Prussian blue, which was Prussian blue treated with ammonia according to Monthiers' process (Monthiers, 1846). *Manox* and *Vossen* are trade names, while Milori originally related to a trade name but became more generally applied. Iron blue is a modern term now widely used for this class of pigments (Buxbaum, 1998).

Prussian blue has been widely reported in analyses. The summary provided in the review by Berrie documents early use of Prussian blue in a work predating 1722 by Adriaen van der Werff (1659–1722) and two Italian paintings of 1719–23 by Canaletto (1697–1768) as well as at least one painting by Antoine Watteau (1684–1721); a receipt dated 1723 for wall paint containing the pigment for Trinity Church, Boston, USA, has also been recorded. Occurrences in numerous other works by a wide range of European and American artists since that time are also given by Berrie and others. In addition, Kirby (1993) has reported an early use of the pigment, demonstrating occurrence by 1712 in Berlin and before 1721 in England. In other contexts, use in Naskapi artefacts is given by Moffatt *et al*. (1997); presence in laundry blueing employed as a pigment in ethnographic material from Oceania is given by Barton and Weik (1998); Selds *et al*. (1999) document Prussian blue among pigments used in South American painting of the period before 1780; the pigment has been observed in a late eighteenth century wax modelling technique by Paschinger and Richard (2000); its use in dark blue stucco-work and overdoors at the late eighteenth century Hodson House in Haarlem, the Netherlands, is given by Verweij (2000); use in decoration on a salon table of 1840 by Franz Xaver Fortner has been reported by Schwarz and Piening (2001). Occurrences in Japanese artefacts are rerported by Leona and Winter (2001) and Kuchitsu and Shimomura (2002).

Hexacyanoferrate group; *Antwerp blue*; *Berlin blue*; *Chinese blue*; *Mineral blue*; *New blue*; *Paris blue*

Barton & Weik (1998); Berrie (1997); Bersch (1901); Buxbaum (1998) 131; Carew-Reid (1997); Carlyle (2001) 470–476; Church (1901); Dossie (1764) 83; Gardner *et al*. (1978); Harley (1982) 70–74; Kirby (1993); Kuchitsu & Shimomura (2002); Leona & Winter (2001); Martel (1860) 16; Moffatt *et al*. (1997); Monthiers (1846); Paschinger & Richard (2000); Riffault *et al*. (1874); Salter (1869) 203; Schwarz & Piening (2001); Selds *et al*. (1999); Standage (1887); Verweij (2000)

PRUSSIAN BROWN

Brown
Synonym, variant or common name

Salter (1869) states that this should be prepared by calcining an aluminous Prussian blue (*q.v.*) or, alternately, 'treating an aluminous ferrocyanide of peroxide of iron with an alkali'. Later, he also cites Bouvier (1827) under what he terms French Prussian brown; this was produced by charring a 'moderately dark' Prussian blue, 'neither one too intense, which gives a heavy and opaque brownish-red, nor one too aluminous and bright, which yields a feeble and yellowish tint'. Church (1901) indicates that the Prussian blue used as a starting material should contain no potassium and that his so-called 'insoluble' form of Prussian blue was 'the only one which yields, when roasted, a perfectly satisfactory "Prussian brown"'. His directions are that small hazel-nut size pieces of Prussian blue should be thrown on to an iron plate maintained at red heat until the fragment was the required colour.

Mierzinski (1881) and Zerr and Rübencamp (1906) call this pigment Berlin brown.
See: Prussian black and Prussian blue.

Prussian black; *Prussian blue*
Bouvier (1827); Church (1901); Mierzinski (1881) 33; Salter (1869) 348, 355; Zerr & Rübencamp (1906/1908) 284

PRUSSIAN GREEN

Green
Synonym, variant or common name

The identity of this pigment varied, but early sources describe two varieties: one made by stopping the manufacture of Prussian blue at the stage where the sediment produced was green and another compounded of Dutch pink and Prussian blue (*qq.v.*; *A Practical Treatise*, 1795; de Massoul, 1797; Field, 1835). However, Field also identified another made from potassium cyanide and cobalt nitrate; this must also be the 'double salt of cyanure of iron and cobalt' noted by Vibert (1892; cf. Carlyle, 2001). Further, in the Salter (1869) and Scott Taylor (1885) editions of Field, Prussian green is described as a mixture of Prussian blue and gamboge, though yellow ochre (*qq.v.*) could apparently be substituted for the latter. Interestingly, the term was still current for Heaton (1928) who lists the composition as Brunswick green (*q.v.*); Heaton considered this latter pigment to be comprised of 'mixtures of Prussian blue, chrome yellow and barytes' (*qq.v.*).

Baryte; Gamboge; *Brunswick green*; *Chrome yellow*; *Dutch pink*; *Prussian blue*; *Viridian*; *Yellow ochre*
Carlyle (2001); Field (1835); Heaton (1928) 383; Massoul (1797); *Practical Treatise* (1795); Salter (1869) 281–282; Scott Taylor (1885) 140; Vibert (1892)

PRUSSIAN PURPLE

Purple
Synonym, variant or common name

Described by Salter (1869) who says that 'A prussiate of iron is obtainable of a violet hue [… that] has not, however, been introduced as a pigment, as ordinary Prussian blue [*q.v.*] tinged with red furnishes a similar colour.'

Prussian blue
Salter (1869) 307

PRUSSIAN RED

Red
Synonym, variant or common name

Widely used term in the eighteenth and nineteenth centuries for a modified earth or a synthetic iron oxide pigment. Watin (1785), for example, describes it as either a calcined earth, or, more likely a *caput mortuum* or colcothar (*qq.v.*); he also links it to the term Nürnberg red.

Burnt ochre; *Caput mortuum*; *Colcothar*; *Red ochre*
Watin (1773/edition of 1785) 22–23

PRUSSIATE BLACK

Black
Synonym, variant or common name

Terry (1893) discriminates between Prussian black (calcined Prussian blue; *qq.v.*) and Prussiate black, 'the carbonaceous residue from making yellow prussiate of potash'.

Prussian black; *Prussian blue*
Terry (1893) 26

PSEUDOMALACHITE

Green
Generic compound

Pseudomalachite is a basic copper phosphate mineral with composition $Cu_5(PO_4)_2(OH)_4$. It may contain appreciable AsO_4, forming a series with cornwallite, $Cu_5(AsO_4)_2(OH)_4$. Pseudomalachite occurs as green botryoidal masses, aggregates and crusts or as prismatic crystals and is named after its similarity in appearance to malachite (*q.v.*). It was described by Hausmann in 1813 and is relatively common worldwide, occurring as a secondary mineral in the oxidised zones of copper deposits, often in association with libethenite (*q.v.*). Pseudomalachite is polymorphous with reichenbachite (also monoclinic) and the triclinic form ludjibaite (Shoemaker *et al.*, 1981), compounds which had been synthesised much earlier than their discovery as natural minerals by Siber *et al.* (1987) and Piret and Deliens (1988). The three polymorphs form in the same natural setting, often mixed together, although pseudomalachite is the most abundant; it is therefore possible that when natural pseudomalachite is identified in an art context, the presence of the other polymorphs should also be considered (Anderson *et al.*, 1997; Dana, 1932; Ghose, 1962, 1963).

This compound has been identified by Richter (1988) in a painting dated 1497 and by Naumova *et al.* (1990) in Russian frescos dating back to the early sixteenth century in the Cathedral of the Nativity of the Virgin of the Ferapontov monastery, Vologda Region.

Copper phosphates group; Libethenite; Malachite
Anderson *et al.* (1977); Dana (1932) 716; Ghose (1962); Ghose (1963); Naumova *et al.* (1990); Piret & Deliens (1988); Richter (1988); Shoemaker *et al.* (1981); Siber *et al.* (1987)

PSEUDOPURPURIN

Red-Brown
Generic compound

Pseudopurpurin, 1,2,4-trihydroxyanthraquinone-3-carboxylic acid, is one of the main anthraquinones, along with pupurin and alizarin, found in madder (*qq.v.*) derived from *Rubia tinctorum* L. and many other plants of the Rubiaceae including *Gallium* and *Relbunium* species. It is selectively extracted and used for the preparation of rose madder (*q.v.*). The shade of any resultant lakes varies depending on the method of extraction and on the substrate (typically aluminium hydroxide or calcium carbonate) (Schweppe and Winter, 1997). It is listed in the *Colour Index* (1971) as CI 75420 when derived from natural sources and in its synthetic form as CI 58220.

Anthraquinones group; Alizarin; Madder; *Rose madder*
Colour Index (1971) 58220, 75420; Schweppe & Winter (1997)

PUMICE
White
Generic compound

Pumice is typically classified as a pyroclastic igneous rock, only produced in highly explosive and infrequent volcanic eruptions where the magmas are of an 'acidic' (silica content greater than 66%) to 'intermediate' (silica content about 56–66%) composition and very viscous. For such magmas, however, pumice can dominate the eruption products and cubic kilometres of material may be produced in a single eruptive event. It is therefore locally abundant. Pumice is an aerated, silicon oxide glass; a solidified foam or froth. It forms at the top of magma chambers, just prior to eruption as a result of rapid decompression of the melt. It is usually white, yellowish, pale grey or grey brown in colour and of very low density being highly vesicular (rich in bubbles). Such densities of less than 1 $g.cm^{-3}$ mean that it will float on water and fragments may be transported across seas and down rivers from its original source. Pumice can vary in texture from being soft and friable to being relatively hard and rigid; crystalline inclusions may be also present. These vary in composition depending on the specific magma composition but are typically quartz, mica, hornblende, apatite (*qq.v.*), zircon and sphene. Pumice may degrade via the processes of devitrification to various clay minerals including kaolinite, halloysite (*qq.v.*) and so forth. Major pumice deposits are found in the Mediterranean particularly in southern Italy (Roman and Neapolitan volcanic provinces) and on the Greek islands of Melos and Santorini. Other major deposits are in the Cascade ranges of the North American Pacific Coast and in North Island, New Zealand. Pumicite is powdered pumice.

Pumice is mentioned as an addition to prepared oils, mixed with calcined hartshorn, in the *Strasburg MS* (Clarke MS 2000; tr. Borradaile, 1966).

Apatite group; Clay minerals group; Mica group; Halloysite; Honblende; Kaolinite; Quartz
Strasburg MS (15th cent/tr. Borradaile, 1966)

PUMICITE
White
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77019), pumicite is a whitish powdery volcanic ash mined extensively in the US.
See: pumice.

Pumice
Colour Index (1971) 77019

PURE SCARLET
Red
Synonym, variant or common name

Pure scarlet was synonymous with iodine scarlet (mercury iodide, *q.v.*); authors who used this term include the later editors of Field's *Chromatography*, Salter (1869) and Scott Taylor (1885), as well as Seward (1889). It is listed as an obsolete or rarely used term by Heaton (1928).

Mercury iodide
Heaton (1928) 383; Salter (1869) 150–151; Scott Taylor (1885) 74; Seward (1889)

PUREE
Yellow
Synonym, variant or common name

Historical term associated with Indian yellow listed, for example, by Heaton (1928), though it was by then considered by him to be only an obsolete or rarely used term.
See: piuri and Indian yellow.

Indian yellow; *Piuri*
Heaton (1928) 383

PUREX WHITE LEAD
White
Synonym, variant or common name

Heaton (1928) lists Purex white lead as a by-then obsolete or rarely used term for a pigment composed of 'basic sulphate of lead'.

Lead sulfates group
Heaton (1928) 383

PURPLE BLACK
Black
Synonym, variant or common name

Various nineteenth century British sources such as Field (1835), Fielding (1839) and Salter (1869) describe purple black as prepared from madder (*q.v.*), probably in the form of a calcined lake.

Madder
Field (1835); Fielding (1839) 128; Salter (1869)

PURPLE BROWN
Purple
Synonym, variant or common name

The term purple brown is used by Heaton (1928), who gives the composition as the 'deepest shade of artificial oxide of iron'. This is probably related to the 'purple brown calx of iron' mentioned in *A Practical Treatise* (1795) and the various synthetic iron oxide pigments discussed in a British patent of 1794 by Atkinson described as 'chocolate purple brown, blue purple and dark purple brown' (cf. Harley, 1982).
See: mars violet and mars pigments.

Iron oxides and hydroxides group; *Mars pigments*; *Mars violet*
Atkinson (1794) 89–97; Harley (1982) 122; Heaton (1928) 383; *Practical Treatise* (1795)

PURPLE LAKE
Purple
Synonym, variant or common name

Carlyle (2001), in her study of nineteenth century British documentary sources, specifically notes that purple lake was consistently reported to be made from a cochineal lake although she also lists it as a synonym for, or prepared from, alizarin (*qq.v.*). Field (1835) states that 'The best purple lake so called is prepared from cochineal … [it] is of a rich and powerful colour, inclined to crimson.' Salter (1869) adds that it is 'a species of crimson lake with a purple cast, transparent and deep-toned'.

Alizarin; Cochineal
Carlyle (2001) 502; Field (1835) 137; Salter (1869) 137

PURPLE MADDER

Purple
Synonym, variant or common name

See: Field's purple.

PURPLE OCHRE

Purple
Synonym, variant or common name

Field (1835) describes purple ochre as a native ochre from the Forest of Dean, Gloucestershire, England, though in the 1841 edition he notes that it can be made artificially by calcining natural red ochres (*qq.v.*) and 'has been employed under the denomination of *Violet de Mars*'. Salter (1869) remarks on the difficulty of obtaining the pigment and says mars violet was often compounded, though usually with Indian red (*qq.v.*) as the base. Vibert (1892) on the other hand included it with permanent iron oxide colours which were either naturally fixed on clay or artificially on alumina.

Ochre; *Indian red*; *Mars violet*; *Red ochre*
Field (1835) 137–138; Field (1841) 249; Salter (1869) 299; Vibert (1892)

PURPLE OF CASSIUS

Red-Purple
Synonym, variant or common name

Purple of Cassius is variously coloured from ruby red to purple and was used first in the colouring of glass and ceramic glazes, eventually being produced as an artists' pigment. It was purportedly discovered by Andreas Cassius the elder (died c. 1673; first published 1685), a scientist working in Hamburg in the late seventeenth century; however, Partington (1961; cf. Harley, 1982) has found a red glass of similar composition described in the fourteenth century and the fifteenth century Bolognese manuscript (Clarke MS 160; cf. Merrifield, 1849) which gives a description of the process of making a purple colour from gold. Several mediaeval glassmaking manuscripts such as *Il codice di Montpellier* of 1536 (cf. Zecchin, 1990) also give recipes for gold-ruby glass. *L'Arte Vetraria* by Neri (1612) describes heating gold '*che venga in poluere rossa, and quella cacinatione si faccia con aqua regis piu volte … che seguira in piu giorni … cristallo fine and poco a poco il vero rosso trasparente di Rubino*' ('which becomes a red powder, and this calcination is added to *aqua regia* [a mixture of nitric and hydrochloric acids] several times … there will follow in a few days … a fine crystal and bit by bit the true transparent red of Rubino'. These latter recipes do not mention the addition of a solution of tin filings (this also dissolved in *aqua regia*) whereas Dossie writing in 1758 (cf. Harley), states that the solution of powdered gold should be poured into water and then a smaller amount of the tin solution added until a red precipitate forms, this is also called gold red (*q.v.*; Salter, 1869). This he considered to be an enamelling colour; however, by 1797 de Massoul lists precipitate of gold as an artists' pigment. Field states in 1809 that the colour was used primarily in miniature painting due to its very great cost, he additionally describes a variant called gold blue (*q.v.*). The purple form is made by the addition of a solution of potassium carbonate. It is also still listed as a pigment by Osborn in 1845, described as not brilliant but of great solidity and great expense.

Tin was also contained in the gold-ruby glass prepared by Kunckel in 1689 following recipes of Georgius Agricola (1556) and Antonio Neri (1612). Kunckel probably used so-called purple of Cassius, formed by colloidal metallic gold adsorbed into hydrated tin(IV) oxide, reducing $AuCl_4^-$ with $SnCl_2$ (or following the alchemist language by *praecipitatio Solis cum Jove*). Kunckel fixed this colouring agent into the raw glass by firing the glass mass until formation of a brilliant ruby colour.

It is important to stress that the coloration of the glass by clusters (different from that by metallic ions) is effective only with the more noble metals. Gold salts give rise to a ruby colour; copper salts were used in the glass typologies called *rosso de la Magna*, *rosechiero*, *aventurina*, etc.; silver salts produced the yellow typical of the mediaeval-stained glasses. In these glasses the colour is mainly imparted by the fine dispersion of precipitated metal (or oxide) in the glass and it is due to the light scattered from the particles. In the presence of more transition metal ions the atmosphere of the furnace determines redox reactions among the various ions present. These reactions among the different metal ions, during the preparation steps, are responsible for the formation of the glass colour.

In particular, for gold-ruby glass, the colour depends on the size of the precipitated particles, which in turn depends on the procedure adopted in the manufacture. A properly controlled temperature programme promotes the growth of the metallic gold droplets to the size required to produce the ruby colour. The ancient procedure is unknown, since it has not been recorded among the old recipes of the glassmakers. However, the source of the colour continues to fascinate researchers (Alvarez *et al.*, 1997).

Gold group; *Gold blue*; *Gold red*
Agricola (1556/trans. Hoover & Hoover, 1950); Alvarez *et al.* (1997); Cassius (1685); Dossie (1758); Field (1809); Harley (1982) 128; Kunckel (1689) 275; Massoul (1797); Merrifield (1849) 388; Neri (1612/Mentasti, 1980) 108–109; Osborn (1845); Salter (1869) 166; Zecchin (1990) 248

PURPLE RED

Red-Purple
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77825), purple red is synonymous with silver chromate (*q.v.*; Ag_2CrO_4). Produced by precipitating silver nitrate with potassium chromate, it is stated to have been used as an artists' colour. However, the composition of purple red named in the sketchbook of Bouguereau (1869) is given as mercuric chromate (*q.v.*; Walker, 2003). A possibly related term 'purple scarlet' is listed in a Rowney catalogue of 1849, although the composition is unknown (cf. Carlyle, 2001).

Mercury chromate; Silver chromate
Carlyle (2001); *Colour Index* (1971) 77825; Walker (2003)

PURPLE SCARLET

Purple
Synonym, variant or common name

Purple scarlet is listed in a Rowney catalogue of 1849; the composition is unknown, however (cf. Carlyle, 2001).

Carlyle (2001) 502

PURPURIN

Red
Generic compound

Purpurin, 1,2,4-trihydroxyanthraquinone, is an anthraquinone found in association with alizarin and pseudopurpurin in dyestuffs derived from various Rubiaceae ('madder') species therefore a common component of lake pigments produced from them. It is also produced synthetically and may be used for so-called 'alizarin violet'. The synthetic form is listed in the *Colour Index* (1971) as CI 58205, the natural form as CI 75410.

Madder treated by soaking and saturation with sulfuric acid and heat produces the pigment known as Kopp's purpurin (Kopp, 1864; cf. Schweppe and Winter, 1997). Purpurin or the madder preparation Kopp's purpurin is the colourant for purpurin madder lake.
See: madder.

Anthraquinones group; Alizarin; Madder; Pseudopurpurin
Colour Index (1971) 58205, 75410; Schweppe & Winter (1997)

PURPURINO

Yellow
Synonym, variant or common name

See: tin sulfides group and mosaic gold.

PURPURINUS

Yellow
Synonym, variant or common name

Purpurinus was used as a term for mosaic gold (*q.v.*; tin(IV) sulfide). For example, the MS of Jehan Le Begue *Experimenta de Coloribus* (1431, Clarke MS 2790; cf. and tr. Merrifield, 1849) provides the following recipe: '*To make the colour purpurinus* … sal ammoniac … quicksilver … sulphur vivum … tin. Melt the tin over the fire, pour the quicksilver into it … allow to stand … grind sal ammoniac and sulfur together, add to melted tin and quicksilver … put all in a glass flask … cover with chalk. Place flask in a small furnace, in a hole at the top of a furnace … by means of a hole made in the side of a furnace. Make a strong fire in it, and cover the mouth of the flask with a plate of iron, pierced in order that the vapour may escape from the flask, and continue the fire strongly until the fumes cease to come from the flask. Then remove it from the fire, let it cool, break the flask, and take your purpurinus.'

Mosaic gold
Merrifield (1849) I, 54

PURPURITE

Purple
Generic compound

Purpurite is a manganese(III) phosphate mineral with composition $MnPO_4$. It may also contain iron as it forms a solid solution series with heterosite, $FePO_4$; in older mineralogical texts, the formula for purpurite is actually given as iron manganese phosphate. It was first described by Graton and Schaller in 1905 from the Faires mine (North Carolina, USA) and is named from the Latin word for purple, *purpureus*. It is a rare mineral, occurring as earthy purple masses, crusts and nodules, or as granular aggregates, but rarely as larger well-formed crystals; the colour may also vary from pale purple to dark red, with brown-black surfaces sometimes encountered due to oxidation. Purpurite forms as a secondary mineral in pegmatite rocks, usually as an alteration product of lithium phosphate minerals (e.g. lithiophyllite, $LiMnPO_4$) by Li-leaching. It is usually found in association with heterosite, lithiophyllite, quartz and members of the feldspar group (*qq.v.*) of minerals. It is known from Vasterbotten (Sweden), Fregeneda (Spain; e.g. Roda *et al.*, 1996), French Pyrenees (France) and Sandamab mine (Namibia).

There is little evidence for its historical use as a pigment although it is currently available from Kremer Pigmente, Germany.

Feldspar group; Manganese group; Manganese phosphates group; Quartz
Roda *et al.* (1996)

PURREE

Yellow
Synonym, variant or common name

See: piuri and Indian yellow.

PYRAZOLONE PIGMENTS

Yellow-Orange
Group term

Group of yellow to orange azo pigments that are based on pyrazolone.
See: azo pigments group.

PYRITE

Yellow-Brown
Generic compound

Pyrite, along with marcasite, are naturally occurring metallic yellow iron sulfide compounds (FeS_2). Terry (1893) mentions iron black as a ground iron sulfide; however it is not clear if this is from the mineral source. A tentative proposal for the use of a bismuth and antimony-rich iron mineral such as an impure pyrite in the dark pigments of Frà Bartolomeo's paintings has been noted by Buzzegoli *et al.* (1998).

Pyrite has also been noted as an admixture in Egyptian blue (*q.v.*) by Scott (2002).

Iron sulfides group; *Egyptian blue*
Buzzegoli *et al.* (1998); Scott (2002) 257–262; Terry (1893) 26

PYROLUSITE

Black
Generic compound

Pyrolusite is a manganese(IV) oxide mineral with composition MnO_2 (often designated as β-MnO_2). It is the most common of the manganese minerals and usually occurs as dark grey submetallic masses and crusts that may have an internal fibrous or radiating structure; it also occurs with fine dendritic growth or as acicular hair-like aggregates. It is only rarely found as larger well-developed crystals, and with this morphology it is usually known as polianite. Pyrolusite forms in the oxidised zones of manganese deposits along with other manganese oxide minerals such as manganite, manganosite, braunite and bixbyite (*qq.v.*), which aggregate together in nodules; it also forms in shallow marine, lacustrine or bog environments, with colloidal and bacterial processes playing an important role; it also occurs as an alteration product of manganite, rhodochrosite or hausmannite and may be found as a component of wad (*qq.v.*). Pyrolusite is found in localities around Broken Hill (New South Wales, Australia), Ariège (France), Elgersburg (Germany), Laurion (Attica, Greece), Styria (Austria), Cornwall (England), Tuscany (Italy) and Irasberg (Vermont, USA). Although pyrolusite is a well-characterised tetragonal manganese oxide mineral, the term has been applied to any manganese mineral with dendritic habit or any black alteration product of manganese minerals (see Rutley, 1988 and Dana, 1944).

Pyrolusite has been identified by Sánchez-Moral *et al.* (2002) as a component of the black pigments in the prehistoric caves of Galdar (Canary Islands, Spain). The compound has been identified with various iron oxides in prehistoric pictographs in Seminole Canyon, USA, by Zolensky (1982). Middleton (1999) has identified pyrolusite on Egyptian painted reliefs (tomb of Djehutyhotep at El-Bersheh, later twelfth dynasty). Panev (1979) has identified pyrolusite (and the related hausmannite) in Bulgarian icons of the Middle Ages and Renaissance. Use of manganese oxide as a pigment in paintings by Correggio (c. 1489–1534) is discussed by Seccaroni (1999a).

Manganese oxides and hydroxides group; Bixbyite; Braunite; Hausmannite; Manganese(IV) oxide; Manganite; Manganosite; Wad; *Manganese Brown*

Dana (1944) 562; Middleton (1999); Panev (1979); Rutley (1988) 268; Sánchez-Moral *et al.* (2002); Seccaroni (1999a); Zolensky (1982)

PYROMORPHITE

Variable

Generic compound

Pyromorphite is a lead phosphate mineral, with ideal composition $Pb_5(PO_4)_3Cl$, although it may also contain additional elements such as magnesium, copper, zinc, barium, potassium, arsenic, calcium and fluorine. It is most commonly bright green or yellow-green, but may be yellow, grey or yellow-red, orange or colourless due to the presence of such impurities. The green examples are also known as green lead ore. It was first discovered by Hausmann in 1813 and belongs to the apatite group (*q.v.*) of minerals as it has the same structure. It is isomorphous and chemically most similar to the minerals mimetite and vanadinite ($Pb_5(VO_4)_3Cl$) (*qq.v.*). Pyromorphite forms a complete chemical series with mimetite in which the anion groups (PO_4, AsO_4) are interchangeable so that intermediate compositions may be found. Pyromorphite is a relatively rare mineral and forms in the oxidising zone of lead deposits as brightly coloured prismatic crystals aggregated together, as granular crusts, or as reniform or botryoidal masses (Dana, 1932; Rutley, 1988). It is found in areas such as Cornwall and Cumbria (England), Idaho (USA), Durango (Mexico), Harz and Saxony (Germany), Broken Hill (New South Wales, Australia), Tsumeb (Namibia) and Attica (Greece), where it often occurs with cerussite, galena and anglesite (*qq.v.*).

Pyromorphite has been identified by Béarat (1996b) in a discussion of lead-based pigments in Roman mural paintings. Winter (1981) has identified white lead phosphate on a fourteenth century (Kamakura) panel to which he found pyromorphite, oxypyromorphite ($Pb_{10}(PO_4)_6O$) and mimetite the most closely related natural minerals.

Apatite group; Lead group; Lead phosphates group; Anglesite; Cerussite; Galena; Limonite; Mimetite

Béarat (1996b); Dana (1932) 706; Rutley (1988) 338–339; Winter (1981)

PYROPHYLLITE

White

Generic compound

Pyrophyllite is a white aluminium sheet silicate mineral with composition $Al_4[Si_8O_{20}](OH)_4$. It belongs to the mica group (*q.v.*) of minerals. It is commonly pure although minor impurities of Fe, Mg, Ca, Na, K, Ti or F do occur, resulting in brown, brown-green, yellow or pale blue varieties. Pyrophyllite occurs as compact scaly masses, radiating acicular crystals or as fine-grained flexible laminae. Its layered internal structure, consisting of SiO_4 sheets separated by Al cations in selected octahedral sites (a dioctahedral mica), promotes cleaving into scales and laminae (Deer *et al.*, 1992). It differs from the other micas in that it contains no Al within the SiO_4 sheets. The constituent layers of pyrophyllite are stacked slightly differently to those of the other micas, and of the two polymorphs of pyrophyllite ('2M' monoclinic and '1T' triclinic), the two-layered (2M) repeating structure is the most common (Dana, 1932; Rutley, 1988). In nature, pyrophyllite forms in Al-rich metamorphic rocks with quartz and mica group minerals, or as a secondary product from the hydrothermal alteration of feldspar group (*qq.v.*) minerals and muscovite. It is found in areas such as Krassik (Russia), Valais (Switzerland), Minas Gerais (Brazil), Gundaga (New South Wales, Australia), Bisbee (Arizona, USA), Hesse (Germany), Tuscany (Italy), Varmland (Sweden) and Lizard (Cornwall, England). The structure of pyrophyllite has been described by Gruner (1934) and Lee and Guggenheim (1981).

The *Colour Index* (1971) describes naturally occurring micaceous potassium aluminium silicates as CI Pigment White 20/26.

Aluminium group; Feldspar group; Mica group; Sheet silicates group; Muscovite; Quartz

Colour Index (1971); Dana (1932) 683; Deer *et al.* (1992) 324–326; Gruner (1934); Lee & Guggenheim (1981); Rutley (1988) 404–405

Q

QUARTZ

White

Generic compound

Quartz is a silicon dioxide mineral with composition SiO_2. It is generally found close to purity and therefore colourless or white, but it can have impurities which cause many coloured varieties, such as: rose quartz (pink), which contains titanium or tiny needles of rutile (*q.v.*); citrine (yellow), which contains colloidal ferric hydroxide; amethyst (*q.v.*) is a purple semi-precious variety containing Fe^{3+}; smoky quartz (grey-brown) may have aluminium in the crystal structure. Quartz is the stable form of SiO_2 at ambient conditions and is polymorphous with the high temperature forms tridymite (>870°C) and cristobalite (>1470°C (*qq.v*), although transitions may take place at lower temperatures when other fluxing phases are present); high pressure forms, coesite and stishovite, are also known to exist. Quartz has two polymorphs itself: α-quartz (or low quartz), which is trigonal, is the most common polymorph as it is stable to approximately 570°C; above this temperature it inverts to the hexagonal β-quartz (or high quartz); the two structures are similar, involving slight distortions and rotations of the constituent SiO_4 tetrahedra. After the feldspar group (*q.v.*) of minerals, quartz is the most abundant mineral at the earth's surface. It is thus a very common mineral, occurring in a wide variety of geological settings in association with many other minerals. Quartz is a primary component of acid igneous rocks (such as granites) and important in many intermediate igneous and metamorphic rocks, where it is found as anhedral crystals, often intergrown with plagioclase, sanadine and orthoclase feldspars; it is the primary constituent of many sedimentary rocks (such as arsenites) where it is found as angular to rounded grains; it also occurs as a secondary mineral in hydrothermal and ore veins, with euhedral prisms and coloured varieties common; it also forms a cementing agent in sediments. The hardness, inertness and lack of cleavage of quartz means that it is a very stable and durable material. Hence it is one of the final minerals to be broken down during the weathering of these rock types and is a common detrital material. Quartz therefore often forms a large proportion of beach material and is often referred to as 'sand', although this term strictly refers to a grain size (0.06–1 μm). The properties and abundant availability of quartz meant that it was often used to assist in the grinding of pigments; hence, relict quartz may be found within pigment samples (Rutley, 1988).

Quartz is frequently found among pigments, probably most often as an associated material. Examples of identifications include the lid of a 3000-year-old Egyptian mummy case by Havrevold (1985), Roman pigment pots from Mainz, Germany, by Bachmann and Pfeffer (1979), pigments and plasters from wall paintings of Buddhist temples in northwest China by Duang *et al.* (1987) and among murals pigments of Qutan Temple, Qinghai, China by Wang *et al.* (1993a). Aboriginal rock-painting pigments near Laura, North Queensland, analysed by Watchman *et al.* (1993) contained quartz; Watchman *et al.* (2001) identified quartz in rock surface crusts covering ancient rock engravings at the Carpenter's Gap archaeological site (Kimberley, Australia); here the quartz was found in association with whewellite, weddellite, bassanite, calcite, ankerite, dolomite, albite, muscovite and kaolinite, with minor gypsum, anhydrite, epsomite and halite (*qq.v.*) also present. Quartz is also reported to be present in Anglo-Saxon polychrome plaster and other materials from the excavations of Monkwearmouth and Jarrow, UK, by Cramp and Cronyn (1990) as well as on paintings by Johann Georg Rudolphi (1633–93) by Maue *et al.* (1979) and Johan Christian Dahl (1788–1857) by Plahter and Plahter (1988). Plesters (1993) has indicated from analysis of X-ray diffraction data of lazurite (*q.v.*) that some samples may additionally contain quartz with calcite, forsterite and diopside also (*qq.v.*).

Feldspar group; Silicates group; Amethyst; Cristobalite; Tridymite

Bachmann & Pfeffer (1979); Cramp & Cronyn (1990); Duang *et al.* (1987); Havrevold (1985); Maue *et al.* (1979); Plahter & Plahter (1988); Plesters (1993); Rutley (1988) 427–429; Wang *et al.* (1993a); Watchman *et al.* (1993); Watchman *et al.* (2001)

QUEEN'S YELLOW

Yellow

Synonym, variant or common name

Queen's yellow was applied in historical chemistry as a term for a mercury sulfate: Ure (1839), for example, reports that '*Queen's yellow* is an ancient name of Turbith Mineral, or yellow subsulfate of mercury'. Presumably there was some analogy here to the use of 'King's yellow' for orpiment.

Mercury sulfate; *Turbith mineral*

Ure (1839) 1054

QUERCETIN

Yellow

Generic compound

Quercetin, 2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-4H-1-benzopyran-4-one (or: 3,3′,4′,5,7-pentahydroxyflavone), is a flavonoid compound which, along with its glycosides is the most widely distributed in the plant kingdom, particularly in rinds and barks (Schweppe, 1992). It forms the principal component in the dye known as quercitron (*q.v.*), which was used historically to produce yellow dyes and lake pigments.

Thompson (1935) has noted the use of apple tree bark to produce a yellow described in two fifteenth century German texts; *Malus* species (Rosaceae) are known to contain quercetin in their bark, especially that covering the roots and quercetin is a minor component of *Vaccinium myrtillus* L. and walnut dyes from species such as *Juglans nigra* L.

Also sometimes given incorrectly as quercitin. Quercitrin is the glucoside (3-L-rhamnoside; *Colour Index*, 1971, CI 75720/Natural Yellow 10) in *Quercus velutina* Lam. bark. The *Colour Index* lists quercetin under CI 75670/Natural Yellow 10, 13/Natural Red 1.

Flavonoids group; Quercitron; Vaccinium; Walnut; *Apple-tree bark*
Colour Index (1971); Schweppe (1992) 331; Thompson (1935) 415, n.1

QUERCITRON

Yellow
Generic compound

Quercitron was a historically important natural yellow dye derived from the black or dark brown bark of the black oak (also sometimes known as the yellow oak), *Quercus velutina* Lam. (Fagaceae; formerly also known as *Q. tintoria* Bartr. Ex. Michn., *Q. nigra* du Roi non L. and *Q. discolor* Ait.), which is native to the eastern and midwestern part of the United States (Mills and White, 1994). The principal colouring matter is quercetin (*q.v.*), a flavonoid dyestuff found in a wide range of plants, along with quercetagetin and flavine. Quercetin produces a bright yellow with aluminium and tin, a tan colour with chromium and an olive green with iron; quercetagetin produces shades of orange and flavine gives a brilliant yellow with aluminium or tin. The dye is extracted from the oak bark with boiling water, the outermost layer giving a bright yellow while the inner bark gives darker oranges and tans. Quercitron is also said to have been latterly more commonly used in the form of flavin, which was the precipitate formed by treating a boiling decoction of quercitron with sulfuric acid.

Ethnographic use of bark from *Quercus velutina* was known prior to its discovery and introduction into England in the late eighteenth century by Edward Bancroft as a substitute for other yellow dyes such as weld and fustic. (In fact use for this purpose is recorded by the Ojibwe Indians, who occupied extensive regions of north-east and midwest US by 1800; see: Smith, 1932; Moerman, 1998.) It seems also to be to Bancroft that we owe the current name, derived as it is from the Latin *Quercus* (*oak*) and *citron* (yellow). Bancroft initially tried importing the dyestuff ready prepared, but degradation of this led him to import the bark instead, the first shipment from Philadelphia to London arriving in 1775. It proved important to the dyeing industry since the dye yield was much higher than with other sources; neither did it suffer discoloration when iron was present. Free importation began around 1798 and the earliest examples of lake pigments using quercitron appear to commence shortly after this time (though Bancroft himself seems to have ignored this outlet). For example, Ackermann's yellow (cf. Harley, 1982; dated to 1801) was probably an early example of a pigment based on this while Field (1835) describes it explicitly when recommending it as a good yellow lake. According to Harley, quercitron was subsequently used extensively in Britain during the second half of the nineteenth century, being sold under various names such as yellow lake, yellow carmine, yellow madder, Italian pink and brown pink (Scott Taylor, 1885). Gettens and Stout (1966) also mention flavin lake as a current term.

Flavonoids group; Quercetin; *Ackermann's yellow*; *Brown pink*; *Dutch pink*; *Flavin lake*; *Italian pink*; *Yellow carmine*; *Yellow lake*; *Yellow madder*
Bancroft (1813); Field (1835) 84; Gettens & Stout (1966); Harley (1982) 115; Gettens & Stout (1942) 114; Mills & White (1994) 146; Moerman (1998); Scott Taylor (1885) 29, 50, 52; Smith (1932) 425

QUINACRIDONE

Red-Purple
Synonym, variant or common name

See: polycyclic pigments group: quinacridone sub-group.

QUININE GREEN

Green
Synonym, variant or common name

Salter (1869) lists this, but it is unclear why as he states that 'Quinine green is rather adapted for a dye than an artist-colour.' However, he adds some further information on preparation, saying: 'It is furnished by acting on quinine with hypochlorate of lime, hydrochloric acid, and ammonia, successively. Thus prepared, the green resembles a resin, insoluble in water, but soluble in alcohol, and turned blue by acetic acid.'

Salter (1869) 289

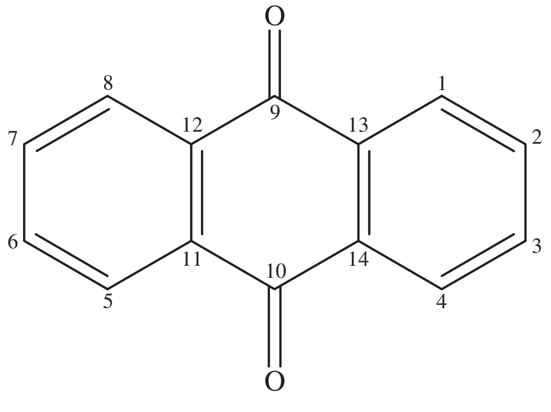
QUINONES GROUP

Variable
Group term

A large group of natural and synthetic dyestuffs based on the anthraquinone, benzoquinone and naphthaquinone structures have found use in the formation of lake and other pigments. The categories included here are:

Anthraquinones:

Anthraquinone



Carminic acid, found in cochineal from insect species such as *Dactylopius coccus*, *D. confusus*; *Porphyrophora polonica* L. and *P. hamelii*.

Kermesic acid; kermes from insect species such as *Kermes vermilio* Planch. and *Kermococcus illicis*.

Laccaic acids found in lac from insect species such as *Kerria (Kerria) lacca lacca* Kerr.

Aloe-emodin, Aloin and Emodin, found in aloe brown from plant species such as *Aloe barbadensis* Miller (also known as *A. vera* Linné), *A. ferox* and *A. perryi*.

Alizarin, Lucidin, Munjistin, Pseudopurpurin, Purpurin, Rubiadin and numerous other hydroxyanthraquinones found in madder and other closely related dyestuffs of natural origin from plant species such as *Rubia tinctorum* L. and other *R.* spp., *Oldenlandia*, *Morinda* and *Galium* spp.

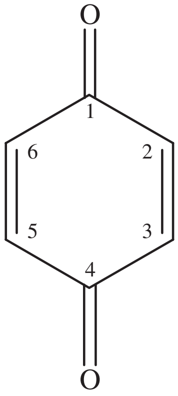
Chrysophanol, which occurs in *Aloe* spp. as well as in rhubarb from *Rheum* spp.

Rhein, found in *Rheum* spp.

Benzoquinones:

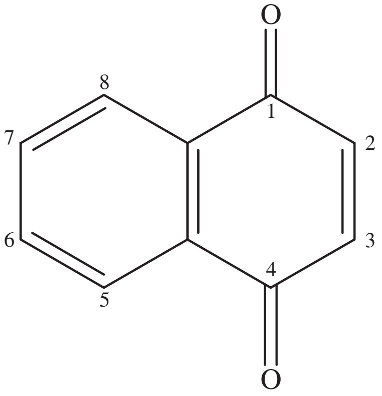
Carthamin, found in safflower from *Carthamus tinctoria*.

p-benzoquinone



Naphthoquinones:

(1,4)-Naphthoquinone



Alkannin, in alkanet from plant species such as *Alkanna lehmannii* Tineo (formerly known as *Alkanna tinctoria* Tausch.), *Macrotomia* spp. and *Onosma* spp.

Juglone, in walnut from *Juglans* spp.

Anthraquinones group; Naphthoquinones group; Alizarin; Alkanet; Alkannin; Aloe; Aloe-emodin; Aloin; Carminic acid; Carthamin; Cochineal; Juglone; Kermes; Kermesic acid; Lac; Laccaic acid; Madder; Munjistin; Pseudopurpurin; Purpurin; Rubiadin; Safflower; Walnut

QUINOPHTHALONE YELLOW

Yellow

Synonym, variant or common name

See: polycyclic pigments group: quinophthalone sub-group.

R

RADIANT YELLOW

Yellow
Synonym, variant or common name

A shade variant of cadmium yellow which was a speciality of the British firm of colourmen Reeves and first listed by them in 1892 (cf. Carlyle, 2001).

Cadmium yellow
Carlyle (2001)

RADIOGRADASE

Blue
Synonym, variant or common name

The term radiogradase was associated with Prussian blue (*q.v.*; Berrie, 1997).

Prussian blue
Berrie (1997)

RASPITE

Yellow
Generic compound

Raspite is a monoclinic lead tungstate mineral with composition $PbWO_4$ and is sometimes known as lead wulframate. It is polymorphous with stolzite (*q.v.*), the tetragonal form, although the relative stabilities of these minerals are not well known. Raspite forms as relatively soft yellow to yellow-brown tabular or prismatic vitreous crystals. It often occurs in association with stolzite and forms as a secondary mineral in areas of heavy metal deposits such as Cumbria, England (Neall and Green, 2001) and Broken Hill, Australia (Fujita *et al.*, 1977).

Lead tungstate (*q.v.*) has been synthesised as a white pigment, as described by Riffault *et al.* (1874), although it is unknown what crystal system the synthetic form takes. It is sometimes referred to as tungsten white, although this is also applied to barium tungstate (*qq.v.*).

Lead group; Tungsten group; Barium tungstate; Lead tungstate; Stolzite; *Tungsten white*
Fujita *et al.* (1977); Neall & Green (2001); Riffault *et al.* (1874) 159–160

RATTAN YELLOW

Yellow
Synonym, variant or common name

Rattan yellow has been used historically to refer to gamboge (*q.v.*; Winter, 1997). Yü (1955) for example, uses this term. He notes that when sold in Chinese pigment shops it is called ‘moon’ yellow (*yue* yellow) because the best quality was from Yuenan (Vietnam); the next best quality came from Myanmar and Thailand. Yü also states that it was imported into China before the Tang dynasty, and was called ‘Zhenla painting yellow’ (Zhenla was a small state in the northern portion of present day Laos and Vietnam) and ‘Linyi yellow’ (Linyi was a small state on the Malay Peninsula).

Gamboge
Winter (1997); Yü (1955/trans. Silbergold & McNair 1988) 13

RAUSCHROT

Red
Synonym, variant or common name

Rauschrot is synonymous with realgar (*q.v.*; FitzHugh, 1997).

Realgar
FitzHugh (1997)

RAW SIENNA

Brown
Synonym, variant or common name

See: sienna.

RAW UMBER

Brown
Synonym, variant or common name

See: umber.

READING GREEN

Green
Synonym, variant or common name

According to Heaton (1928) Reading green was a then-current term for a chromium oxide-based pigment. The most common context appears to be for the painting of rail vehicles (Newman, 1997).

Chromium group; Chromium oxide
Heaton (1928) 383; Newman (1997)

REALGAR

Red-Orange
Generic compound

Realgar is an orange-red sulphide of arsenic (As_2S_2) containing $\sim$70% arsenic. Realgar frequently occurs in association with orpiment (*q.v.*), to which it may revert on exposure. Other arsenic sulfide minerals are often found associated with orpiment and realgar including pararealgar (AsS), duranusite (As_4S), alacranite (As_8S_9), dimorphite (As_4S_3) and uzonite (*qq.v.*; As_4S_5). Realgar is found primarily in association with volcanic hot springs and with hydrothermal-related mineralisation where it occurs as an oxidised product. The change to orpiment drastically reduces realgar’s stability as a pigment in its own right. It is abundant as traces in orpiment-based pigments. Geological occurrences of this mineral are discussed with orpiment and the interested reader may further refer to Bancroft *et al.* (1991), Garavelli and Vurro (1994), Heinrich and Eadington (1986) and Zhang *et al.* (1993).

Realgar is easily synthesised by heating orpiment and the methods of preparing this pigment are discussed by Wallert (1984). In *De Natura Fossilium*, Agricola (1556) says that realgar can be made from orpiment by heating the latter in a sealed crucible for five hours. This is probably the *auripigmentum facticum* referred to in his *De Re Metallica* (see Hoover and Hoover, 1950). Tingry (1804) also says that realgar can be synthesised and this product is called 'ruby of arsenic'. Haydocke (cf. Harley, 1982) calls this material burnt orpiment and Merrifield (1849) also gives the Spanish names *jalde quemado* or *oropimente quemado* (burnt orpiment). Terry (1893) also details the processes for manufacturing realgar by sublimation, saying that its main use was in pigments and pyrotechnics. He also says that synthetic realgar 'has not the brilliant colour of the native mineral'.

The name 'realgar' used in English and most other Latin-based languages is derived from the Arabic *rahj-al-ghar*, 'powder of the mine' (Dana, 1944). The classical authors referred to a red called *sandaraca* while later texts use *sandarach*: sandaraca is used by Theophrastus (c. 315 BC) and this term is adopted by Pliny (77 AD) and Vitruvius (first century BC), but it is clear that none of the authors are familiar with the material and know only that it comes 'from mines'. There is certainly the possibility of all authors using sandaraca to mean particular varieties of red ochres and not arsenic sulfide minerals at all. However, Vitruvius discusses it alongside orpiment and some relationship of the two minerals may have been perceived. Vitruvius also says that these mines were in Pontus and it is certainly possible that the volcanic region of Cappadocia (modern Turkey) was a source of this mineral. Both realgar and orpiment are known to occur in Turkey; Kuscu (1995), for example, records these in Golbasi (Isparta) epithermal arsenic mineralisation; also the Sevan-Amasya region. Working of orpiment and realgar deposits is associated with ancient metallurgy in this region: arsenic is mainly associated with copper, which occurs in the territory of Central Transcaucasia in the form of realgar and orpiment types (see Abesadze and Bakhtadze, 1987). The anonymous Graeco-Egyptian trade manual known as the *Periplus maris Erythraei* ('Periplus of the Erythrean Sea' or 'Voyages of the Indian Ocean'; Schoff, 1912; Casson, 1989), a document probably written in the first century AD, records trade in realgar and orpiment to the Indian ports of Barygaza (Bharuch, Gujarat) and Bacare (or Barace; tentatively identified as Purakkad, Kerala).

Agricola (1556) calls realgar *Rosgeel*; in modern German, realgar is *Schwefelarsenik*. Realgar is not commonly used as a pigment, and when it is, it is referred to as 'red orpiment' in most English texts. Despite his detailed coverage of orpiment, Dossie (1764) does not mention realgar. Given this fact, Harley (1982) believes that it was probably imported wholesale with orpiment and not clearly distinguished. Field (1835) calls it *Orange orpiment*. FitzHugh (1997) also records *rubis d'orpiment*, *Rote Arsenblende* and *Rauschrot* as terms encountered in de Mayerne and other texts; Weber (1923) lists realgar but gives no detail.

As in the case of orpiment, realgar is known to react with copper- and lead-based pigments.

The apparent rarity of realgar in works of art is corroborated by the very few confirmed analyses. It has been identified in orpiment-based pigments from Roman contexts (by Barbet *et al.* (1997)) and occurs on very few other examples of western art up to the eighteenth century (FitzHugh, 1997). Yü (1955) lists it as present on Chinese palettes.

Arsenic sulfides group; Alacranite; Dimorphite; Duranusite; Orpiment; Pararealgar; *Jalde quemado*; *Oropimente quemado*; *Rauschrot*; *Red orpiment*; *Rosgeel*; *Rote arsenblende*; *Rubis d'orpiment*; *Sandarach*
Abesadze & Bakhtadze (1987) 52; Agricola (1556/trans. Hoover & Hoover, 1950) 111, 222; Bancroft *et al.* (1991); Barbet *et al.* (1997); Casson (1989); Dana (1868) 26; Dana (1944) 255; Dossit (1764); Field (1835) 101; FitzHugh (1997); Garavelli & Vurro (1994); Harley (1982); Heinrich & Eadington (1986); Kuscu (1995); Merrifield (1849) clxviii; Pliny (1st cent AD/Rackham, 1952) XXIV.lv; Schoff (1912); Terry (1893) 281; Theophrastus (c. 315 BC/Caley & Richards, 1956) 51; Tingry (1804) 358; Vitruvius (1st cent BC/Grainger, 1934) VII.5; Wallert (1984); Weber (1923); Yü (1955/trans. Silbergold & McNair, 1988); Zhang *et al.* (1993)

REBENSCHWARTZ

Black
Synonym, variant or common name

See: vine black.

REBOULLEAU'S BLUE

Blue-Green
Synonym, variant or common name

A term of equivalence for Schweinfurt blue (*q.v.*) given by, for example, Salter in his 1869 edition of Field's *Chromatography*. It was a copper-arsenic compound.

Schweinfurt blue
Salter (1869) 230

RECKITT'S BLUE

Blue
Synonym, variant or common name

The English firm of Reckitt & Sons produced the laundry product *Reckitt's blue* from 1852, which was originally a combination of synthetic ultramarine and sodium hydrogen carbonate (sodium bicarbonate). Use of Reckitt's blue and other laundry blueings is documented in a number of ethnographic contexts such as artefacts from Papua New Guinea (Hill, 2001) and Australian rock art (Chippindale and Taçon, 1998). For further information see the entries for laundry blue and ultramarine.

Ultramarine; *Laundry blue*
Chippindale & Taçon (1998); Hill (2001)

RED BOLE

Red
Synonym, variant or common name

See: bole.

RED CHALK

Red
Synonym, variant or common name

See: red ochre.

RED CHROME

Red-Orange
Synonym, variant or common name

See: chrome red.

Red indigo

Red-Blue
Synonym, variant or common name

See: litmus.

Red lake C

Red
Synonym, variant or common name

Diazotised o-chloro-m-toluidine-p-sulphonic acid coupled with alkaline β-naphthol and formed as the barium salt (cf. de Keijzer, 1999). Listed by the *Colour Index* as CI Pigment Red 53:1.

Azo pigments group: β-Naphthol sub-group
Colour Index (1971); Keijzer (1999)

Red lapíz

Red
Synonym, variant or common name

Mentioned in the late seventeenth century Spanish treatise *Principios para estudiarel nobilisimo y real arte de la pintura* by Garcia Hidalgo (1693), Veliz (1986) identifies this as 'a kind of red ochre' (*q.v.*).

Red ochre
Garcia Hidalgo (1693); Veliz (1986) 211, n.8

Red lead

Red
Synonym, variant or common name

Historical synonym for lead(II,IV) oxide ($2PbO.PbO_2$ or Pb_3O_4; *q.v.*), used, for example, by Toch (1916). It was commonly known as *minium*, though this now strictly refers to the mineral form, and there were numerous other associated terms.
See: lead(II,IV) oxide and minium.

Lead(II,IV) oxide; *minium*
Toch (1916) 55

Red lead chromate

Red
Synonym, variant or common name

According to the *Merck Index* (1996), this is synonymous with chrome red (lead chromate(VI) oxide).

Lead chromate(VI) oxide; *Chrome red*
Merck Index (1996) 923

Red ochre

Red
Synonym, variant or common name

The principal colouring matter in red ochres is the naturally occurring iron(III) oxide hematite (*q.v.*), Fe_2O_3, which can occur as very fine grained (sub-micron-scale) particles disseminated throughout rock or earth. Deposits can additionally be associated with ilmenite (which can form a solid solution with hematite producing minerals of the composition $FeTiO_3$), rutile, feldspars, magnetite and calcite (*qq.v.*). These phases are therefore likely to be present in red ochre-derived pigments, as a coarser grain sized fraction.

Red ochres form in the oxidised, weathered portions of iron-rich mineral deposits, especially those associated with so-called volcanic massive sulfide (VMS) deposits where they are derived from the breakdown of minerals such as iron pyrite and chalcopyrite and also from the direct weathering of hematite, the main variety of iron mineralisation occurring in oxic conditions (that is, above the water table). Ochres *sensu lato* may also form in many environments as soils, concentrating hematite derived from the underlying bedrock (called variously iron pans, *terra rossa*, laterites, ferricretes, podzols and krasnozems according to their environment of deposition, in which climate is an important factor, chemistry and age). Important red ochre sources today are France, Australia, Cyprus, Italy and the USA (Buxbaum, 1998; Tingry, 1804).

More unusual sources of red ochres include use of the Red Chalk outcropping, quite spectacularly at Hunstanton, Norfolk, UK and described as a pigment source by Church (1901). This is an unusually hematite-rich chalk deposit, a strong red-orange in colour, where the hematite is disseminated with fine grained calcium carbonate in the form of coccoliths (see: Chalk). Such a relationship could easily be interpreted as the use of chalk as an extender. Iron(III) oxide may form flocculents when iron-rich ground waters enter the surface environment and thus hematite-rich scums or muds may form in streams, rivers or lakes. This is particularly common as a result of mine drainage but also forms naturally. Such hematite-rich ochrous deposits have been recorded by Scott *et al.* (2002) at Chumash rock art sites in California, where the locals refer to it as *moo'ic*, differentiating it from other 'earthy' ochres (*navyot*).

Artificially produced red ochres may be manufactured by roasting yellow, brown or red ochres in air which will convert iron oxide hydroxides and iron oxides to the stable iron(III) oxide. In some cases it may be difficult to distinguish these burnt ochres (*q.v.*) from naturally occurring red ochres. However, if temperatures do not exceed 800–900°C (which is likely) crystallographic analysis will reveal a substantial amount of disorder in the crystal structure. Naturally occurring hematite has an ordered crystal structure.

Red ochre pigments are prepared by washing, levigation and grinding. They produce strong colours of various shades of red and various levels of transparency. They are suitable for both indoor or outdoor use and work in all media, being permanent and very stable. Identifications of red ochre in works of art are universal. A selection intended to illustrate the global use of the pigment is given here. Early uses of the pigment have been documented by Barham (2002) in South Africa where it was used by early hominids (pre-dating *Homo sapiens*) between 270,000 and 170,000 years ago. Subsequently it was used during the later Palaeolithic as an important pigment for cave paintings (see Hameau *et al.*, 2001; Pomiès *et al.*, 1999). It also had important ritual use in many Palaeolithic and later burials, apparently covering the bodies. A well-known example is the Red Lady of Pavilland, UK (Aldhouse-Green and Pettitt, 1998) other cases are documented by Duarte *et al.* (1999) and Edwards *et al.* (2001); see also Watts (2002). Use is routine among aboriginal cultures worldwide. Stafford *et al.* (2003) have detected 11,000 year old ochre workings in eastern Wyoming (Clovis–late Paleoindian periods). Other North American identifications are found in Edwards *et al.* (1998), Scott *et al.* (2002) and Hyman *et al.* (1996). The pigment is abundant and well used throughout Australasia and the Pacific (see Jercher *et al.*, 1998; Smith and Pell, 1997; Watchman *et al.*, 1993; Barton and Reynolds, 1985). Maori uses of red ochre pigments have been overinterpreted. Although the culture did use red ochre (and called it *kokowai*) its use has not been as widespread as restorers have assumed (see Barton and Reynolds, 1985). In Amarna period Egypt red ochres were commonly used possibly adulterated with quartz sand and also in relatively pure forms as identified by David *et al.* (2001).

The classical authors Theophrastus (c. 315 BC), Vitruvius (first century BC) and Pliny (77 AD) all discuss the red ochre pigments. The general Latin term for the common red ochres is *rubrica* (from which we derive the English 'rubric'; the Roman law was written in red) and in Greek it was *miltos*. The best red ochre was imported from Anatolia. The classical sources (Pliny, Vitruvius and Theophrastus) speak highly of this 'sinoper' (*q.v.*) or 'sinopia', an earthy, but relatively pure form of the oxide. Theophrastus tells us that this red pigment was named after the port of Sinope (on the Pontus, the Anatolian coast of the Black Sea) from where it was shipped but was actually derived from inland Cappadocia. This is corroborated by the geographer Strabo (first century BC), himself a native of the Pontus: 'In Cappadocia is produced also the raddle called "Sinopean", the best in the world, although the Iberian rivals it. It was named "Sinopean" because the merchants were wont to bring it down thence to Sinope before the traffic of the Ephesians had penetrated as far as the people of Cappadocia.'

Theophrastus also says that both ochre and 'raddle' (miltos) were mined together in Cappadocia. 'Miltos' has varied connotations in the Greek literature, and here it is interpreted as an earthy or sandy form of red ochre. Pliny states that the Greeks called (the Latin) *minium* 'cinnabar' to differentiate it from ochre and miltos, and it is to the 'Iberian' cinnabar that Strabo refers to in the passage quoted above. The ancient Greeks used red ochres for architectural and sculptural paints (see Riederer, 1985) as well as for wall paintings (of which very few survive).

Other deposits known and used during the Roman period were those in Egypt, on the Balearic Islands, and from Lemnos in the Aegean (Vitruvius). Lemnos ochre, Pliny tells us, was also called 'Sinopean' so one can assume this too was of good quality. He says it was used as an undercoat for vermilion (Roman *minium*, *qq.v.*). The Romans were also aware of the technology of burning yellow ochre to produce red ochres and also adulterated burnt red ochres with white lead (*cerussa*), a concoction that Pliny calls *sandyx*. *Sandyx* was also mixed with sinoper for use as an undercoat. Red ochres were widely used in Roman art (see Béarat, 1997, and other papers within the same volume; Edwards *et al.*, 2002).

Red ochres have been reported in Byzantine icons and frescos (Bikiaris *et al.*, 1999; Lelekova, 1998; Panev, 1979; Sr. Daniila *et al.*, 2002), mediaeval frescos (Perez *et al.*, 1999), used on the Turin Shroud (McCrone, 1986) and on playing cards (Richter and Härlin, 1976). Ochres occur in easel painting world-wide. For examples see Gettens and Turner (1951, Mexican santeros); Bomford *et al.* (1990, Italian Renaissance); Kühn (1968, Vermeer); Townsend (1996, Turner); Newman *et al.* (1980, Winslow Homer) and Laar and Burnstock (1997, general).

There is an extensive list of synonyms and source variants for red ochres. For example, under red ochre Field (1835) lists Indian red, light red, terra puzzolli, carnagione, Venetian red, scarlet ochre and Spanish red. Salter (1869) adds English red, Persian red, Prussian red, brown red, Indian ochre, English vermilion, Spanish brown, *Majolica*, redding, ruddle, bole, *Almagra*, *sil Atticum* and *terra sinopica*. Ruddle is variously called *reddle* or *raddle*. Bole and bolus are also synonyms for red ochre (Weber, 1923; Bristow, 1996). *Armenian bole* was the variety used as a base for gilding. Church (1901) further lists: *red haematite*, *red iron ore*, *scarlet ochre*, *red chalk*, *sinoper* and *sinopis*, *rubrica*, *miltos*, *terra rosa* and *arrabida red*. *Turgite* (*q.v.*), a form of tarnish occurring on hematite, is also mentioned by him. Church also lists *Indian red*, *Persian red* and *Indian red ochre*, although he states that these terms may refer to both synthetic or naturally occurring varieties. The original natural varieties came from Ormuz in Persia; Church also mentions good quality ochre derived from the Forest of Dean, UK (this is the crawshay red described by Heaton, 1928, also referred to as Indian red).

For a discussion of ochres generally, see the entries iron oxides and hydroxides group and ochre.

Earth pigments group; Feldspar group; Iron oxides and hydroxides group; Calcite; Chalk; Hematite; Ilmenite; Magnetite; Ochre; Rutile; Turgite; *Arrabida red*; *Bole*; *Burnt ochre*; *Gulf red*; *Indian red*; *Miltos*; *Persian Gulf oxide*; *Rubrica*; *Ruddle*; *Sinoper*; *Sinopia*; *Terra rosa*; *Yellow ochre*
Aldhouse-Green & Pettitt (1998); Barham (2002); Barton & Reynolds (1985); Béarat (1997); Bikiaris *et al.* (1999); Bomford *et al.* (1990); Bristow (1996b) 30–33; Buxbaum (1998) 83; Church (1901) 180, 183; Daniila *et al.* (2002); David *et al.* (2001); Duarte *et al.* (1999); Edwards *et al.* (1998); Edwards *et al.* (2001); Edwards *et al.* (2002); Field (1835) 95–97; Gettens & Turner (1951); Hameau *et al.* (2001); Heaton (1928) 116; Hyman *et al.* (1996); Jercher *et al.* (1998); Kühn (1968); Laar & Burnstock (1997); Lelekova (1998); McCrone (1986); Newman *et al.* (1980); Panev (1979); Perez *et al.* (1999); Pliny (1st cent AD/Rackham, 1952) XXXV; Pomiès *et al.* (1999); Richter & Härlin (1976); Riederer (1985); Salter (1869) 147–150; Scott *et al.* (2002); Smith & Pell (1997); Stafford *et al.* (2003); Strabo (1st century BC/1923) III.ii.6, XII.ii.10; Theophrastus (c. 315 BC/Caley & Richards, 1956) 50–60; Tingry (1804) 351; Townsend (1996); Vitruvius (1st cent BC/Grainger, 1934) VII.vii.2; Watchman *et al.* (1993); Watts (2002)

RED ORPIMENT

Red
Synonym, variant or common name

Red orpiment has been used synonymously for realgar (*q.v.*; FitzHugh, 1997). However, Field (1835) says that this is incorrect and that it should be called orange orpiment.

Realgar; *Orange orpiment*
Field (1835) 119; FitzHugh (1997)

RED OXIDE OF COPPER

Red
Synonym, variant or common name

See: cuprite.

RED PRECIPITATE

Red-Orange-Yellow
Synonym, variant or common name

Salter (1869) lists this as mercuric oxide (mercury(II) oxide, HgO), stating that it was possible to make brick red or orange-yellow colours.

Mercury group
Salter (1869) 173

REFINER'S VERDITER

Blue-Green
Synonym, variant or common name

Refiner's verditer has been used as a term for synthetic blue and green copper carbonate hydroxide pigments, analogous to the minerals azurite and malachite. The origin is from silver refining, the pigment being a by-product (Mactaggart and Mactaggart, 1980; Harley, 1982).
See: verditer.

Copper carbonate hydroxide, azurite type; Copper carbonate hydroxide, malachite type; *Blue verditer*; *Green verditer*; *Verditer*
Harley (1982) 51; Mactaggart & Mactaggart (1980)

REMBRANDT'S MADDER

Brown
Synonym, variant or common name

According to Carlyle (2001), Rembrandt's madder was available from several British artists' colourmen (Roberson; Winsor & Newton) in the late nineteenth century. It was apparently compounded of rose and brown madders and burnt sienna.

Brown madder; *Burnt sienna*; *Rose madder*
Carlyle (2001) 489

RETZEL

Red
Synonym, variant or common name

The term *retzel* is found in formulas in German texts from the middle ages. It is a term for madder root, *Rubia tinctorum* L. (Ploss, 1962).

Madder
Ploss (1962)

RETZWURZ

Red
Synonym, variant or common name

The term *retzwurz* is found in formulas in German texts from the Middle Ages as a term for madder root, *Rubia tinctorum* L. (Ploss, 1962). For example a fifteenth century book of recipes (Munich Staatsbibliothek, Cgm. 720; Clarke MS. 2200, cf Oltrogge, 2003) states '*Nÿm reczwurcz vnd zeuch di haut ab vnd seud di heüt vnd har oder faden durich ein ander vnd geuss ein wenig essig dar ein so wirt es schon rott*' ('Take madder root and remove the skin and cook the skin and flax together and add a little vinegar so that it will become a beautiful red').

Madder
Oltrogge (2003); Ploss (1962)

REZZA

Red
Synonym, variant or common name

Rezza is the Old High German for madder (Ploss, 1962; Schweppe and Winter, 1997).

Madder
Ploss (1962) 111; Schweppe & Winter (1997)

RHAMNETIN

Yellow
Generic compound

Chemically 2-(3,4-dihydroxyphenyl)-3,5-dihydroxy-7-methoxy-4H-1-benzopyran-4-one (or: 3,3′,4′,5-tetrahydroxy-7-methoxyflavone; or: 7-methylquercetin). A flavonoid dyestuff principally derived from the berries of various plants belonging to the Rhamnaceae, though it may also be synthesised (*Merck Index*, 1996). It is listed in the *Colour Index* as CI 75690/Natural Yellow 13.
See: rhamnus.

Colour index (1971) 75690; *Merck Index* (1996) 8337

RHAMNOCITRIN

Green-Yellow
Generic compound

Rhamnocitrin, kaempferol-7-methylether, is a flavonoid component of dye extracts of *Rhamnus catharticus* L. (Schweppe, 1992). It is listed in the *Colour Index* (1971) as CI 75650/Natural Yellow 13/Natural Green 2.
See: rhamnus.

Flavonoids group
Colour index (1971) 75650; Schweppe (1992) 328

RHAMNUS

Green-Yellow
Common generic composite

Various species of the Rhamnaceae family give a yellow dye on extraction of the unripe berries (drupes); ripe berries produce a green colour. Principal components of this dye are rhamnocathartin, rhamnotannic acid, rhamnin and rhamnetin; the latter compound, a flavonoid, is generally considered to be the main dyestuff. Minor components include chrysophanol, kaempherol, quercetin, xanthorhamin, emodin, frangulin, rhamnazin, rhamnocitrin, although these differ somewhat in each of the different species.

The common names for *rhamnus* include buckthorn in English; *nerprun* purgatif in French; *cerval* in Spanish; *prugna meroli* in Latin and Italian. Cardon (2003) gives a clear indication of the plant origin and the various associated names given to the berries used as dyestuff. The most common species throughout Europe were *R. catharticus* L (there is also a north American naturalisation; Mabberley, 1998), and *R. alaternus* L as well as *R. saxatilis* Jacq. and the two sub-species; *R. infectorius* L. and *R. tinctorius* Waldst. and Kit. The berries of these species were most often traded in Europe under the name Avignon berries, *graines d'Avignon* or French berries; Hungary berries were produced from *R. catharticus* and *R. saxatilis;* the berries in Italy were solely from *R. infectorius* while those in Spain from *R. saxatilis.* The other most common name for the berries was Persian berries, these being imported through the Levant, resulting in the terms, Aleppo and Smyrna berries, these being from *R. saxatilis, R. lyciodes* (and the subspecies *oleoides* and *R. amygdalinus* L.). Furthermore, in Anatolia (Turkey) *R. petiolaris* L. was cultivated and in China, *R. utilis* Decne. (Mabberley). (For more information on these plants see: Cardon.) The dyes were in widespread use and it is often unclear from early recipes exactly which source was used. It is therefore difficult to be certain if the many names for this colour and for the lake pigment refer to the product of a specific plant.

All of these berries were used to produce a yellow or green dye which was then added to a substrate such as calcium carbonate, chalk or even travertine to produce a lake pigment (for example see: Bolognese MS, fifteenth century, Clarke MS 160; cf. Merrifield, 1849).

The recipes are generally quite specific as to the time of year the berries should be used and that to produce yellow they should be unripe and for the green dye and lake pigments they should be ripe, black and dark. The 'Paduan' MS. *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849) gives recipes for both colours, distinguishing them by the ripeness of the berries and Boltz von Ruffach (1549) also states that for making *Beergäl* (berry yellow) the berries should be gathered in August and to produce *Safftgrien* (juice green) the berries should be collected 14 days before Michaelmas (29 September). Historical terms for the yellow lake pigment include *giallo santo* (Italian); *stil de grain,* (French); *Schüttgelb* (German); *shitgeel* (Dutch). Dutch pink and French pink. For the green colour; sap green or *vert de* *vessie* and Chinese green or *Lokao* (*qq.v.*). The Italian terms *giallo di Spincervino (spincervino yellow)* and *giallo santo* are associated with *R. cathartica* L. This has generally also been considered the source of the colour known as *sap green.* In English sources Dossie (1764) mentions the use of 'French berries' in the preparation of Dutch pink (*q.v.*) and light pink, and Smith (1815) in the preparation of a brown pink. Bristow (1996b) cites the records of the firm Berger where Turkey berries (from Îzmir – formerly Smyrna – or Aleppo) and Persian berries were used for production of Dutch and brown pink.

Many of the lakes purportedly formed with the *rhamnus* dyestuff may well have been made using other plant sources such as weld (*Residea luteola* L.), dyer's broom (*Genista tinctoria* L), and woad (*Isatis tinctoria* L.; *qq.v.*).
See: Italian, Dutch and English pink, sap green and *lokao.*

Emidin, Frangulin, Quercitin, Rhamnetin; *Avignon berries*; *Buckthorn*; *Chinese Green*; *Dutch pink*; *English pink*; *Italian pink*; *Lokao*; *Persian berries*; *Sap green*; *Turkey berries*; *Yellow berries*
Boltz von Ruffach (1549/Benziger 1913) 72–74; Bristow (1996b); Cardon (2003); Dossie (1764) 100; Mabberley (1998) 612; Merrifield (1849) 362–364; Schweppe (1992) 542, 666; Smith (1815)

RHEIN

Orange
Generic compound

The anthraquinone compound Rhein, 1,8-dihydroxyanthriquinone-3-carboxylic acid, is found in various *Cassia* and *Rheum* species (*Merck Index*, 1996). It is also known as 'rhubarb yellow'.

Anthraquinones group; Rhubarb; *Cassia fistula*
Merck Index (1996) 8342

RHENISH EARTH

Green
Synonym, variant or common name

The term Rhenish earth was associated with green earth (*q.v.*; Grissom, 1986).

Green earth
Grissom (1986)

RHUBARB

Red
Generic compound

Rhubarb, plants of *Rheum* species (Polygonaceae; Europe to temperate and warm Asia), appears to have had some limited use in producing pigments for manuscript illumination. Chrysophanol, the principal colouring constituent along with emodin, aloe-emodin and rhein (*qq.v.*), are found in *Rheum*, though these compounds are also found in other dyestuffs and therefore cannot be taken as diagnostic. Various *Rheum* plants are listed in dye literature; *Rheum palmatum* L. (north-west and north China, eastern Tibet); *R. rhabarberum* L. (Mongolia, southwest China and Turkestan); *R. rhaponticum* L. (southern Siberia, Caspian Sea) (Schweppe, 1992; WHO, 1999).

There is little mention of this plant being used to make a pigment; however, the le Begue Manuscript (1431; Clarke MS 2790; cf. Merrifield, 1849) does give a recipe where copperas and verdigris are mixed with 'rubarbe'. It is possible that red pigment obtained from rhubarb was used by extraction from dyed cloth (see: *Cimatura*). Scott *et al.* (2001b) have identified rhubarb in a fifteenth-century German illuminated manuscript *Barlaam und Josaphat*, in the collections of the J. Paul Getty Museum; the pigment appears to be on an aluminium base, bound in a glue medium.

Aloe-emodin; Chrysophanol; Emodin; Rhein; *Cimatura*; *Copperas*; *verdigris*;
Merrifield (1849) 89; Schweppe (1992) 224–225; Scott *et al.* (2001b); WHO (1999) 231–240

RIEBECKITE

Blue
Generic compound

Riebeckite, $Na_2(Fe^{2+} Mg)_3(Fe_2^{3+})_2Si_8O_{22}(OH)_2$, is a dark blue to black iron-containing variety of the mineral glaucophane (*q.v.*). This mineral, along with glaucophane has been found in association with so-called 'Egyptian blue' (a synthetic calcium copper silicate pigment) in material from Knossos, Crete, dated to 2100 BC, and Thera (Santorini; 1500 BC), (Filippakis *et al.*, 1976; Cameron *et al.*, 1977; Profi *et al.*, 1977). Riebeckite also has an important asbestiform variant known as crocidolite, otherwise known as 'blue asbestos'; for more information, see: asbestos

Calcium copper silicate; Glaucophane; *Asbestos*; *Egyptian blue*
Cameron *et al.* (1977); Filippakis *et al.* (1976); Profi *et al.* (1977)

RING WHITE

White
Synonym, variant or common name

Ring white is derived from the Latin terms *anulare* mentioned in Pliny (77 AD) and *anularium vitro* in Vitruvius (first century BC). Pliny states that this was a colour used particularly for painting female complexions and was a pigment composed of 'white earth' mixed with crushed glass derived from the 'rings of the lower classes'. Vitruvius adds that crushed glass beads (*anularium vitro)* were used as a substrate for woad dye (*Isatis tinctoria).*
See: glass.

Glass
Pliny (1st cent AD/Rackham 1952) XXXV.xxx.48; Vitruvius (1st cent BC/Grainger 1934) VII.xiv.2

RINMANN'S GREEN

Green
Synonym, variant or common name

Rinmann's green was an alternate term for cobalt green, a pigment similar to cobalt blue (*qq.v.*) except that zinc oxide partially or wholly replaces the aluminium hydroxide (*Colour Index*, 1971). Rinmann discovered this colour in the last quarter of the eighteenth century. Zerr and Rübencamp (1906) state that this was an unpopular colour due to its high cost. It was also called zinc green.

Cobalt group; Cobalt zinc oxide; Cobalt blue; *Cobalt green*
Colour Index (1971) 77335; Zerr & Rübencamp (1906/1908) 242

RISALGALLO

Red
Synonym, variant or common name

See: realgar.

ROBBIA

Red
Synonym, variant or common name

A sixteenth century Italian term for madder (*q.v.*; Merrifield, 1849).

See: rubia.

Madder; Rubia
Merrifield (1849) clxxviii

ROCK INDIGO

Blue
Synonym, variant or common name

Form of natural indigo (Schweppe, 1997). This term is presumably derived from the fact that indigo, when first imported into Europe, was thought to have been a mineral.
See: indigo.

Schweppe (1997)

ROETE

Red
Synonym, variant or common name

The term '*roeta*' is found in formulae in German texts from the Middle Ages (Schweppe and Winter, 1997). It is a term for madder root, *Rubia tinctorum* L. (Ploss, 1962).

Madder
Ploss (1962) 30; Schweppe & Winter (1997)

ROMAN BROWN

Brown
Synonym, variant or common name

Doerner (1935) states that Roman brown was equivalent to Florentine (that is, Florence) brown, a copper hexacyanoferrate(II) compound (*q.v.*).

Copper Hexacyanoferrate(II); *Florence brown*
Doerner (1935) 88

ROMAN GREEN

Green
Synonym, variant or common name

Briefly discussed by Salter (1869), who says of it: 'Roman green, brought from Rome some years back by a President of the Royal Academy, appeared to be a mixture of Prussian blue and Dutch or Italian pink.'

Dutch pink; *Italian pink*; *Prussian blue*
Salter (1869) 290

ROMAN LAKE

Red
Synonym, variant or common name

Osborn (1845) lists this as a variety of cochineal (*q.v.*) lake.

Cochineal
Osborn (1845) 20

ROMAN OCHRE

Yellow
Synonym, variant or common name

A form of yellow ochre. Pliny (*Naturalis Historiae*, 77 AD) mentions an ochre found near Rome in classical times.

Salter (1869) describes it as 'rather deeper and more powerful than [yellow ochre], as well as more transparent and cool in tint'.

Yellow ochre
Pliny (1st cent AD/Rackham, 1952) XXXV.xvii; Salter (1869) 107–108

ROMAN WHITE

White
Synonym, variant or common name

Variant term for a lead white (*q.v.*). Salter (1869) describes Roman white as 'of the purest white colour, and differs only from blanc d'argent in the warm flesh tint of the external surface of the large, square masses in which it is commonly prepared'.
See: *blanc d'argent*, *silver white* and *French white*.

Lead carbonates group; *Blanc d'argent*; *French white*; *Lead white*; *Silver white*
Salter (1869) 74

ROMAN YELLOW

Yellow
Synonym, variant or common name

Name recently proposed by Roy and Berrie (1998) along with Poussin yellow for a lead antimony tin oxide said to have been used principally in Rome in the seventeenth century and by Nicolas Poussin in particular.

Lead antimony tin oxide; *Poussin yellow*
Roy & Berrie (1998)

ROMANECHITE

Black
Generic compound

Romanechite is a black barium manganese hydroxide of the psilomelane minerals group and is named from deposits near Romaneche-Thorins in Burgundy, France. The composition may be given as $BaMn_9O_{16}(OH)_4$, though Post (1999) states it as $Ba_{0.66}Mn(IV)_{3.68}Mn(III)_{1.32}O_{10}.1.34H_2O$. On heating above about 550ºC, romanechite transforms into hollandite (*q.v.*; Fleischer and Richmond, 1943). These two minerals also commonly intergrow on a very fine scale (Turner and Buseck, 1979).

Traces of the mineral have been found as a pigment in European Palaeolithic cave art, notably at the caves of Peche Merle and Lascaux, where it is mixed with hollandite, carbon-based black, calcite, quartz, goethite and clay group minerals (*qq.v.*; Vouvé *et al.*, 1992; Guineau *et al.*, 2001).

Barium group; Clay group minerals; Manganese group; Manganese oxides and hydroxides group; Calcite; Goethite; Hollandite; Quartz
Fleischer & Richmond (1943); Guineau *et al.* (2001); Post (1999); Turner & Buseck (1979); Vouvé *et al.* (1992)

ROMARCHITE

Black-Brown
Generic compound

Romarchite is a tin(II) oxide mineral with composition SnO. It is a secondary mineral which occurs as thin soft black crusts with metallic lustre, or as microscopic laths, formed as a weathering product of tin compounds. It was first reported by Organ and Mandarino (1971) as a corrosion product of tin pannikins which had been immersed in water at Boundary Falls (Ontario, Canada). Romarchite is named after the acronym for the Royal Ontario Museum of archaeology, and is often found in association with the hydroxyl-bearing form hydroromarchite, which also has tetragonal symmetry.

Romarchite (incorrectly given as tin(I) oxide) has been identified as a corrosion product on tin leaf on the frame to Carlo Crivelli's altarpiece *The Annunciation* (National Gallery, London, No. 739; see: Smith *et al.*, 1989).

Tin group
Organ & Mandarino (1971); Smith *et al.* (1989)

ROSASITE

Green
Generic compound

Rosasite is a copper zinc carbonate hydroxide mineral with composition $(Cu,Zn)_2(CO_3)(OH)_2$. It is chemically and structurally similar to azurite and malachite (*qq.v.*) with partial substitution of zinc for copper. Rosasite is named after its type locality at the Rosas mine (Sardinia), from where it was described by Lovisato in 1908 (Dana, 1932). Rosasite commonly occurs with spherical, botryoidal, nodular or encrusting habits, but may also be found as aggregates of small blue-green fibrous crystals. It forms as a secondary mineral in the oxidation zones of copper zinc ore deposits and is often found in association with malachite, azurite, aurichalcite, smithsonite, limonite, geothite (*qq.v.*) or hemimorphite. Rosasite is often confused with aurichalcite to which it is chemically very similar (aurichalcite has a higher Zn:Cu ratio), but rosasite is a much harder mineral. It is found in areas including Cumbria (England), Salzburg (Austria), Saxony (Germany), Attica (Greece), Tuscany (Italy), Arizona (USA); Broken Hill (Australia), Durango (Mexico) and Tsumeb (Namibia).

Rosasite has been identified by Dunkerton and Roy (1996) on David Ghirlandaio's *The Virgin and Child with Saint John* (National Gallery, London). As they point out, this was unlikely to have been considered at that time as other than a form of malachite. Martin and Eveno (1992) also discuss the compound in the context of pre-eighteenth century western easel painting.

When encountered as a pigment, it may be the synthetic analogue, copper zinc carbonate, rosasite type (*q.v.*), rather than the mineral itself. This is produced in a similar manner to copper carbonate hydroxides ('verditer') but with brass, a Cu-Zn alloy, substituted for copper as the starting material. Other occurrences of this type of replacement are known, such as is seen through the presence of tin in Egyptian blue (*q.v.*) when a bronze (a Cu-Sn alloy) was used.

Copper carbonates group; Aurichalcite; Azurite; Claraite; Copper zinc carbonate, rosasite type; Goethite; Limonite; Malachite; Smithsonite; *Egyptian blue*
Dana (1932) 528; Dunkerton & Roy (1996); Martin & Eveno (1992)

ROSE MADDER

Red
Synonym, variant or common name

Rose madder (also known as Pink madder) is a manufacturing variant of madder lake produced by selective extraction and deposition of pseudopurpurin, an anthraquinone compound present in the dyestuff extracted from plants such as *Rubia tinctorum* L. and other Rubiaceae species. Schweppe and Winter (1997) describe an exemplar preparation, which involves initial extraction of powdered madder root for one day with cold 3–4% sulfurous acid. Two per cent sulphuric acid is then added and the temperature raised to 55°C on which the pseudopurpurin precipitates in flakes that can be redissolved in an alum solution. The lake is then precipitated from that liquid, raised to 70°C, by the addition of sodium carbonate. Apparently a concentrated colour is produced by precipitating onto aluminium hydroxide, while a brighter shade occurs when the dye is precipitated onto calcium carbonate. Pseudopurpurin lakes are reputed to have excellent lightfastness, superior to other selective lakes such as those based on purpurin (*qq.v.*).

Rose madder is mentioned in sources such as that of the British colourman Field (1835), a noted manufacturer of this pigment in the early nineteenth century.
See: madder.

Anthraquinones group; Alizarin; Madder; Pseudopurpurin; Purpurin
Field (1835) 97; Schweppe & Winter (1997)

ROSE PINK

Pink
Synonym, variant or common name

The earliest reference to rose pink appears to be that in the English translation of the *Traité de mignature* (thought to be by Claude Boutet, 1674; English ed., 1729) where in the original French the term *lacque colombine* is employed for a brazil lake (cf. Harley, 1982). Dossie (1764) writes 'Of rose lake, commonly called rose pink'; he says that it is like red lake, but the base is usually chalk and the dye from Brazilwood or Campeachy ('commonly called Peachy') wood (*qq.v.*), adding that it was used mostly for housepainting or wallpaper. The seventeenth century name for this in English was *roset* (Kirby, 2003). Field (1835; cf. Salter, 1869) adds to this that rose pink is 'a coarse kind of lake, produced by dyeing chalk or whitening with decoction of Brazil wood, peachwood, sapan, bar, camwood, &c. It is a pigment much used by paper-stainers, and in the commonest distemper painting, &c.' The term is listed with the same meaning, though as an obsolete or rare one, by Heaton (1928).

Brazilwood; Campeachy; Chalk; *Roset*
Boutet (1674); Dossie (1764) I-68; Field (1835) 101; Harley (1982) 145; Heaton (1928) 383; Kirby (2003); Salter (1869) 131–133

ROSENSTIEHL'S GREEN

Green
Synonym, variant or common name

A manufacturing variant of manganese green (barium manganate, *q.v.*). According to Terry (1893), it was prepared by 'fusing together caustic baryta, chlorate of potash, and binoxide of manganese', producing what he considered to be an inferior product as compared to other formulations. By the time Heaton was writing in 1928 the product had apparently become obsolete or only rarely used.

Barium manganate(VI); *Manganese green*
Heaton (1928) 383; Terry (1893) 111

ROSET

Pink
Synonym, variant or common name

A brazilwood (*q.v.*) lake laid on a calcium-based substrate. The term is probably derived from the mediaeval Latin *rosetus*, the meaning of 'rose-coloured' being given by du Cagne (1678; cf. *OED*, 2002). Lyte (1578; cf. *OED*) describes a roset made of Brasil, while the *Arte of Limming* (1573) notes that roset 'may be allayed with chalk or ceruse'; Peacham (1634) instructs that roset should be ground with 'florey blew' to make a deep violet. Leybourn (1674) states that 'rosset differs not much in colour from lake'. Kirby (2003) indicates this was a 17th century term for rose pink (*q.v.*). It should be noted that this term is also probably related to *russet*, although this is generally a term used to describe a brownish red colour; the *Arte of Limming*, for example, calls russet a 'sad brown'.

Brazilwood; *Rose pink*
du Cagne (1678/ed. 1840–50); Kirby (2003); Leybourn (1674) 309; *Arte of Limming* (1573) viii; *OED* (2002) 'roset'; Peacham (1634) I.xxii, 80

ROSGEEL

Red
Synonym, variant or common name

Rosgeel was a historical term associated with realgar (*q.v.*; Agricola, 1556; FitzHugh, 1997).

Realgar
Agricola (1556/trans. Hoover & Hoover, 1950) 111; FitzHugh (1997)

ROSIAITE

Yellow
Generic compound

Rosiaite is a trigonal lead antimony oxide mineral with composition $PbSb_2O_6$. It occurs as aggregates of small colourless to pale yellow hexagonal crystals which have a resinous lustre. Rosiaite is very rare and has only recently been described from Le Cetine (Tuscany, Italy) where it was found in association with valentinite and bindheimite (*qq.v.*) to which it is chemically similar (Basso *et al.*, 1996); it has also been recently reported to occur at Bwlch mine in Conwy, North Wales, UK (Ryback and Francis, 2001).

Although rosiaite is unlikely to be encountered as a pigment, synthetic lead antimony oxide (*q.v.*) analogues, notably forms containing tin, are known as yellow pigments.

Lead group; Lead oxides and hydroxides group; Bindheimite; Lead antimony oxide
Basso *et al.* (1996); Ryback & Francis (2001)

ROTE ARSENBLENDE

Red
Synonym, variant or common name

A historical term referring to realgar (*q.v.*; FitzHugh, 1997).

Realgar
FitzHugh (1997)

ROTHOMAGENSIAN GREEN

Green
Synonym, variant or common name

Viride rotomagense, generally translated as Rouen or Rothomagensian green, was apparently a copper acetate-related pigment (that is, verdigris, *q.v.*). Thompson (1935) found numerous recipes for it in twelfth to fifteenth century MSS related to the so-called *De coloribus et mixtionibus* for this pigment. An example can be cited from the *Book of Master Peter of St. Audemar on Making Colours* found in the MS of Jehan Le Begue (1431, Clarke MS 2790, cf. Merrifield, 1849): 'take strips of very pure copper or brass, smear them over with good soap … put in a clean vase … pour into it some pure vinegar; suspend strips of copper or brass in the vase … cover vase, seal, put into warm place for a month, open, shake and scrape out contents, put in earthen jar and in sun to dry'.

Rothomagus was Rouen in France.

Copper acetate group; *Verdigris*
Merrifield (1849) 126; Thompson (1935) 431 + n.1

ROTTENSTONE

White
Synonym, variant or common name

The term tripoli is used to denote fine-grained silicas as a class, being supposedly derived from the term tripolite; Patton (1973a) states that this is because of a superficial resemblance of such silicas to the diatomaceous silica called tripolite that comes from Tripoli in Libya. Another form, known as rottenstone, is mined in Pennsylvania, USA.

Silica
Patton (1973a)

ROUCOU

Yellow
Synonym, variant or common name

See: bixa.

ROUEN GREEN

Green
Synonym, variant or common name

See: Rothomagensian green.

ROUGE

Red
Synonym, variant or common name

Simply meaning 'red' in French, *rouge* has been used to describe a variety of pigments. Most commonly it is applied to synthetic iron(III) oxide but it has also been applied to naturally occurring red ochres and the mineral hematite (*qq.v.*). Jeweller's rouge or Colcothar is very pure, synthetic iron(III) oxide used as a polish because of its very fine (and therefore non-scratching) particle size. However, the term has been applied to other red pigments and compounds. Salter (1869) also states that 'The rouge végétale of the French, is a species of carmine, prepared from safflower or carthamus.' Harley (1982) also lists a safflower (*q.v.*) pigment *assiette rouge*. Tingry (1804) suggests that the rouge used as a cosmetic was a mixture of carmine 'from cochineal' and talc (*q.v.*).

Hematite; Safflower; Talc; *Carmine*; *Colcothar*; *Red ochre*
Harley (1982) 147; Salter (1869) 173–174; Tingry (1804) 333

ROUGE BRUN

Red-Brown
Synonym, variant or common name

Watin (1785) describes *Rouge brun* and *Rouge brun d'Angleterre* as a red ochre imported from England, made in Deptford (London). It was, however, produced by calcining iron sulfate in a furnace, indicating that it was an iron oxide produced as a by-product in the manufacture of sulfuric acid. Watin (1773) adds that it was used principally for distemper and oil paint.

Iron oxides and hydroxides group; *English red*
Watin (1773/edition of 1785) 22

ROUGE VÉGÉTALE

Red
Synonym, variant or common name

Field (1835) lists a number of related terms including *rouge végétale*, Chinese rouge and pink saucers, all of which he says were prepared from safflower (*q.v.*).

Safflower
Field (1835) 101

ROYAL BLUE

Blue
Synonym, variant or common name

Royal blue was principally a synonym for smalt (*q.v.*), for example, Field (1809) records in the early nineteenth century testing a sample from Brandram & Co. sold as '*Royal blue*'. For Heaton (1928) royal blue was a current term for a pigment based on artificial ultramarine (*q.v.*). Mayer, however, states it also referred to 'numerous synthetic organic lakes'.

Smalt; *Ultramarine*
Field (1809) 315, 343, 358; Heaton (1928) 383; Mayer (1991) 55

ROYAL GREEN

Green
Synonym, variant or common name

Heaton (1928) lists Royal green among then-current terms. He states that the composition is 'Brunswick green', which he in turn describes as containing 'mixtures of Prussian blue, chrome yellow and barytes [*q.v.*]'.
See: chrome green

Baryte; *Brunswick green*; *Chrome green*; *Chrome yellow*; *Prussian blue*
Heaton (1928) 383

ROYAL RED

Red
Synonym, variant or common name

See: vermilionette.

ROYAL SCARLET

Red
Synonym, variant or common name

See: mercury iodide.

ROYAL YELLOW

Yellow
Synonym, variant or common name

Royal yellow has been used as a term for the synthetic analogue of orpiment (FitzHugh, 1997).

Orpiment
FitzHugh (1997)

ROZA

Red
Synonym, variant or common name

A sixteenth century Italian term for madder also called *Rosa* and *Roza di Fiandra* (Merrifield, 1849).
See: madder.

Ciocchi; *Granzuolli*; *Robbia*
Merrifield (1849) clxxviii

RUBEA RADIX

Red
Synonym, variant or common name

The term *rubea radix* has been used historically in association with madder (*q.v.*; Schweppe and Winter, 1997).
See: rubia.

Madder; Rubia
Schweppe & Winter (1997)

RUBENS' BROWN

Brown
Synonym, variant or common name

Rubens' brown was apparently either synonymous with, or closely related to, a form of the so-called 'Vandyck brown' (either a humic earth or a composition of earth pigments). Carlyle (2001) found that certain British artists' colourmen such as Reeves and Winsor & Newton were suppliers of Rubens' brown in the mid-nineteenth century. By the time Heaton was writing in the early twentieth century, Ruben's brown was an obsolete or rarely used term.

Humic earth; *Vandyke brown*
Carlyle (2001) 489; Heaton (1928) 383

RUBENS' MADDER

Orange
Synonym, variant or common name

Supplied by Winsor & Newton, Rowney and Reeves in the mid- to late nineteenth century (Carlyle, 2001). Salter (1869) and Standage (1887) mention this pigment, noting the various synonyms such as orange russet, russet rubiate and Field's russet; the former author describes it as 'a very rich crimson russet with a flush of orange; pure, transparent and of a middle hue between orange and purple. Prepared from the madder root.' There is also a recipe in one of the Roberson's recipe books (R.2.N) which is unclear but seemingly includes madder and burnt sienna (*qq.v.*).

Madder; *Burnt sienna*; *Field's russet*; *Orange russet*; *Russet rubiate*
Carlyle (2001) 500; Salter (1869) 321–322; Standage (1887)

RUBIA

Red
Common generic composite

Various species of *Rubia* (Rubiaceae) produce the dyestuff known commonly as madder (*q.v.*); the most common species are: *Rubia tinctorum* L.; *R. peregrina* L.; *R. cordifolia* L.; *R. sikkimensis* Kurz.; *R. akane* Nakai; *R. iberica* C. Koch; *R. rigidifolia* Pojark (Schweppe, 1992; Schweppe and Winter, 1997). For a fuller discussion of the various members of the Rubiaceae that produce madder-related anthraquinone dyestuffs, see the entry for madder.

The term *rubia* has long been used historically in association with the term madder, steming from the Latin name for that material. Pliny (77 AD), for example, called it *rubia* in addition to *erythrodanum* and *ereuthodanum*, the latter being in turn Latinate derivations of the Greek '*erythrodanon*' (such as is used in Dioscorides' 1st century AD, *De materica medica*). Heraclius (tenth–thirteenth century) also mentions this term, however spelled *rubea* (*rubea radix*) (Ilg; cf. Schweppe and Winter). *Robbia* is a sixteenth century Italian derivation of this term (Merrifield, 1849).

Anthraquinones group; Madder; *Robbia*; *Rubea radix*
Dioscorides (1st Cent. AD/Osbaldeston & Wood, 2000) 3, 160; Merrifield (1849) cxxxii; Pliny (1st cent AD/Rackham, 1952); Schweppe & Winter (1997); Schweppe (1992)

RUBIADIN

Yellow
Generic compound

The anthraquinone *Rubiadin*, 1,3-dihydroxy-2-methylanthraquinone, is found as a major component in roots of various *Rubia*, *Galium*, *Coprosma* and *Morinda* species and is therefore a component found in madder dyes (Schweppe, 1992; *Merck Index*, 1996). It is designated by the *Colour Index* as CI 75350.

Anthraquinones group; Madder
Colour Index (1971) 75350; *Merck Index* (1996) 8438; Schweppe (1992) 202

RUBIS D’ORPIMENT

Red
Synonym, variant or common name

See: realgar.

RUBRIC LAKE

Red
Synonym, variant or common name

Field (1835) uses the term rubric lake to denote lake pigments derived from madder (*q.v.*) dyestuffs (that is, root extracts from *Rubia* species, notably *R. tinctorum* L.) and he says of them that they are ‘perfectly transparent, and literally as beautiful and pure in colour as the rose’.

Madder
Field (1835) 97–98

RUBRICA

Red
Synonym, variant or common name

Rubrica (or *rubricae*) is listed by the classical authors on pigments Vitruvius (first century BC) and Pliny (77 AD). It is generally translated as ‘red ochre’, though it is also linked to *sinoper* (*qq.v.*); the English word raddle (or ruddle) has also been used in some translations, though this is perhaps linguistically misleading. Vitruvius states that *rubricae* was found in many places, the best being from Sinope (that is, Sinopia), Egypt, as well as the Balearic Islands and Lemnos. Pliny on the other hand implies that *rubrica* is a second-rate sinoper, adding that it is associated with iron workings and may also be manufactured by burning ochre. The word ‘rubric’ derives from this term, as the titles of laws were written in red.

Red ochre; *Ruddle*; *Sinoper*
Pliny (1st cent AD/Rackham, 1952) XXXV.xv–xvii; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.2

RUBY OF ARSENIC

Red-Orange
Synonym, variant or common name

Ruby of arsenic was synthetic realgar according to Tingry (1804).

Realgar
Tingry (1804) 358

RUDDLE

Red
Synonym, variant or common name

An English word, certainly in use by the seventeenth century and to some extent later, to denote a form of red ochre (*q.v.*). The word derives from ‘rud’ – ‘to make red or ruddy’; variant spellings include raddle and reddle (*OED*, 2002). It came to be used more in connection with marking sheep than painting, although the word was used by some of the early twentieth century translators of the classical authors such as Theophrastus (c. 315 BC) and Pliny (77 AD) as an equivalent for the Greek word miltos (μιλτός).

In the seventeenth century the English author Waller (1686) describes how reddle is to be found at Witney, near Oxford; this was a historically important source for red ochre, sometimes known as Oxford ochre. Harley (1982) also notes that the same term appears in late sixteenth or early seventeenth century anonymous MS Stowe 680 under the heading ‘faint reds’.

Iron oxides and hydroxides group; *Red ochre*
Harley (1982) 119; MS Stowe 680 (nd); *OED* (2002) ‘Ruddle’; Pliny (1st cent AD/Rackham, 1952) XXXV.xii; Theophrastus (c. 315 BC/Caley & Richards, 1956) 51; Waller (1686)

RUE

Yellow
Synonym, variant or common name

The use of a glycosidic exudate from rue – *Ruta graveolens* L. (Rutaceae; found in southern Europe) – has been noted in certain historical recipes for the modification of verdigris. The Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield, 1849), for example, contains such a formulation. Modern experiments duplicating this have been reported by Woudhuysen-Keller and Woudhuysen (1998); grinding verdigris with juice extracted from rue leaves apparently turns the blue-green colour of a ‘neutral verdigris’ into a dark mossy green.

Flavonoids group; *Verdigris*
Merrifield (1849); Woudhuysen-Keller & Woudhuysen (1998)

RUE BLUE

Blue
Synonym, variant or common name

The *Compendium* of 1808 lists this as an organic blue. No further information on its composition is available.

Compendium (1808)

RUFIGALLIC RED

Red
Synonym, variant or common name

Another of the speculative pigments suggested by Salter (1869). He describes it as follows: ‘When a duly proportioned mixture of gallic acid and oil of vitriol is carefully and gradually heated to 140°, a viscid wine-red liquid results. If this be poured into cold water, after cooling, a heavy brown-red granular precipitate is formed.’

Salter (1869) 174–175

RÜGENER CHALK

White
Synonym, variant or common name

A variety of chalk (*q.v.*) from Rügen, in northern Germany.

Chalk

RUSSET RUBIATE

Orange
Synonym, variant or common name

Field (1835) gives this as a synonym for brown madder, also calling it intense madder brown and Field’s russet. He furthermore gives a description of Marrone lake as a madder preparation ‘of great depth, transparency and durability’ (cf. Carlyle, 2001).

Field’s russet; *Madder orange*; *Orange lake*; *Orange russet*; *Rubens’ madder*
Carlyle (2001) 489; Field (1835) 146, 165

RUSSIAN BLACK

Black
Synonym, variant or common name

A term associated with mineral black (*q.v.*). Bouvier (1827) describes it only briefly, as an extremely intense black earth. It is also mentioned in the book by Osborn (1845), an 'edition' of Bouvier, who remarks that it was a natural earth from Russia that 'we imagine is not easy to be procured in this country, even were it not superfluous'.

Mineral black
Bouvier (1827) 80; Osborn (1845) 39

RUTILE

White
Generic compound

Rutile is a tetragonal titanium(IV) oxide mineral with composition TiO_2, named from the Latin word for red *rutilus*, in reference to the common mineral colour. It was first described by Werner in 1803 and is commonly found as red-brown sub-metallic prismatic or acicular crystals, which may be twinned and striated; it also occurs with massive or granular form and varies in colour according to the presence of impurities (such as Fe^{2+}, Fe^{3+}, Cr, Nb, Al). Rutile is the high temperature polymorph of anatase (also tetragonal) and brookite (orthorhombic), stable $>600°C$, and is the most common form of TiO_2. It occurs worldwide in many igneous and metamorphic rocks and its durability means that it also occurs as a sedimentary detrital mineral, sometimes forming beach sands (Dana, 1944; Deer *et al.*, 1992; Rutley, 1988). Rutile (and ilmenite) are major sources of titanium and are used as starting materials for the production of the synthetic white titanium(IV) oxide pigments (*qq.v.*). Economic resources of rutile occur principally in weathered sands, where it is accompanied by zircon and/or ilmenite and other heavy minerals. According to Buxbaum (1998), supply of rutile is insufficient to meet demand and rutile as a source of titanium for conversion into TiO_2 pigments is gradually being replaced by other minerals such as ilmenite. However, the largest producers are Australia, South Africa and Sierra Leone.

The presence of rutile in coloured grounds of paintings from the seventeenth to eighteenth century French School has been noted by Duval (1992) as natural impurities in earth pigments. Laver (1997) indicates that while natural rutile may have been used as a pigment historically, its synthetic analogue, titanium(IV) oxide, rutile type, has been used far more extensively since its first production in the early twentieth century. The use of titanium(IV) oxide as a pigment and in other artists' materials, such as inks, pastels, paper and ceramic glazes, has been reviewed by Laver (1997) and Braun *et al.* (1992).

A number of modern pigments are sometimes referred to as rutile pigments; this is because they share the same basic crystal structure (that is, they are isostructural) rather than because they share a close compositional similarity. For more information, see the entry for rutile pigments.

Titanium group; Titanium oxides and hydroxides group; Anatase; Brookite; Ilmenite; Titanium(IV) oxide, anatase type; Titanium(IV) oxide, rutile type; *Titanium dioxide white*; *Titanium white*
Braun *et al.* (1992); Buxbaum (1998) 47–48; Dana (1944) 544; Deer *et al.* (1992) 548–551; Duval (1992); Laver (1997); Rutley (1988) 266–268

RUTILE PIGMENTS

Yellow-Brown
Group term

The rutile (TiO_2) crystal structure permits substitution of a range of elements to give a series of pigments of commercial importance. The earliest of these were derivatives containing antimony, cobalt and nickel, giving yellow to brown compounds. Other substituents are chromium-tungsten (brown), copper-antimony (lemon yellow), manganese-antimony (dark brown), iron-antimony (grey) and vanadium-antimony (dark grey); most of these have been used primarily as ceramic pigments. However, of more general interest are nickel rutile yellow $(Ti_{0.85}Sb_{0.10}Ni_{0.05})O_2$ (CI 77788/Pigment Yellow 53) and chromium rutile yellow $(Ti_{0.90}Sb_{0.05}Cr_{0.05})O_2$ (CI 77310/Pigment Brown 24) (Buxbaum, 1998).

Rutile; *Chromium rutile yellow*; *Nickel rutile yellow*
Buxbaum (1998) 100; *Colour Index* (1971) 77310, 77788

S

SAALFELD GREEN

Green

Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

SACHSISCHBLAU

Blue

Synonym, variant or common name

Historical term used for smalt (*q.v.*), possibly as a source variant. Presumably related as a term to saxon blue and perhaps also saxony blue (*qq.v.*).

Smalt; *Saxon blue*; *Saxony blue*

SACHTOLITH

White

Synonym, variant or common name

Trade name for a pure form of a precipitated zinc sulfide containing 3% zinc oxide, marketed from 1927 (Buxbaum, 1988; Heaton, 1928).

Zinc group; Zinc sulfides group; Zinc oxide; Zinc sulfide
Buxbaum (1998) 71; Heaton (1928) 89

SAFFER

Blue

Synonym, variant or common name

Heaton (1928) lists saffer as an obsolete or rarely used term, describing it as 'impure' smalt.
See: zaffre.

Smalt; *Zaffre*
Heaton (1928) 385

SAFFER BLUE

Blue

Synonym, variant or common name

See: zaffre.

SAFFLOWER

Red-Orange-Yellow

Common generic composite

Safflower is the common name for a plant producing a red to yellow dye obtained from the flower petals of the plant *Carthamus tinctorius* L. (Compositae). The name carthamus is the latinised form of the Arabic word *quartum* or *gurtum*, which refers to the pigment colour. Dyes were produced from fresh flowers, which were collected during morning shade and dried on muslin trays before storing in tins. Other methods of producing safflower dyes included collecting the heads of flowers before they faded on the plant and removing the yellow corollas. The yellow dye could be extracted by washing the corollas for three to four days in acidified water, which made the pigment dissolve. The principal colour constituent is carthamin (CI 75140/Natural Red 26), though more detailed composition of the flower petal extracts has been given by Akihisa *et al.* (1994), Kazuma *et al.* (2000) and Okuno and Kazuma (2000). Numerous subsidiary compounds occur, including quinochalcones, flavonols such as 6-hydroxykaempferols, hydroxysafflor yellow A, safflor yellow B and safflomin C; significant variations in content according to the colour of the cultivar concerned has also been noted.

The safflower plant is believed to have originated in southern Asia and is known to have been cultivated in China, India, Persia and Egypt almost from prehistoric times. It has been identified by Pfister (1940) on linen from Egypt dating c.1050 BC (Cardon, 2001). During the Middle Ages it was cultivated in Italy, France and Spain, and soon after discovery of America, the Spanish took it to Mexico and then to Venezuela and Colombia. It was introduced into the United States in 1925 from the Mediterranean region. Most usage historically has been as a dyestuff, but there are a number of records where safflower dye has been converted into a pigment for various purposes including cosmetics, as a gilding preparation and for painting. Harley (1982) states that it was used (apart from dyeing government red tape!) as an artists' pigment in nineteenth century Britain. It was also much used in Japan on coloured prints. It has been analysed on a print dating 1770 by Shimoyama and noda (cf. Cardon).

Safflower is also called bastard saffron, for instance Watin (1785) discusses bastard saffron as coming from Alsace and Provence, the best though coming from the Levant. The *Merck Index* (1996) lists *African saffron*, *thistle s.*, *American s.*, *false s.*, *bastard s.* and *dyer's s.* as alternate names; this points to an evident historical confusion with true saffron (from stamens of *Crocus sativus*). A similar situation can be traced in the pigment literature, with frequent interchange between 'saffron' and 'safflower' where clearly the latter is meant. Thus, for example, Alston (1804) writes of 'Saffron flowers prepared in saucers'; likewise *Le maître de miniature* (1820) mentions *saffron en godet*, the meaning again being the same and referring to so-called *saucer colour* (*q.v.*; cf. Harley, 1982), which is known from related contexts to be a safflower-based pigment. Other terms for safflower-based colours include *carthame*, *safranum*, pink saucers, *rouge*, *rouge végétale* and Chinese rouge (Field, 1835).

Carthamin; Saffron; *Assiette rouge*; *Pink saucers*; *Rouge*; *Rouge végétale*; *Saucer colour*
Akihisa *et al.* (1994); Alston (1804) 62; Cardon (2001); *Colour Index* (1971) 75140; Field (1835) 101; Harley (1982) 147; Kazuma *et al.* (2000); *Merck Index* (1996) 27; Okuno & Kazuma (2000); Pfister (1940); Watin (1773/edition of 1785) 27

Saffron
Yellow
Common generic composite

The term saffron in a pigment context refers to a dye derived from the stamens of the plant *Crocus sativus* L., 'prized by illuminators' as the Borradailes stated in their notes to the fifteenth century *Strasburg MS* (Clarke MS 2000). The main dyestuff produced is crocetin.

The Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield, 1849) mentions its use for making 'a yellow for drawing gold flowers on paper' by mixing it with lead white (*q.v.*) and gum water. The Paduan MS (late sixteenth to early seventeenth century; cf. Merrifield, 1849) also describes its preparation: '*128. To prepare saffron for painting*: Take the saffron, tie it up in a rag, and steep it in white vinegar, with a little gum or white of egg beaten and strained; but if you make use of the white of egg, no gum.' The importance of this colour to Mediaeval illuminators is evident from the large number of recipes for it in documentary sources. Clarke (2001) has listed 24 in his examination of manuscripts on colour dating before 1500. As a dye it is one of the oldest known, having been found on a colour table used by the Akkadians in the second century BC (Ebeling, 1923; cf. Schweppe, 1992). It has also been identified on a painting from the first quarter of the fourteenth century as a glaze over orpiment (*q.v.*; Kühn, 1973; cf. Schweppe, 1992).

Considerable confusion exists in the pigment literature over saffron and safflower (*q.v.*); the latter was derived from *Carthamus tinctorius* L. and produced a red to yellow dye used to prepare lake colours. Antimonial saffron was a term for antimony(V) sulfide (*q.v.*).

Antimony(V) sulfide; Carthamin; Crocetin; Orpiment; Safflower; *Antimonial saffron*; *Bastard saffron*; *Carthame*
Clarke (2001) 132; Ebeling (1923); Kühn (1973); Merrifield (1849) 706; Schweppe (1992) 58; *Strasburg MS* (15th cent/tr. Borradaile, 1966) 91

Safranum
Yellow
Synonym, variant or common name

Term for dyes and lake pigments based on safflower (*q.v.*; dye derived from *Carthamis tinctorius* L.). Also called bastard saffron and carthame by Watin (1785).

Safflower; *Bastard saffron*; *Carthame*
Watin (1773/edition of 1785) 27

Saint John's white
White
Synonym, variant or common name

See: bianco di Sangiovanni.

Saint-Cyr white
White
Synonym, variant or common name

According to Riffault *et al.* (1874), Saint-Cyr white was manufactured at the works of Portillon, being a mixture of lead white and zinc white (*qq.v.*).

Lead white; *Zinc white*
Riffault *et al.* (1874) 184

Salt green
Blue-Green
Synonym, variant or common name

See: viride salsum.

Salt of Saturn
White
Synonym, variant or common name

Historical term for lead(II) acetate trihydrate.
See: lead acetates group.

Sampleite
Blue
Generic compound

Sampleite is a hydrous sodium calcium copper phosphate chloride mineral with composition $(Na,K)CaCu_5(PO_4)_4Cl.5H_2O$. It was first described by Hurlbut in 1942 and named after M. Sample, a mine engineer from the locality in Chuquicamata (Chile) where the mineral was originally discovered. Sampleite occurs as blue or blue-green tabular or prismatic crystals and aggregates and forms from the oxidation of copper deposits under arid conditions; it also forms in caves where the phosphate is derived from bat guano (for example, Mbobo Mkulu caves, South Africa).

Angelini *et al.* (1990) identified sampleite in a green pigment cake found in Heliopolis in 1903–05; however, according to Scott (2002), it is possible that this is an alteration product.

Copper phosphates group
Angelini *et al.* (1990); Hurlbut (1942); Scott (2002)

Sandal red
Red
Synonym, variant or common name

This probably refers to the lake pigment made from sandalwood (*q.v.*); however, reference to roots as the source also indicate that it may be from madder (*q.v.*). Salter (1869) uses this term to refer to a pigment derived from a dye-wood (type not specified). The author describes the somewhat complex preparation as follows: 'The powdered root exhausted by alcohol gives a solution to which hydrated oxide of lead is added in excess. The combination of colouring matter and lead oxide is then collected on a filter, washed with alcohol, dried, dissolved in acetic acid, and mixed with a quantity of water. The red being insoluble therein is precipitated, while the acetate of lead remains dissolved. After being washed, the colour is dried at a low temperature.' Salter indicates that he is unaware of its use as a pigment in Britain.

Madder; Sandalwood
Salter (1869) 175–176

Sandalwood
Red
Common generic composite

A common name for *Pterocarpus santalinus*, one of the plants which produce the dyestuff Santalin (*q.v.*). A recipe for making a lake pigment from sandalwood is described by Riffault *et al.* (1874) who gives it the name 'Indian red'. Tingry (1804) also describes it as a colorant for varnishes, unsuitable in oil.
See: Santal red.

Santalin
Riffault *et al.* (1874) 486–487; Tingry (1804) 362

SANDARACA

Yellow
Synonym, variant or common name

See: orpiment.

SANDARACH

Red
Synonym, variant or common name

Early usage of this term is somewhat confused, with Greek and Roman references that could mean orpiment, realgar, cinnabar, red ochres and the yellow lead monoxides (litharge and massicot; *qq.v.*). However, Hey (1993) is firm that *sandaracha* is described by Pliny (77 AD) as a synonym for realgar. We also find in the mineralogical literature that *sandaraca* is a term used synonymously with realgar by Dana (1868) where it is cited as a term of German origin. This is earlier given as *arsenicum sandaraca* of Linnaeus (Dana, 1837).

Sandaraca, generally interpreted as the orange-red sulfide of arsenic, realgar, is mentioned by all the classical sources though none elaborate on its provenance much beyond that it came 'from mines'. Vitruvius (first century BC) says that these mines were in Pontus (which, in ancient times, was the name of the north-eastern province of Asia Minor, a long and narrow strip of land on the southern coast of the Black Sea, *Pontus Euxinus*). and it is certainly plausible that the volcanic regions south of this area were a source of this mineral.

The *Princeton Encyclopedia of Classical Sites* (Stillwell *et al.*, 1976) also makes an unsubstantiated claim that a red sulfate of arsenic was a principal export of the port of Sinope. Whether or not this comment is a result of field evidence or documentary sources is unclear.

Cinnabar; Lead(II,IV) oxide; Litharge; Massicot; Orpiment; Realgar; *Red ochre*
Dana (1837) 434; Dana (1868) 26; Hey (1993); Pliny (1st cent AD/Rackham, 1952) xxxv.6; Stillwell *et al.* (1976); Vitruvius (1st cent BC/Grainger 1934)

SANDERS BLUE

Blue
Synonym, variant or common name

According to Harley (1982) this was an eighteenth century English affectation from the French *cendres bleues*, a term originally covering both natural and synthetic copper carbonates. However, the term was introduced and used as if it were an entirely distinct pigment.

Copper carbonates group; Copper carbonate hydroxide, azurite type; *Blue verditer*; *Cendres bleues*
Harley (1982) 50

SANDYX

Red-Orange
Synonym, variant or common name

The classical author Pliny (77 AD) names two pigments which were blends of other reds, namely *sandyx*, which is a mixture of white lead (*cerussa*) and red ochre which was then roasted (and used for painting flesh tones), and *Syricum*, which was a mixture of sandyx and red ochre (*qq.v.*).

Lead(II,IV) oxide; *Lead white*; *Red ochre*; *Syricum*
Pliny (1st cent AD/Rackham, 1952) XXXV.xxiii

SANGUIS DRACONIS

Red
Synonym, variant or common name

See: dragon's blood.

SANTALIN

Variable
Common generic composite

The dyestuff santalin, used in the manufacture of a number of lake pigments, is made by extraction with ether from the ground wood of *Pterocarpus santalinus* L.f. (south-east India, Sri Lanka, Malaysia, Philippines and East Timor) and *P. indicus* (India, Malaysia, Mayanmar, Andamans, Philippines, South China) (Mabberley, 1998). The crystals thus formed are precipitated from their solution in alcohol by lead acetate as a lead salt. This is then decomposed with sulphuric acid, and the solution is 'separated from the lead sulphate and concentrated, the santalin separating out as small red crystals' (Zerr and Rübencamp, 1906).

A number of sources refer to santalin in a variety of contexts, from the preparation of lakes to its use as an adulterant. Riffault *et al.* (1874) cites Professor Dussauce (1861) who gives a recipe for making a lake pigment from sandalwood (*q.v.*) 'which is nearly equal to carmine in beauty and brightness'.

Schweppe (1992) describes the range of colours that can be produced depending on the laking anion: aluminium produces an intense dark brown going toward purple red; magnesium produces dark brown violet; zinc produces violet brown, tin produces a lilac, lead produces an intense red violet and copper produces a deep violet brown.

The lake pigment from sandalwood is given the name Indian red by Riffault *et al.*; however, this appears to be an unusual association of the term.

Sandalwood; *Sandal red*
Mabberley (1998) 598; Riffault *et al.* (1874) 486–487; Schweppe (1992) 429; Zerr & Rübencamp (1906/1908) 460–461

SAP BLUE

Blue
Synonym, variant or common name

A sample of sap blue is contained in Field's *Practical Journal 1809*. The origin of the pigment is not discussed although it was apparently supplied as lumps and could be used directly in watercolour simply by applying a wet brush (cf. Harley, 1982).

Blue lake
Field (1809) f. 318; Harley (1982) 65

SAP GREEN

Green
Synonym, variant or common name

Sap green was made from a flavonoid dye extracted from the ripe berries of buckthorn (*Rhamnus cathartica* L.) and various other *Rhamnus* species. The related Chinese green and *lokao* were greens produced by *Rhamnus* species found in China (see the entry for *lokao*).

For a full discussion of the plant species involved, constituent compounds, substrates and alternative terminology, see the entry for *Rhamnus*.

There is some considerable contradiction in the literature as to the ripeness required to produce a good green colour. Tingry

(1804) states that the berries should be ‘black and very ripe’ and, according to Boltz (1549), they should be picked ‘fourteen days before Michaelmas’. Mierzinski (1881) suggests that indigo was added as the berries produced a yellow mass. This is possibly because, contrary to the early literature, he states that the berries should be picked when they are not entirely ripe but still green. Riffault *et al.* (1874) believe that the ripe berries produce a dirty or greyish yellow whereas the less ripe berries can produce an undesirable green yellow colour. Following experimentation he gives the following recommendation: ‘The berries should not have reached their complete maturity.... The boiling ... and evaporation ... done at a moderate temperature ... green colour will become apparent by means of the double sulfate of alumina and potassa.... By varying the proportions of alum different tones ... will be obtained.’ (Terry (1893) states that the green dye substrate should only be alum as other substrates change the transparency or viscosity of the pigment.) Other source also indicate the addition of indigo, for example, Zerr and Rübencamp (1906) state that indigo carmine and alum are added to the extract of the berries and other literature references indicate the addition of woad (*Isatis tinctoria*) and iris blue (from various members of the Iridaceae).

Mills and White (1994) state that the colour of sap green is almost entirely due to chlorophyll (*q.v.*) and as such it is possible that other sources were used, for example, in the early seventeenth century Portugese treatise by Nunes, asparagus seeds are cited. Confusion may also arise as greens produced from the petals of various flowers, notably iris, have, in mediaeval literature, occasionally been called sap green. For a discussion of these greens see: Iris green. Field (1835) adds that similar pigments were obtained from coffee berries and named Venetian green or emerald green.

Finally, it is clear that some pigments labelled under this name were composed of a mixture to give a similar colour. Fishwick (1795–1816) describes a sap green compounded of ‘dutch pink, gamboge and Spanish indigo’. Linke and Adam (1913) have called a composite colour of Prussian blue and gamboge by this name (saftgrün) and Winsor & Newton (in a catalogue of 1896) state that ‘In oil the colour is a combination of Quercitron Lake, Ultramarine & Bone Brown’ (cf. Carlyle, 2001).

Sap green is much mentioned in early manuscripts; Clarke (2001) lists nine treatises dating before 1500 giving recipes for the pigment. It was recommended in the Strasburg MS (fifteenth century, Clarke MS 2000) that it be added to azurite ash to make a good green for drapery. However, while it was a very important mediaeval colour that continued in use to some degree through to the nineteenth century, by the early twentieth century Zerr and Rübencamp state that it ‘has only very little practical value’ and Heaton (1928) lists sap green only as an obsolete or rarely-used pigment.

Many of the terms associated with this pigment refer to the fact that it was stored for use in bladders; *verde vessie*, pasta green (Paduan MS., cf. Merrifield, 1849) *verde di veschia, verde vejiga* (Carducho; cf. Veliz, 1986), and bladder green (*qq.v.*). The German terms associated with sap green include, *saftgrien* or *saftgrün* (Boltz, 1549).

Flavonoids group; Chlorophyll; Quercitron; Rhamnus; Ultramarine; *Bladder green*; *Buckthorn*; *Chinese green*; *Iris green*; *Lokao, Venetian green*; *Verde vessie*; *Woad*
Boltz von Ruffach (1549/Benziger 1913) 75; Carlyle (2001) 494; Clarke (2001) 132; Field (1835) 131; Fishwick (1795–1816) 75; Heaton (1928) 383; Linke & Adam (1913) 69–70; Merrifield (1849) ccxix; Mierzinski (1881) 411; Mills & White (1994) 146; Nunes (1615) 65; Riffault *et al.* (1874) 535; *Strasburg MS* (15th cent/tr. Borradaile 1966) 50; Terry (1893) 132–133; Tingry (1804) 375–376; Veliz (1986) 198, n.10; Zerr & Rübencamp (1906/1908) 460

SAPPAN-WOOD
Red
Synonym, variant or common name

See: brazilwood.

SARANGUY
Red
Synonym, variant or common name

See: aal and madder.

SATIN WHITE
White
Synonym, variant or common name

There is some confusion over this term. Salter (1869) states that it is ‘a sulphate of lime and alumina, which dries to a glossy surface’, while according to Heaton (1928) satin white consisted of a mixture of calcium sulfate and calcium aluminate (*qq.v.*) and was used as a base for preparing lake pigments, preparation being by the precipitation of aluminium sulfate with lime. Terry (1893) states that this sometimes refers to baryta white or fine gypsum (*qq.v.*). More confusingly, this has also been called Troy or Spanish white, names generally given to chalk (*qq.v.*) for example, Dossie (1764) gives a recipe which corresponds to satin white but calls this Spanish a Troy white.

Heaton and Hurst do not appear to say the same thing, though Heaton is a revision of the text by Hurst. Bristow (1996b) states that Hurst says it is made from calcium sulfate and aluminium sulfate, adding that he thinks that it was made with alum (potassium aluminium sulfate) as opposed to aluminium sulfate.

Baryte; Calcium aluminium oxide; Calcium sulfate; Chalk; Gypsum; *Spanish white*; *Troy white*; *Troyes white*
Bristow (1996b) 8; Dossie (1764) 137; Heaton (1928) 109; Salter (1869) 80; Terry (1893) 246; Waller (1686)

SATINSPAR
White
Generic variety

A variety of gypsum (*q.v.*). Listed in the *Colour Index* (1971) as a source of CI 77231/Pigment White 25 (calcium sulfate; *q.v.*).

Calcium sulfate; Gypsum
Colour Index (1971) 77231

SATURN RED
Red-Orange
Synonym, variant or common name

Saturn red has been used as a term for lead(II,IV) oxide (*q.v.*; Doerner, 1935; FitzHugh, 1986).

Lead(II,IV) oxide
Doerner (1935) 74; FitzHugh (1986)

SATURNINE RED
Red-Orange
Synonym, variant or common name

Saturnine red was used as a term for lead(II,IV) oxide (*q.v.*) by authors such as Salter (1869). Harley (1982) records that de Massoul lists Saturnine red as a pure and expensive type of minium (*q.v.*) which had been repeatedly washed with water.

Lead(II,IV) oxide; Minium; *Red lead*
FitzHugh (1986); Harley (1982); Salter (1869) 151

SAUCER COLOUR

Red
Synonym, variant or common name

A group of related terms exists which refer to pigments based on safflower (*q.v.*). Alston's *Hints to young Practitioners in the Study of Landscape Painting* (c. 1804; cf. Harley, 1982) reports that 'Saffron flowers prepared in saucers are sold in some shops, called saucer colour', this giving a rose colour. It should be noted that there was a common historical confusion between safflower and saffron (*q.v.*); safflower is clearly meant in this context. Alston adds that the colour could previously only to be obtained from French milliners, but that it was by that time available from colour shops. *Saffron en godet* ('saffron in saucers') is mentioned by *Le maître de miniature* of 1820 (cf. Harley, 1982). Field (1835) also lists *pink saucers*, noting correctly the preparation from safflower.

Other associated terms are *assiette rouge*, *Chinese rouge* and *rouge végétale*. The preponderance of French terms underlines the apparent origins of this pigment.

Safflower; Saffron
Alston (1804); Field (1835) 101; Harley (1982) 146–147; Le maître de miniature (1820)

SAXON BLUE

Blue
Synonym, variant or common name

Historical term used for smalt possibly as a source variant as Tingry (1804) states that 'it is manufactured on a large scale in Saxony, where mines of cobalt are abundant. From this circumstance only it has acquired the denomination of Saxon blue.' Fishwick (1795–1816) gives a recipe for Saxon blue using '3 oz spanish indigo. 4 oz french Do [indigo], levigated and add 14th paris white'. For Terry (1893) it was apparently a form of Prussian blue, the recipe he gives being likely to form this compound: 'Dissolve 8 lb. alum and 1 lb. green copperas in 16 gallons of water. Add separate solutions of pearlash and yellow prussiate till precipitate ceases to go down.' Heaton (1928) lists Saxon blue as a then-current term synonymous with smalt.

Presumably related as a term to *sachsischblau* and saxony blue, though the latter is also described by Riffault *et al.* (1874) as a modified indigo. Balfour-Paul (1998) also uses this term to describe the modified indigo also known as indigo carmine (*q.v.*).

Indigo; Smalt; *Indigo carmine*; *Prussian blue*; *Sachsischblau*; *Saxony blue*
Balfour Paul (1998) 116; Fishwick (1795–1816) 2; Heaton (1928) 384; Riffault *et al.* (1874) 351; Terry (1893) 69; Tingry (1804) 300–301

SAXON EARTH

Green
Synonym, variant or common name

See: green earth.

SAXONY BLUE

Blue
Synonym, variant or common name

Riffault *et al.* (1874) describe this pigment as synonymous with indigo carmine (*q.v.*). There is however, a further contradictory reference to this in Riffault *et al.* as synonymous with smalt (*q.v.*), Saxony being where 'this colour is prepared the best'. Tingry (1804) also considers this to be vitreous oxide of cobalt or smalt. See also: Saxon blue.

Indigoid group; Smalt; *Indigo carmine*; *Saxon blue*
Riffault *et al.* (1874) 268, 361; Tingry (1804) 300

SCARLET CHROME

Red
Synonym, variant or common name

A variant of scarlet red and synonymous with chrome red, a lead chromate(VI) oxide (*qq.v.*) pigment. According to Carlyle (2001), it was first listed by Salter (1869), who described it as 'a bright chromate of lead of an orange-red colour'.

Lead chromate(VI) oxide; *Chrome red*
Carlyle (2001) 504; Salter (1869) 151

SCARLET LAKE

Red
Synonym, variant or common name

Scarlet lake may refer to either a cochineal lake or, according to Field (1835), a 'crimson lake and vermilion' or iodine scarlet (mercury iodide; *qq.v.*). Salter (1869) states that scarlet lake 'is prepared in the form of drops from cochineal, and is of a fine transparent red colour and excellent body . . . It is generally tinted with vermilion.' Heaton (1928) indicates that this was still a term of current use, listing two meanings, one a pigment based on cochineal and vermilion and another a 'scarlet from artificial dyes'.

Cochineal; Mercury iodide; *Vermilion*
Field (1835) 99; Heaton (1928) 383; Salter (1869) 136

SCARLET MADDER

Red
Synonym, variant or common name

Carlyle (2001) has noted that different artists' colourmen recorded this to be either derived from alizarin or a variety of rose madder (*qq.v.*).

Alizarin; Madder; *Rose madder*
Carlyle (2001) 506, 509

SCARLET OCHRE

Red
Synonym, variant or common name

See: red ochre.

SCARLET VERMILION

Red
Synonym, variant or common name

This appears to have been a shade variant of vermilion (*q.v.*; mercury(II) sulfide). Carlyle (2001) has noted that there were extensive citations of this pigment in British artists' colourmens' catalogues of the nineteenth century where, initially distinct, it subsequently became wholly synonymous with the term extract of vermilion. Heaton (1928) still lists it as a current term, describing it as a 'bright tint of vermilion'. Doerner (1935) on the other hand lists this as iodine scarlet (mercury iodide; *q.v.*).

Mercury iodide; Mercury(II) sulfide; *Extract of vermilion*; *Vermilion*
Carlyle (2001) 511–512; Doerner (1935) 74; Heaton (1928) 383

SCHEELE'S GREEN

Green
Synonym, variant or common name

Scheele's green is normally described as being copper arsenite, though this disguises considerable complexity in the composition and structure of the pigment. For a fuller discussion of the issues surrounding the chemistry and manufacture of the pigment, see the Copper arsenite group (*q.v.*) entry; discussion of the related emerald green can also be found under that entry.

Although Mérimée (1830) postulated that 'the ancients knew… the arseniate of copper', it is generally accepted that this pigment was discovered by the Swedish chemist Carl Wilhelm Scheele in 1775 while he was carrying out research on arsenic. The findings were published in 1778 although the precise methodology involved in its production was kept secret, allowing Scheele to profit from his invention. The basic procedure, however, was to mix solutions of copper sulfate and arsenic(VI) oxide dissolved with the aid of potassium carbonate. The pigment consequently became known as Scheele's or Swedish green. Later production in Germany, by a slightly different process, led to the pigment being produced in both 'ordinary' and 'German' varieties, depending on the production technique used (Zerr and Rübencamp, 1906). A process for producing an 'improved' form of the pigment was also patented by Parker in England in 1812, being sold under the name patent green.

Salter (1869) describes producing a calcined form with an olive colour, stating that 'cupric arsenite, when heated, gives off arsenious acid and water, leaving a residue of arsenide of copper and copper arseniate.'

It was popular as an artist's pigment when it was first introduced, owing to the fact that there were few other good greens at that time; however, its greatest use was as a colour for fabric and wallpaper. It appears to have been little used in Britain (Harley, 1982) and Church (1901) went so far as to say that 'it should not find a place on the palette of an artist'.

Even accounting for historical confusions between emerald and Scheele's greens, there was a proliferation of terms used in association with the pigment, possibly to hide their association with the known toxicity of Scheele's green. Fiedler and Bayard (1997), for example, list mineral green and Swedish green as well as ash green, while Schaaff and Riederer (1992) list some 86 names connected with emerald and Scheele's greens. Brunswick green and green verditer (*qq.v.*) have also been used, though erroneously.

The pigment has been discussed at length by Schweizer and Mühlethaler (1968) and reviewed by Schaaff and Riederer (1992), Fiedler and Bayard (1997) and Scott (2002).

It is listed in the *Colour index* as CI 77412/Pigment Green 22.

Copper arsenite group; *African green*; *Bremen green*; *Brunswick green*; *Copper green*; *Dust green*; *Eisenach green*; *Emerald green*; *English green*; *Green verditer*; *Haystack green*; *High green*; *Jasmine green*; *Kaiser green*; *King green*; *Kirchberg green*; *Kurrers green*; *Leobschutz green*; *Mineral green*; *Mitis green*; *Munich green*; *Neuwied green*; *Opaque green*; *Patent green*; *Swiss green*
Church (1901) 83–84; *Colour Index* (1971) 77412; Fiedler & Bayard (1997); Harley (1982) 83–84; Mérimée (1830/trans. Taylor, 1839) 176; Salter (1869) 332; Schaaff & Riederer (1992); Schweizer & Mühlethaler (1968); Scott (2002) 307; Zerr & Rübencamp (1906/1908) 226–227

SCHEELITE

Yellow
Generic compound

Scheelite is a calcium tungstate mineral with composition $CaWO_4$ although it may contain appreciable molybdenum. It was named after the Swedish chemist C.W. Scheele (1742–86). Scheelite forms yellow, yellow-orange or brown tabular, prismatic or octahedral crystals which have a greasy appearance; it is also found with reniform, granular or massive habit, or as disseminated particles (Rutley, 1988). It occurs, often with quartz (*q.v.*), in high temperature hydrothermal veins (e.g. Montagne Noire, France), in contact metamorphic rocks and in pegmatites worldwide, usually associated with granite masses. Known occurrences are found at Chalkidiki, northern Greece (Kilias and Konnerup-Madsen, 1997), the Felbertal deposit, Austria (Eichhorn *et al.* 1995) and Kara, north-west Tasmania (Zaw and Singoyi, 2000).

The natural mineral is not known in a pigment context, but the yellow synthetic form, calcium tungstate (*q.v.*), is listed as tungsten yellow in the *Colour Index* (CI 77250), and its manufacture has been described in the early twentieth century treatise on pigment manufacture by Zerr and Rübencamp (1906).
See: calcium tungstate.

Calcium group; Tungsten group; Calcium tungstate; Quartz; *Tungsten yellow*
Colour Index (1971) 77250; Eichhorn *et al.* (1995); Kilias & Konnerup-Madsen (1997); Rutley (1988) 345; Zaw & Singoyi (2000); Zerr & Rübencamp (1906/1908) 155

SCHIST BLACK

Black
Synonym, variant or common name

Riffault *et al.* (1874) describe the use of a calcined bituminous 'schist' as an 'intense and handsome black' pigment. This probably refers to a hydrocarbon-bearing black shale.
See: hydrocarbons group.

Hydrocarbons group
Riffault *et al.* (1874) 512–513

SCHNEEWEISS

White
Synonym, variant or common name

Schneeweiss (literally: 'snow white') was apparently used as a term for a synthetic barium sulfate (*q.v.*) pigment (Feller, 1986). However, according to Riffault *et al.* (1874), a zinc oxide prepared by combustion of metallic vapours in air gave an 'exceedingly light' product called snow white (*qq.v.*).

Barium sulphate; Zinc oxide; *Blanc Fixe*; *Snow white*; *Zinc white*
Feller (1986); Riffault *et al.* (1874) 182

SCHNITZER'S GREEN

Green
Synonym, variant or common name

According to Zerr and Rübencamp (1906) this is a chromium phosphate 'differing only a little from Plessy's green, but far more expensive'.
See: Arnaudon's chrome green.

Zerr & Rübencamp (1906/1908) 240

SCHUETTEITE

Yellow
Generic compound

Schuettite is a trimercury(II) dioxide sulfide mineral with composition $Hg_3(SO_4)O_2$ (Weil, 2001), named after the American mining engineer and geologist C.N. Schuette (1895–1975). It was first reported by Bailey *et al.* (1959) and occurs as yellow, yellow-orange or green-yellow platy crystals and crusts. It forms from the oxidation of cinnabar (*q.v.*) ore, or as a deposit in mercury furnaces. Schuettite is not a common mineral but is known from Silver Cloud mine (Nevada, USA) and Sulfur Bank mine (California, USA).

Heaton (1928) gives the composition of the obsolete or rare pigment he calls mercury yellow as a 'basic sulphate of mercury', while 'mercury oxonium sulfate' is listed by the *Merck Index* (1996) as synonymous with turbith mineral (*qq.v.*); it is this latter association which is most important for historical pigments.

Mercury sulfates group; Cinnabar; *Mercury yellow*; *Turbith mineral*
Bailey *et al.* (1959); Heaton (1928) 382; *Merck Index* (1996); Weil (2001)

SCHWEINFURT BLUE

Blue
Synonym, variant or common name

Listed in Field's *Chromatography* (1835), the Salter edition of 1869 describes Schweinfurt blue (or Reboulleau's blue) as 'prepared by fusing together equal weights of ordinary arseniate of protoxide of copper and arseniate of potash, and adding one-fifth its weight of nitre to the fused mass'. The author adds that 'The result is . . . a sort of blue Scheele's green (*q.v.*), into which latter colour it soon passes when rubbed with oil.'

Reboulleau's blue; *Scheele's green*
Field (1835); Salter (1869) 230

SCHWEINFURT GREEN

Green
Synonym, variant or common name

Schweinfurt (or 'Schweinfurth') green was one of the principal synonyms for emerald green (*q.v.*) (copper acetate arsenite), the name deriving from mass production of the pigment at Wilhelm Sattler's *Farben und Bleiweiss-Fabrik* firm in Schweinfurt. It seemingly superseded earlier terms such as Mitis green and Vienna green and was produced as 'ordinary' and 'distilled' varieties, depending on the type of the verdigris (*q.v.*) used in the production (Zerr and Rübencamp, 1906; Gentele, 1860; Rose, 1916; Fiedler and Bayard, 1997).

Copper arsenite group; Copper acetate arsenite; *Emerald green*; *Verdigris*
Fiedler & Bayard (1997); Gentele (1860) 253; Rose (1916); Zerr & Rübencamp (1906/1908)

SCHWERSPATH

White
Synonym, variant or common name

Schwerspath is a historical synonym for the barium sulfate mineral baryte (*q.v.*).

Baryte

SEA COAL

Black
Synonym, variant or common name

John Smith (1676; cf. Harley, 1982) mentions sea coal as a pigment.
See: coal.

Harley (1982) 157; Smith (1676) 14

SELENITE

White
Generic variety

Selenite is a variety of gypsum with transparent or translucent, well formed crystals, with a rhombic tabular habit or sometimes twinned with 'swallowtail' habit. Like gypsum, its chemical formula is $CaSO_4.2H_2O$.

White pigments based on selenite are transparent in all media. In oils, it has a pearlescent quality. Before grinding it may be roasted to reduce it to anhydrite. In appearance, finely ground selenite is identical to any other form of gypsum. Hence, references to selenite could easily be for alabaster (De Mayerne, BL MS Sloane 2052 [1620] mentions 'unburnt alabaster', recommending it as a base for verditer). Selenite, broken into small flakes may have been used, like mica, as a 'glitter' for decorating surfaces (Bromehead, 1943) and it may occur in plasters used as a base for wall paintings (for example in Egypt and other bronze age Mediterranean cultures, see Weatherhead, 2001, for general discussion of fresco and secco techniques).

The term selenite is derived from Greek and means 'moonstone', but it should not be confused with the semi-precious gem of the feldspar variety adularia. The use of the term referring to transparent varieties of gypsum seems to have been derived from Agricola's *De natura fossilium* (1556) wherein it is listed with gypsum, though it is not clear that he is referring to the same or similar material. The *lapis specularis* mentioned by Pliny (77 AD) is likely to be selenite, given the distribution of the places he lists as quarry sites. Agricola also calls selenite 'Mary's Glass' (*glaciae divae maria*). It was called 'Marienglass' (*q.v.*) in German, and also, by extension, occasionally in English. The use and derivation of the term in classical, mediaeval and Renaissance texts is discussed by Bromehead (1943). Selenite may also be referred to as gypsum spar. It is a component of gypsum-based pigments such as terra alba and mineral white.

Listed in the *Colour Index* (1971) as source of CI 77231/Pigment White 25 (gypsum/calcium sulfate).

Calcium sulfates group; Feldspar group; Alabaster; Anhydrite; Gypsum; *Satin white*
Agricola (1556/trans. Hoover & Hoover 1950); Bromehead (1943); *Colour Index* (1971) 77231; Mayerne (1620); Pliny (1st cent AD/ Rackham 1952) XXXVI, XXXIII.xxii; Weatherhead (2001)

SELENIUM RED

Red
Synonym, variant or common name

Selenium red is listed as a then-current synonym for cadmium red (*q.v.*) by Heaton (1928).

Cadmium red
Heaton (1928) 383

SELINUS EARTH

White
Synonym, variant or common name

The classical author Pliny (77 AD) describes '*Creta Selinusiam vel anulariam*' – 'Earth of Selinus or ring-earth'. Selinus may be identified not with the ancient Greek city that existed on Sicily (which was destroyed in the mid-third century BC), but with the westerly coastal port of Cilicia (in modern Anatolia, Turkey).

Pliny (1st cent AD/Rackham, 1952) XXXV.xxxvii

SENARMONTITE

White

Generic compound

Senarmontite is a cubic antimony oxide mineral with composition α-Sb_2O_3. It forms as soft white or grey octahedral crystals which fracture conchoidally, although granular or encrusting forms may be more commonly found. Senarmontite is polymorphous with the orthorhombic valentinite (β-Sb_2O_3, *q.v.*; White *et al.*, 1967) but is less common even though it is the lower temperature form. Senarmontite forms from the oxidation of antimony-bearing minerals such as stibnite (*q.v.*) with which it is often found, along with valentinite, kermesite and quartz (*qq.v.*; Rutley, 1988). These minerals occur in areas associated with metal deposits such as Cornwall (England), Attica (Greece), Constantine (Algeria), Quebec (Canada), and California (USA).

Senarmontite is not thought to have been used as a pigment. However, as with valentinite, senarmontite may be found as a relict phase in the roasting of stibnite which is performed to produce the synthetic white pigment, antimony(III) oxide ('antimony white', *qq.v.*).

Antimony group; Antimony oxides and hydroxides group; Antimony white; Antimony(III) oxide; Kermesite; Quartz; Stibnite; Valentinite

Rutley (1988) 265–266; White *et al.* (1967)

SEPIA

Brown

Generic compound

Sepia is a brown pigment derived from the ink sac of various species of cephalopoda, principally the cuttlefish *Sepia officinalis* L. Among five subspecies along the European-African coast, *S. o. officinalis*, *S. o. hierredda* and *S. o. vermicularata* are important for fisheries.

The pigment from *Sepia* species contains melanin. Melanin refers to a group of biological pigments that are commonly divided into two types, the black eumelanins and the reddish brown pheomelanins. Eumelanins are composed of indolic units derived from the oxidation of tyrosine while pheomelanins are composed of benzothiazine derivatives derived from the oxidation of cysteinyldopa molecules; in the case of sepia, the ink contains a pure eumelanin. Given that melanins are some of the most ubiquitous natural pigments, it may appear surprising that their chemical structures and biological role(s) are still subject to debate. However, to date, it has proven impossible to assign a molecular structure to melanin (Simon *et al.*, 2002).

Terry (1893, but apparently from Ure) describes this pigment and its preparation at length, noting that 'When the creatures are captured, their glands are carefully extracted and sun-dried so as to solidify the contents. In this state ink bags are sent into commerce. The colourman subjects the sacs to boiling in a solution of soda or potash, whereby the colour is dissolved out of the receptacle, and being filtered clear of all fragments of the animal tissue, is next precipitated by the addition of acid, collected on a filter, washed and dried.'

Historical synonyms or variants of the term include *seppia, liquid sepia* and *animal aethiops; warm sepia* and *Roman sepia* were sepia tonally modified by additions of other pigments (Salter, 1869).

Harley (1982) implies that sepia became available at the beginning of the nineteenth century when it partially displaced Indian ink and bistre (*q.v.*). She also points out that samples of the pigment can be found in Field's *Practical Journal 1809*, f. 338, and Fielding's *Mixed Tints* (1830).

Bistre

Field (1809); Fielding (1830); Harley (1982) 155–156; Salter (1869) 348–351; Simon *et al.* (2002); Terry (1893) 104–105

SEPIOLITE

White

Generic compound

Sepiolite is a hydrated magnesium silicate clay mineral with composition $Mg_4Si_6O_{15}(OH)_2.6H_2O$. It is a member of the clay minerals group, belonging specifically to the minor palygorskite sub-group and forms a series with palygorskite (*qq.v.*), itself through the replacement of Mg and Si by Al (Deer *et al.*, 1992; Brauner and Preisinger, 1956). Sepiolite is mentioned by Glocker in 1847 and is named from the Greek word *sepia* meaning cuttlefish in allusion to the bone of this animal which resembles the low density and high porosity of this mineral; sepiolite is also known as *meerschaum*, the German word for sea foam, for similar reasons (Dana, 1932). Sepiolite occurs as soft earthy masses or with fibrous or nodular form. It is usually white but may be pale yellow, grey, blue, green or red due to the presence of impurities such as Fe, Al, Ca and Ni. Sepiolite forms as a secondary mineral, particularly from the weathering of magnesite and serpentine group minerals (*qq.v.*). It is found in small amounts in many places worldwide such as Baldissero Canavese (Italy), Eskishehir (Turkey), Ampandrandaava (Madagascar), Crestmore (California, USA), Durango (Mexico), Lake Natron (Tanzania), Vallecas (Madrid, Spain), Mt St Hilaire (Quebec, Canada), Lizard (Cornwall, England) and Varmland (Sweden).

Sepiolite and palygorskite are known to provide a basis for the preparation of Maya blue (*q.v.*).

Clay minerals group; Clay minerals group: palygorskite sub-group; Magnesium group; Serpentine group; Sheet silicates group; Magnesite; Maya blue; Palygorskite

Brauner & Preisinger (1956); Dana (1932) 679; Deer *et al.* (1992); Glocker (1847)

SERI BLUE

Blue

Common generic composite

Until recently Seri blue was commonly used by the Seri Indians of Sonora in north-western Mexico, who called this pigment *antezj kóil*. The pigment is prepared from a mixture of an off-white montmorillonitic clay (*q.v.*) and a green organic resin from the plant *Guaiacum coulteri* to form a compound pigment in the manner of Maya blue (*q.v.*; Beck Moser, 1964; Wesley Pierce, 1964). Wesley Pierce also records that *G. coulteri* grows as far south as Oaxaca and that a similar species *G. sanctum* grows in Yucatán. While there might be a correlation between Seri blue and Maya blue, it is uncertain whether Seri blue was in fact used outside of north-western Mexico. Moreover, Anderson (1948) indicates that the Aztecs also made a dark green or blue-green colourant, *matlali*, from the flowers of *G. coulteri* and, although neither Sahagún (1950–82) nor Anderson mention that *matlali* was made with a clay base like Seri blue, it is possible that the two colourants are similar.

Seri blue has been discussed in the context of colourants on maps of the early post-colonial period in Mexico by Haude (1998).

Maya blue; Montmorillonite

Anderson (1948); Beck Moser (1964); Haude (1998); Sahagún (1950–82); Wesley Pierce (1964)

SERPENTINE GROUP

Variable
Group term

The serpentine group consists of a suite of magnesium silicate minerals with approximate composition $Mg_6Si_4O_{10}(OH)_8$, although they often additionally contain iron. The three principal members of the group included here are antigorite, lizardite and chrysotile; the polymorphs of chrysotile (ortho-, para-, and clino-chrysotile are also important (*qq.v.*; Deer *et al.*, 1992; O'Hanley, 1989)). Of these, lizardite is the most common, although chrysotile may be the most well known as its finely fibrous nature means that it is the most important commercial source of asbestos. Serpentine minerals vary in colour (they may be white, yellow, green, green-blue and red) and are usually very fine-grained, occurring with a large variety of textures and habits. They form from the hydrothermal alteration of igneous rocks that are composed predominantly of olivine, pyroxene and amphibole group minerals (*q.v.*). Lizardite is the lowest temperature member of the group, with chrysotile and antigorite forming with increasing temperature, respectively (Deer *et al.*, 1992; Wicks and O'Hanley, 1988). See individual entries for more details.

Amphibole group; Magnesium group; Silicates group; Antigorite; Chrysotile; Lizardite
Deer *et al.* (1992) 344–352; O'Hanley *et al.* (1989); Wicks & O'Hanley (1988)

SHALE

Black
Generic variety

See: slate.

SHALE BLACK

Black
Synonym, variant or common name

See: schist black.

SHEET SILICATES GROUP

Variable
Group term

Sheet silicates (or phyllosilicates) are formed from a plane of silica tetrahedra, each linked to another at three corners. This structure is often echoed clearly in the mineral, producing minerals of high aspect ratio, with a well-developed cleavage. The silicate layers are often weakly bonded and commonly have water molecules and other neutral atoms or molecules trapped between the sheets. This is why this sub-class produces very soft minerals such as talc. Some members of this sub-class have the sheets rolled into tubes that produce fibres as in asbestiform serpentine. Members of this group are often the last to chemically breakdown in erosion and weathering processes and thus constitute a significant amount of soils and fine-grained sedimentary rocks. This group is also generally tolerant of high pressures and temperatures and they make up a large part of metamorphic rocks. The clay minerals, chlorites and micas are all sheet silicates and include:

Chlorite group: Chamosite; Clinochlore; Pennanite.
Clay minerals group: Attapulgite; Beidellite; Bentonite; Celadonite; Dickite; Glauconite; Halloysite; Hydromuscorite; Illite; Kaolinite; Metahalloysite; Metakaolinite; Montmorillonite; Nacrite; Natrontite; Palygorskite; Sepiolite.
Magnesium silicates group: Talc.
Mica group: Biotite; Lepidolite; Muscovite; Paragonite; Phlogopite.
Serpentine group: Antigorite; Asbestos; Chrysotile; Clinochrysotile; Lizardite; Orthochrysotile; Parachrysotile.

These minerals have found use in a wide variety of pigments. Many pigments are based on clays, so, for example, green earths are rich in clay minerals and chlorites. Micas have been used as pearlescent paints and occur as traces in many pigments.

See the group entries for fuller discussion and occurrences.

SHELL WHITE

White
Synonym, variant or common name

Biogenically precipitated calcium carbonate in the form of aragonite (*q.v.*) is the main component of the majority of shells produced by the phylum Mollusca. It is mainly the class bivalvia (lamellibranchia) and particularly the shells of the oyster family that have been collected and used, crushed, for pigment. Traditional preparation involves allowing the shells to stand for several years so that all tissue can decompose. The shells are then crushed, impurities removed, and the powder levigated and sieved. Calcination is not required (Gettens *et al.*, 1993a); consequently, the characteristic lamellar texture of the shell is often visible under magnification.

It is in Japan that shell white or '*gofun*' has found its greatest use, particularly for flesh tones. Gettens *et al.* (1993a) believe that the earliest known use of *gofun* was in 1439 at the Hokanji Temple, Yasaka. However, Moran (1960) has detected it on eighth century Japanese wooden sculpture. It is first known in paintings on a sixteenth century screen (FitzHugh, 1979). Winter (1981) suggests that gofun entirely replaced the use of lead-based whites during the fifteenth to sixteenth centuries in Japan.

Elsewhere, mollusc shell whites are uncommon but they have been recognised from paintings at Karnak in Egypt by Rouchon *et al.* (1990) and Scott and Hyder (1993) have tentatively identified shell white in Chumash rock paintings in California. Terry (1893) recommends crushed oyster shells for producing luminous paints for the interiors of rail carriages, etc., where the crushed white parts of the shell are calcined with 'flowers of sulphur', reducing them to the phosphorescent compound calcium sulfide.

Other organic calcium carbonate pigments derived from molluscs and from coral (*q.v.*). The crushed cuttlefish bone (*q.v.*) was mentioned in many sources as a base for vegetable dyes (Merrifield, 1849). Eggshell-(*q.v.*) based pigments are also sometimes called shell white and they too are composed of calcium carbonate. The English colourman Field (1835) and other authors additionally mention the use of mother-of-pearl as an opalescent pigment. Field also includes eggshell whites under the general heading of terrene white.

Calcium carbonates group; Calcium group; Aragonite; Calcite; Coral; Cuttlefish bone; *Eggshell*; *Gofun*; *Mother-of-pearl*; *Pearl white*; *Terrene white*; *Tyrian purple*
Field (1835) 70; FitzHugh (1979); Gettens *et al.* (1993a); Merrifield (1849) clii; Moran (1960); Rouchon *et al.* (1990); Scott & Hyder (1993); Terry (1893) 286; Winter (1981)

SHELLAC

Red
Generic compound

See: lac.

SHUNGITE
Black
Generic variety

Shungite is a black amorphous or nanocrystalline form of carbon. Its natural occurrence has been reported from only a few localities in Russia. The major deposit of shungite is found at Zazhoginskoye (Karelia, Russia) near the village of Shunga, after which the material is named. At this location shungite occurs as an amorphous matrix, enriched in nitrogen, sulfur, hydrogen and oxygen, enclosing small (<1 μm) crystalline silicate particles (Jehlicka and Rouzaud, 1993; Kovalevski *et al.*, 2000). The shungite found in this rock type (known as shungite rock), which occurs as layers, veins or lenses, is considered to have formed from an intensive accumulation of organic material of biogenic origin (algal or bacterial) in a lagoonal environment which was later metamorphosed at temperatures of 300–350°C (Melezhik *et al.*, 1999; Melezhik and Fallick, 2000). Other minor quantities of shungite have been reported in volcanic rocks from Kamchatka (Glavatskikh and Trubkin, 2000), and from the high temperature (1000–1300°C) burning of spoil heaps in the Chelyabinsk coal basin (Sharygin *et al.*, 1999).

Shungite is available as a pigment, sold as carbon black or under the name shungite natural black.

Carbon-based blacks group; *Black ochre*
Glavatskikh & Trubkin (2000); Jehlicka & Rouzaud (1993); Kovalevski *et al.* (2000); Melezhik & Fallick (2000); Melezhik *et al.* (1999); Sharygin *et al.* (1999)

SICILIAN BROWN
Brown
Synonym, variant or common name

Mayer (1991) lists this as a synonym for raw umber (*q.v.*).

Umber; *Raw umber*
Mayer (1991) 56

SIDERIN YELLOW
Yellow
Synonym, variant or common name

According to Zerr and Rübencamp (1906), siderin yellow referred to iron(III) chromate, 'ferric chromate, $Fe_2(CrO_4)_3$' and was also known by the name Mars yellow (*q.v.*). However, they cannot have thought highly of it, remarking that it has 'received more attention of late than its slight superiority justifies'. MacIntyre (1992) gives the identical composition, listing it as CI Pigment Yellow 45 (CI 77505, *Colour Index*, 1971), with synthesis from a mixture of sodium chromate and ferric iron. According to Kühn and Curran (1986), Siderin yellow is an iron chromate precipitated from a mixture of ferric chloride and potassium chromate, although the exact stoichiometry of the iron chromate is not given.

It was termed *Sideringelb* by Kletzinsky (1872), who is associated with early manufacturing of iron chromate.

Iron chromates group; *Mars yellow*
Colour Index (1971) 77505; Kletzinsky (1872); Kühn & Curran (1986); MacIntyre (1992) 3090; Zerr & Rübencamp (1906/1908) 126

SIDERITE
Yellow
Generic compound

Siderite, also known as chalybite or spathose iron, is an iron carbonate mineral with composition $FeCO_3$. It is named from the Greek word *sideros* meaning 'iron' and forms solid solution series with both magnesite (*q.v.*) and rhodochrosite. It is common worldwide and occurs as yellow to yellow-brown crystals that may take a wide range of habits including rhombic, tabular, prismatic, botryoidal, nodular, spherulitic, massive and concretionary. Siderite forms in sedimentary deposits often with clay minerals and chamosite, in hydrothermal veins with calcite, fluorite, baryte, sphalerite and galena, or by replacement of other minerals during metamorphism, particularly in limestone (*qq.v.*). The surfaces of siderite may possess an iridescent sheen due to alteration to goethite, hematite or magnetite (*qq.v.*; Deer *et al.*, 1992; Rutley, 1988). It may be found as a component of ochre (*q.v.*); the *Colour Index* (1971; CI 77004) states that China clay (*q.v.*) may contain iron carbonate.

Clay minerals group; Iron group; Baryte; Calcite; Chamosite; Galena; Goethite; Hematite; Limestone; Magnesite; Magnetite; Ochre; Sphalerite; *China clay*
Colour index (1971) 77004; Deer *et al.* (1992) 638–640; Rutley (1988) 293–294

SIENNA
Yellow-Brown
Common generic composite

Siennas (or sienas) are earth pigments, generally described simply as a variety of yellow ochre (*q.v.*). However, they differ in chemical composition in that they contain a small percentage of manganese oxides (less than 10%) in addition to the iron oxides (primarily the iron oxide hydroxide goethite) which are the main colouring components. Additionally they may contain a few per cent of peaty or organic material (Church, 1901). In this way they are transitional in composition between ochres and umbers. However, although the pigments are well known and still widely used there is very little information available concerning them. The original pigment was derived from Siena in Tuscany. Of the nineteenth–early twentieth century authors, the most informative is Terry (1893). He writes that siennas are found on the western slopes of Monte Amiata, Tuscany and are 'true lacustrine deposits found amid trachytic rocks, of which [the earth] is principally composed'. They are covered by a 'vegetable soil'. A variation in colour is naturally available. They are called yellow earths when ochre yellow or bole when of a chestnut colour. Bole is the typical sienna, 'a very richly coloured yellow ochre' (Weber, 1923). The Tuscan bole is classed by quality, with the value rising as the tint deepens. Terry lists the names of the grades in descending order of quality as *boletta, fascia, cerchione* and *terra guilla*.

Sienna deposits are also known from the USA where they are called 'paint-beds', and good quality siennas are found at Lehigh Gap, Pennsylvania (Terry). Church (1901) also lists the Harz Mountains, Germany, as another source.

Like ochres, siennas produce very stable, non-fugitive pigments. They may be used in their natural state after washing, levigation and grinding (raw sienna) or after calcining (burnt sienna). Burnt sienna was popular because of its 'beautiful, warm reddish hue' (Church, 1901). This view was not upheld by all, however. Payne says that sienna was a 'greasy colour' and 'inferior to gallstone' (cf. Harley, 1982).

Siennas have been recognised worldwide, although their exact chemistry has rarely been determined. Early identifications are from Palaeolithic rock paintings in the Altamira cave (northern Spain; Cabrera-Garrido, 1978), 200 BC–600 AD Ajanta frescos in India (Kahn, 1949), on Coptic canvas paintings, wall paintings and wooden carving by Le Fur *et al.* (1990) and on Irish mediaeval wall paintings by McGrath (1984). Siennas were used both in the original and restoration work of wall paintings in the Aqsa Mosque, Jerusalem (Lazzarini and Schwartzbaum, 1985). Sienna pigment has been found on panel paintings by the Master of St Giles (Kirby, 1977), on an eighteenth century portrait by C.W. Peale (restored by Volkmar in the nineteenth century) by Stoner *et al.* (1979). Siennas have also been found by Most and Hückel (1996) on an early nineteenth century, printed wall-hanging by Joseph Dufour and on Chinese textiles by Lee-Whitman and Skelton (1983). Laar and Burnstock (1997) have found Siennas in the archives of the Amsterdam colourmen Claus and Fritz.

Harley writes that the pigment was called *Terra di Siena* whether burnt or unburnt until the nineteenth century, when the anglicised versions appeared and *raw sienna* and *burnt sienna* came into routine use. Church also lists various literal translations of the term 'sienna earth': *Terre de Sienne*, *Siena-erde* and *Terra di Siena*.

Earth pigments group; Iron oxides and hydroxides group; Manganese oxides and hydroxides group; Goethite; Ochre; Umber; Wad; *Burnt sienna*; *Raw sienna*; *Yellow ochre*

Cabrera Garrido (1978); Church (1901) 229, 231; Harley (1982) 90; Kahn (1949); Kirby (1977); Laar & Burnstock (1997); Lazzarini & Schwartzbaum (1985); Le Fur *et al.* (1990); Lee-Whitman & Skelton (1983); McGrath (1984); Most & Hückel (1996); Stoner *et al.* (1979); Terry (1893) 272; Weber (1923) 103

SIGNAL RED

Red

Synonym, variant or common name

See: para red and vermilionette.

SIL

Yellow

Synonym, variant or common name

Yellow ochre, containing the hydrated iron oxides generically referred to as limonite, was the main yellow pigment in classical times and like red ochre, it came from many and widespread sources. The best, which had reached legendary status by the time of Vitruvius (first century BC) and Pliny (77 AD) was yellow ochre from the silver mines west of Athens at Laurion (Laurium), 'Attic Slime' as Pliny describes it. Confusingly, although Vitruvius tells us supplies had been exhausted by his time, Pliny quotes us a price of two denarii a pound for this ochre. Vitruvius refers to yellow ochre as *ochra* and *sil*, Pliny as *sil*.

Pliny in his *Naturalis Historiae* describes various natural ochres '*In argenti et auri metallis nascuntur etiamnum pigmenta sil et caerulium*' ('In gold and silver mines also are formed the pigments yellow ochre and blue'). He goes on to state that yellow ochre – 'sil' – is a 'slime', adding that the best kind comes from Attica, followed in quality by a marbled ochre and a third form called Scyricum from the island of Scyros. Other sources mentioned by both authors are Achaia, Lydia, Gaul and Rome; of the last Pliny states that it is also burnt: '*effoditur et ad xx ab urbe lapidem in montibus; postea uritur pressum appellantibus qui adulterant*' ('This ochre is also dug up in the mountains 20 miles from Rome. It is afterwards burnt, and by some people it is adulterated and passed off as dark ochre').

Red ochre; *Yellow ochre*

Pliny (1st cent AD/Rackham, 1952) XXXIII.lvi; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.1

SILEX

White

Synonym, variant or common name

Synonym for silica (*q.v.*; Mayer, 1991).

Silica

Mayer (1991) 56

SILICA

White

Generic compound

The term 'silica' is used to cover a number of distinct pigments differentiated either by their degree of crystallinity (such as 'amorphous' and 'microcrystalline' silicas) or source (for example, diatomaceous silica). All are silicon dioxide, in a range of crystalline states.

Quartz (*q.v.*) is the most common type of crystalline silica. Some publications will use quartz and crystalline silica interchangeably, but the term crystalline silica actually encompasses several forms: α- and β-quartz, cristobalite, tridymite (*qq.v.*) and several rarer forms. The term 'sand' is used interchangeably although this strictly refers to a grain size (0.06–1 μm).

According to Patton (1973a, b), the designation 'amorphous' is a misnomer since it is actually cryptocrystalline quartz – that is, one where the crystallite size is so fine that it is invisible under light microscopy.

The term tripoli is used to denote fine-grained silicas as a class. Patton states that this is because of a superficial resemblance of such silicas to the diatomaceous silica called 'tripolite' that comes from Tripoli in Libya. They are characterised as lightweight, porous, friable forms of decomposed siliceous rocks. Amorphous silica was discovered near Seneca, Missouri, USA, in 1869 and exploited from 1872; whiter deposits in southern Illinois, USA, were mined by hand from around 1900 with wider commercialisation from around 1911. Major sources of tripoli are still exploited in the USA, while another form, known as rottenstone, is mined in Pennsylvania, USA. The material is prepared by mining, calcining and water-quenching, crushing and grinding. Some is jet-milled to produce ultra-fine material. Amorphous silica is also known as 'soft' silica to distinguish it from 'hard' silicas, which are crushed and ground silica from 'sand' and other similar sources.

Patton also differentiates 'microcrystalline' silica in a form known commercially as *Novaculite*.

Pigment-grade crystalline 'hard' silica is manufactured from quartz sand. According to Katic (1973), while silica deposits are abundantly distributed in nature, those that are sufficiently free of impurities to have commercial value are comparatively rare. For example, the (four) major formations of quality silica in the USA are quartzite deposits, the purest of which, at Lewistown, Pennsylvania, was mined from 1868. Processing involves blasting the compacted silica into rocks, which are then crushed and ground to the required grade. The final product may contain traces of aluminium, calcium, iron, magnesium and titanium.

Given the ubiquity of quartz it is perhaps therefore not surprising that it has been identified in so many contexts. For example, Reindell and Riederer (1978) detected quartz in earth pigments from Persian archaeological excavations. Bachmann and Pfeffer (1979) found quartz in Roman pigment pots from Mainz, Germany. Havrevold (1985) encountered a ground consisting of a 'greyish-brown layer containing lime spar and quartz' on an Egyptian mummy case lid. Duang *et al.* (1987) detected α-quartz in wall paintings of Buddhist temples in Dunhuang, north-west China, while Wang *et al.* (1993a) found quartz in pigments used for the Qutan Temple, Qinghai, China. Cramp and Cronyn (1990) noted the presence of quartz in Anglo-Saxon polychrome plasters in England. Watchman *et al.* (1993) identified quartz in Aboriginal rock-painting pigments from a location near Laura, north Queensland, Australia. Maue *et al.* (1979) identified quartz in pigments used by the German artist Johann Georg Rudolphi (1633–93). Plahter and Plahter (1988) found quartz in pigments used by the Norwegian artist J.C. Dahl (1788–1857).

Other forms of silica are much rarer, however; for example, the only identification of cristobalite located by the present authors was from their own analysis of various pigment pots from Pompeii, Italy. Tridymite is mentioned as a phase found in Egyptian blue by Colinart *et al.* (1998).

So-called 'diatomaceous' silica is produced from natural diatomite (*q.v.*) a sedimentary rock of varying degrees of consolidation that is composed of fossilised siliceous skeletal remains of single-cell aquatic plant organisms known as diatoms (Kranich, 1973). Diatoms (class Bacillariophyceae) are one of several groups of algae which biomineralise silicate; deposition of silicate results in rigid, opaline cell walls which can take on a complex variety of geometric shapes. The skeleton of a diatom, or *frustule*, is made of very pure silica coated with a layer of organic material; the frustule silica is amorphous. This skeleton is divided into two parts, one of which (the epitheca) overlaps the other (the hypotheca) like the lid of a box or petri dish.

Economic deposits of diatomite occur worldwide, with the principal commercial applications being as abrasives and filters. Modern conversion to pigmentary grades involves strip mining, crushing, milling and drying in heated air. Cyclone separation is employed to separate the silica into different degrees of fineness. Calcined forms are prepared by treatment in a furnace at high temperature with a small amount of a fluxing agent.

Béarat (1997) has noted the presence of diatomite among pigments from Pompeii; the present authors found freshwater diatoms, as a major phase in similar material from that site (Walsh *et al.*, 2004). Watson (1967) states that North American Indians used diatomaceous earth for kiva murals and rock art. Leechman (1932) has recorded the use of diatomaceous earth in East Coast Haida and Tsimshian painting techniques in Canada. However, according to Kranich modern use of diatomaceous silica started in the late 1920s with white flux-calcined grades introduced as extenders in the early 1930s.

Diatomaceous silica is also known as d. earth, diatomite, infusorial earth, kieselguhr and tripolite; modern trade names include *Celite, Celatom, Dicalite, Kenite* and *Aquafil* (Kranich). It is listed by the *Colour Index* as CI 77811/Pigment White 27.

Both a precipitated and a pyrogenic method of producing silica are applied in the manufacture of modern pigments (Boland and Wagner, 1973; Fratzscher *et al.*, 1973). Silica aerogels and hydrogels are also to be found in pigments, these are, however, generally added as bulking agents or thickening agents (Teicher, 1973).

Silicates group; Silicon group; Cristobalite; Diatomite; Quartz; *Infusorial earth*; *Kieselguhr*; *Novaculite*; *Rottenstone*; *Tripoli*; *Tripolite*
Bachmann & Pfeffer (1979); Béarat (1997); Boland & Wagner (1973); Colinart *et al.* (1998); *Colour Index* (1971) 77811; Cramp & Cronyn (1990); Duang *et al.* (1987); Fratzscher *et al.* (1973); Havrevold (1985); Katic (1973); Kranich (1973a); Leechman (1932); Maue *et al.* (1979); Patton (1973a); Patton (1973b); Plahter & Plahter (1988); Reindell & Riederer (1978); Teicher (1973); Walsh *et al.* (2004); Wang *et al.* (1993a); Watchman *et al.* (1993); Watson (1967)

SILICATE OF BARYTA

Green
Synonym, variant or common name

Salter (1869) lists a silicate of baryta, describing how it can be prepared by heating to whiteness one part silica to three parts baryta. It gives a pale green which is 'deficient in colour when ground' that the author merely suggests might be used for enamelling.

Barium group
Salter (1869) 290

SILICATES GROUP

Variable
Group term

Silicates may exist as either crystalline or amorphous (i.e. glass) forms. Among glasses, important pigments such as smalt (*q.v.*) are classed; for more information see: Glass.

Silicates are by far the most abundant chemical groups of minerals. The crystalline structure is based on a tetrahedron with a central silicon ion attached to four oxygen ions. These silica tetrahedra may be polymerised in various ways, and this has led to the following universally applied classification of crystalline silicates in the mineral sciences.

Orthosilicates exhibit either no or limited polymerisation of the silica tetrahedra. The mineral forsterite (a variety of olivine) belongs to this group.

Sorosilicates consist of two joined silica tetrahedra, which are otherwise isolated, and the epidote group minerals are the most common variety of this case.

Ring silicates or cyclosilicates contain rings of silica tetrahedra that are isolated from other silica rings. The only important pigment related ring silicate is the synthetic Han purple (*q.v.*) $BaCuSi_2O_6$.

Chain silicates contain either single or double chains of polymerised silica tetrahedra. Single chain silicates, characterised by the pyroxene group of minerals, contain polymerised lengths of silica tetrahedra bridged by other molecules. The amphibole group (*q.v.*) are double chain silicates.

Sheet silicates (phyllosilicates), as the name suggests, form a plane of silica tetrahedra, each linked to another at three corners. This structure is often echoed clearly in the mineral, producing minerals of high aspect ratio, with a well-developed cleavage. The clay minerals, chlorite minerals and micas are sheet silicates (*qq.v.*).

Framework silicates comprise, as the name suggests, an open, three-dimensional network of joined silica tetrahedra. Quartz itself is a classic example of a framework silicate. The feldspars and feldspathoids (including lazurite, *qq.v.*) also demonstrate this structure.

Additionally, silicate minerals are grouped by family. For the minerals listed in this work the main family groupings are as follows:

Amphibole group (Chain silicates): Actinolite; Anthophyllite; Crossite; Glaucophane; Hornblende; Riebeckite; Tremolite.

Copper silicate group (Chain silicates): Cuprorivaite, cuprowollastonite.

Feldspar group (Framework silicates): Albite; Andesine; Anorthite; Anorthoclase; Bytownite; Labradorite; Microcline; Oligoclase; Orthoclase.

Feldspathoid group (Framework silicates): Haüyne; Lazurite; Nepheline; Sodalite.

Pyroxene group (Chain silicates): Aegirine; Augite; Diopside; Enstatite; (Wollastonite).

Quartz group (Silicon oxides group; framework silicates): Amethyst; Cristobalite; Quartz; Tridymite.

Minerals belonging to the pyroxene and feldspathoid groups appear too infrequently in pigment contexts to be merited with a group entry; for information regarding these entries, see the individual mineral. Conversely, because sheet silicates are so common, these are dealt with under a separate group entry. It should also be noted that this entry focuses on the naturally occurring silicate minerals. However, important pigments including those based on glass and the copper silicates Egyptian blue and Han blue and purple (*qq.v.*) are synthetic phases. To this group should also be added the lead silicates, and the aluminium-rich silicates employed in synthetic ultramarines.

Amphibole group; Chlorite group; Clay group; Feldspar group; Mica group; Sheet silicates group; Glass; Lazurite; Ultramarine; *Han Blue*; *Han Purple*.

SILICINE

White
Synonym, variant or common name

Silicine is listed by Heaton (1928) as a 'generally accepted trade name for a pigment in general use', in this case giving the composition as 'natural silica' (*q.v.*).

Silica
Heaton (1928) 384

SILICON GROUP

Variable
Group term

Silicon is frequently encountered as an element within pigments, most commonly as a component of silicate compounds in which the silicon is bonded to four (or more) oxygen anions. The silicates, which form the largest subdivision of the silicon group, are encountered both as natural minerals and synthetic products, and these are more fully reviewed under the general heading of Silicates group (*q.v.*). This group also includes the simple silicon dioxide (SiO_2) compound silica (*q.v.*), of which there are several polymorphs. Of these, quartz is the most common, with the other polymorphs cristobalite and tridymite (*qq.v.*) also discussed in this work; novaculite (*q.v.*) is a massive form of microcrystalline silica (Patton, 1973a) found in Arkansas (USA). Synthetic silica is manufactured by precipitation or pyrogenic methods for use in modern paints, in which it acts mainly as a thickening agent or a dye carrier due to its high absorbtion capacity (Boland and Wagner, 1973; Frazscher *et al.*, 1973). Teicher (1973) has further discussed the use of silica aerogels and hydrogels in pigments as bulking or thickening agents.

Several (X-ray) amorphous or cryptocrystalline forms of silicon dioxide also exist naturally, of which the semi-precious stone opal may be the most familiar form. The cryptocrystalline varieties of silica considered to have been used as pigmentsare those of biogenic origin, derived from the shells of certain lacustrine- and marine-dwelling unicellular animals and plants, particularly diatoms (see: diatomite (*q.v.*)).

Silicates group; Silicon oxides and hydroxides group; Cristobalite; Diatomite; Novaculite; Quartz; Silica; Tridymite
Boland & Wagner (1973); Fratzscher *et al.* (1973); Patton (1973a); Teicher (1973)

SILICON OXIDES AND HYDROXIDES GROUP

Variable
Group term

The group consists of both natural and synthetic forms of anhydrous and hydrated silicon dioxide or silica (SiO_2; *q.v.*). Several crystalline polymorphs of silica exist in nature and of these quartz, tridymite and cristobalite (*qq.v.*) are discussed here. Quartz is the polymorph most commonly encountered in a pigment context, although usually as an associated material rather than as a pigment in its own right; tridymite has also been encountered in samples of Egyptian blue (Colinart *et al.*, 1998). A further form of microcrystalline silica, novaculite (*q.v.*), is found in a massive deposit close to Hot Springs (Arkansas, USA; Patton, 1973b). Amorphous and cryptocrystalline varieties of silica also exist in nature. These are derived mainly from the silica tests of micro-organisms (radiolaria and diatoms) which dwell in lake or marine environments (see entry for Diatomite).

Synthetic forms of silica and hydrated silica (including silica aerogels and hydrogels) are manufactured for use in the modern paint industry. In this context they are used mainly as thickening agents or as dye carriers due to their high absorptive properties (Teicher, 1973; Boland and Wagner, 1973; Fratzscher *et al.*, 1973).

Silicon group; Cristobalite; Diatomite; Novaculite; Quartz; Silica; Tridymite
Boland & Wagner (1973); Colinart *et al.* (1998); Fratzscher *et al.* (1973); Patton (1973b); Teicher (1973)

SILK GREEN

Green
Synonym, variant or common name

The term silk green refers to a bright green pigment according to Riffault *et al.* (1874) which is a chrome green or green cinnabar with the addition of 'a small proportion of indigo carmine which gives great brightness and a bluish tinge' (*qq.v.*). It has also been applied to a yellowish form of chrome green (Doerner, 1935).

Chrome green; *Green cinnabar*; *Indigo carmine*
Doerner (1935) 63, 85; Riffault *et al.* (1874) 387

SILVER

Metal
Generic compound

In addition to the widespread use of silver leaf, milled silver had an important place in the illumination of manuscripts. Thompson (1956) states that powdered silver was used to imitate gold by admixing a golden colour such as saffron or by painting over it with a yellow glaze that was often derived from aloes.

Silver group; Aloe; Metal pigments; Saffron
Thompson (1956) 184

SILVER BLUE

Blue
Synonym, variant or common name

Various formulations of an indefinite or undetermined nature are known as 'silver blue', Harley (1982) noting a number of

seventeenth century recipes of a clearly archaic origin. The fullest discussion is that of Orna *et al.* (1980, 1985) who found that copper acetates (*q.v.*) were typically formed from the copper content of the silver sheets used.
See: refiner's verditer.

Copper acetate group
Harley (1982) 49; Orna *et al.* (1980); Orna *et al.* (1985)

SILVER CHROMATE

Red
Generic compound

Silver chromate(VI), with composition Ag_2CrO_4, is listed by the *Colour Index* (1971; CI 77825) as a purple pigment precipitated from a mixture of silver nitrate and potassium chromate, and used as an artists' colour under the name of purple red (*q.v.*). It is described by Riffault *et al.* (1874) as a purple-red pigment, and is mentioned by other late nineteenth century documentary sources such as Scott Taylor (1885) and Salter (1869), the latter of whom describes silver red as being made from silver nitrate and 'monochromate of potash' to give a 'fine ochre-red' colour.

Synonyms for silver chromate include chromate of silver, silver red and purple red.

Chromates group; *Chromate of silver*; *Silver red*
Colour Index (1971) 77825; Riffault *et al.* (1874) 440; Salter (1869) 176; Scott Taylor (1885) 198

SILVER GROUP

Variable
Group term

Metallic silver was processed and used for illuminated manuscripts and Thompson (1956) describes the use of powdered silver for imitation gold pigments. According to de Massoul (1797) silver was also used in early recipes of silver white (*q.v.*), although later recipes indicate it to be based on lead white (*q.v.*). Silver has more recently been used in the manufacture of ultramarine (*q.v.*) by replacement of sodium to give variation in colour. Many pigments, such as litharge and verditer (*qq.v.*), were produced as by-products of the cupellation of silver. The compounds of silver used as pigments included here are:

Chromates: Silver chromate(VI) (Ag_2CrO_4)
Sulfates: Gold silver sulfide (Ag-Au-S)

Further silver compounds that are mentioned in a pigment context are silver nitrate ($AgNO_3$) and silver sulfate (Ag_2SO_4), which may be produced in the synthesis of light white (*q.v.*).

Gold silver sulfide; Litharge; Silver chromate; Ultramarine; Verditer; *Lead white*; *Light white*; *Silver white*
Massoul (1797); Thompson (1956) 184

SILVER RED

Red
Synonym, variant or common name

See: silver chromate.

SILVER WHITE

White
Synonym, variant or common name

According to de Massoul (1797) an early form of this pigment was actually made from silver and there are potentially many silver mineral or synthetic compounds which could give white pigments; the original terminology is, however, confusing. Field (1835) on the other hand considers silver white to be a high quality lead white, the name synonymous with *Blanc d'argent* and French white, while Osborn's 1845 'edition' of Bouvier links it additionally to Krems white. Church (1901) notes 'The blanc d'argent of the French is supposed to be lead carbonate free from any hydrate, but the great majority are nothing but flake-white of good quality.' In more recent contexts, the term might refer to a zinc white or a high-quality lead white.

Osborn states that silver white was supplied in the form of drops, 'that is, little cones', adding that 'A Silver White has of late years been manufactured at the establishment at Clichy, near Paris ... It is said to be fully equal, if not superior, to the Austrian. That which we have been accustomed to use here, came . . . from Hungary. Within a short time this has given place to a silver white from London, which is of equal, if not greater, beauty.'

Seccarroni (pers. comm., 2003) has suggested that earlier references to silver white are in fact silver chloride. The compound was known by the alchemists, and there are some pigment recipes for this compound based on the reaction of strong acid (aqua fortis) with silver and sodium chloride.

Silver group; *Blanc d'argent*; *French white*; *Krems white*; *Lead white*; *Zinc white*
Church (1901) 334; Field (1835) 69; Massoul (1797); Osborn (1845) 1–2, 7

SINKING STONE

White
Synonym, variant or common name

Riffault *et al.* (1874) indicate this as a term for baryte (*q.v.*).

Baryte
Riffault *et al.* (1874) 193, 199

SINOPER

Red
Synonym, variant or common name

A variety of high-quality red ochre called sinoper that was traded from the Ionian Greek port and city-state of Sinope in Pontus (modern Sinop, on the Black Sea in Turkey) is described by the classical authors Vitruvius (first century BC) and Pliny (77 AD). There are a number of rivers in that region noted for their alluvial deposits, especially the Kizilirmak ('red river') which forms a delta around Bafra, near to Sinop; it is probably these which provided the pigment. However, Vitruvius and Pliny both say that the actual source was in the volcanic area of Cappadocia.

The *Book of Master Peter of St. Audemar on Making Colours* (fifteenth century, Clarke MS 2790, cf. Merrifield, 1849) states that 'Sinopis . . . is a . . . colour redder than vermilion, so that when the vermilion itself is very precious on account of its beauty, the heralds praising it call it sinopis, although the vermilion resembles it on account of its redness.' Strabo, writing in the first century before Christ, also compared sinoper to the Iberian vermilion. 'In Cappadocia is produced also the ruddle, called "Sinopean", the best in the world, although the Iberian rivals it. It was named "Sinopean" because the merchants were wont to bring it down thence to Sinope before the traffic of the Ephesians had penetrated as far as the people of Cappadocia.'

Related terms such as sinopia, sinopis and sinopite came to be used for the red undersketch applied in fresco painting. Sinople is stated by the US Bureau of Mines *Dictionary of Mining, Mineral, and Related Terms* to be a red or brownish red variety of quartz containing inclusions of hematite; also *-pal* and *-pel* in this context. At certain periods confusion has also existed with other terms of similar sound or form; for example, Harley (1982) discusses the seventeenth century British misunderstanding of 'sinoper lake' (probably derived from cynople/sinople, which is generally a red dye-based pigment), Bartolomeus Angelicus (fl. 1230, cf. Clarke, 2001) says that *synobio* (sinobium) is 'cinabatim among the Greeks' and is true dragon's blood, and the Bodleian MS Ashmole 1480 gives a recipe for what is clearly cinnabar (*q.v.*; vermilion) under the name synoper (Harley).

Sinoper and related forms are also listed by more recent authors; for example, Church (1901) gives sinopia as a synonym for red ochre. According to Montagna (1993) it is also associated with the term *cinabrese* which is a sinoper mixed with calcium carbonate.

Cinnabar; Hematite; Quartz; *Cinabrese*; *Cynople*; *Red ochre*
Church (1901) 182; Clarke (2001) 47–48; Harley (1982) 132; Merrifield (1849) 142; Montagna (1993) 114; Pliny (1st cent AD/Rackham, 1952) XXXV.xiv; Strabo (1st cent BC) XII.II.x; Vitruvius (1st cent BC/Grainger, 1934) VII.vii.2, VIII.iii.9

SINOPER LAKE
Red
Synonym, variant or common name

See: cynople.

SINOPIA
Red
Synonym, variant or common name

See: sinoper.

SINOPIS
Red
Synonym, variant or common name

See: sinoper.

SINTRA UMBER
Brown
Synonym, variant or common name

Sintra – properly 'Cintra', a mountain near Lisbon, Portugal – probably indicates the geographic origin of this pigment, which is to be associated with umber. It is mentioned by the early seventeenth century Portuguese author Nunes (Veliz, 1986).

Umber
Nunes (1615) 55 ff; Veliz (1986) 3, 5, 7, 8

SKY BLUE
Blue
Synonym, variant or common name

Goeree (1670) describes a '*Himmel-blau*' which as a cheaper alternative for ultramarine. This is probably azurite (*q.v.*). Gentele (1860) seems to have tried to simplify the production of cobalt blue by drying 100 parts of alum with 5 to 10 parts cobalt sulfate, which was then calcined strongly in an air oven for 7 to 8 hours. To get rid of the reddish tone he added zinc vitriol (sulfate), which apparently turned it into sky blue. Mierzinski (1881) gives three formulations for sky blue: the first is a copper arsenic compound, apparently prepared from an acetified potassium arsenate and copper sulfate; the second involves the reaction of copper sulfate and sodium phosphate; the third seems to be an imitation based on mixtures of lead or zinc white and Berlin blue (*qq.v.*). The British firm of colourmen Winsor &Newton list sky blue in their catalogues of 1892 and 1896, describing it in the latter as 'A cheap imitation of Cobalt, consisting of Ultramarine with a trace of Lemon Yellow' (*q.v.*; cf. Carlyle, 2001). Heaton (1928) then considers it to be a 'pale artificial ultramarine', and a term in current usage at that time.

Azurite; Ultramarine; *Berlin blue*; *Cobalt blue*; *Lead white*; *Lemon yellow*; *zinc white*
Carlyle (2001) 474, 533; Gentele (1860) 228; Goeree (1670) 275–277; Heaton (1928) 384; Mierzinski (1881) 193

SLATE
Grey
Generic compound

Slate is a generic name for a metamorphosed mudstone or shale, a fine-grained rock that has developed a strong, planar cleavage in a direction suitable for the manufacture of roof tiles. The term does not denote a specific mineralogy and this is entirely dependent on the local composition of the mudstone from which it was formed. Typically fine micas are present (and it is these planar minerals which align to promote the cleavage) with varying amounts of iron oxides, iron pyrite and elemental carbon in the form of graphite (*qq.v.*). Very fine-grained quartz is frequently present. Clay minerals (*q.v.*) may be present, but these are generally converted to mica during the processes of metamorphism. Individual grains within most slates are beyond the resolution of optical microscopes. Slates form in areas of continental crust that have undergone moderate burial and deformation during their geological history.

Waste from cutting and trimming slates is an abundant by-product. According to Heaton (1928) this was ground to a powder and supplied in grades of varying fineness. Slate powder was used in the paint industry as an inert filler for the preparation of stopping and filling compounds for woodwork, machinery, etc.

Clay minerals group; Mica group; Shale; *Davy's grey*; *Slate black*; *Slate grey*; *Slate white*
Heaton (1928) 112

SLATE BLACK
Black
Synonym, variant or common name

Apparently a 'shale black containing 15% carbon' could be made by calcining bituminous shale (Mayer, 1991).

Slate
Mayer (1991) 56–57

SLATE WHITE
White
Synonym, variant or common name

See: lead white.

SMALLCOAL
Black
Synonym, variant or common name

Harley (1982) explains this term thus: 'At one time there were two names for the product obtained by partially burning twigs or small branches. One, charcoal, is still in use today because it is still made by the same slow-burning process, but *smallcoal* is obsolete.' A detailed description of the production is given by Chambers in his *Cyclopedia* of 1738: 'Small-coal is prepar'd from the Spray, and Brush Wood, stripp'd off from the Branches of Coppice Wood; sometimes bound in Bavins for that purpose, and sometimes prepar'd without binding. The wood they dispose on a level Floor, and setting a Portion of it on fire, throw on more and more, as fast as it kindles; whence arises a sudden blaze, till all be burnt that was near the place. As soon as all the wood is thrown on, they cast Water on the Heap, from a large Dish, or Scoop; and thus keep plying the Heap of glowing Coals, which stops the Fury of the Fire, while with a Rake they spread it open, and turn it with Shovels till no more Fire appears. When cold, they are put up into Sacks for use.'

Carbon-based blacks group; *Charcoal*
Chambers (1738); Harley (1982) 155–156

SMALT

Blue
Generic compound

Smalt is a widely used term for a cobalt-doped glass, $SiO_2(vit)Co_x$, the word smalt coming from the Italian term *smaltare*, which means 'to melt'.

Particle size is hugely influential to the final colour and smalt was sold in size grades (Beckmann, 1846). 'Strewing smalt' (also: *streublau* and *strooi blauw*; a sample of the latter exists in the so-called Hafkenscheid Collection of pigments) was a particularly coarse grade used to sprinkle onto an adhesive surface.

Some smalt pigments are known for their fugitive nature. Severe discoloration from blue to grey is known from important works including those by Murillo, El Greco and Veronese (see: Mühlethaler and Thissen, 1993). This may be influenced by (a) discoloration of the paint medium. The refractive indices of drying oils and smalt are similar; therefore the observed colour of the smalt will be affected by the discoloration of the oil. (b) The instability of potash glasses means that excess potassium may be leached and form saponification products with the oil. Likewise, (c), migration of the cobalt ion into the oils will form similar reactions (Plesters, 1969). Further studies by Mühlethaler and Thissen have shown that devitrification of the particles is not significant in the degradation of the colour and that reactions with oleo-resinous media are known to occur. It should be noted that smalt was recommended in the eighteenth century as a siccative for poor-drying blue pigments (Palomino, 1715–24). Smalt has also been observed in pigment mixtures where the colour would not be noticed; this has been interpreted as use of smalt as a siccative.

Cobalt occurs as a constituent of various minerals found in many parts of the world. Cobalt ore was heated to form an oxide which was then mixed with silica 'quartz sand' and sold under the name saffer (also, 'saffre' or 'zaffre') to glassmakers. The principal source of cobalt historically was the mineral skutterudite ($(Co,Ni)As_{3-x}$; named after its locality Skutterud, Norway; this mineral was also known historically as 'smaltite' (*q.v.*) in reference to its use for smalt). Deposits in Saxony were, for centuries, the main supply of European cobalt; however, there are sources in France and Spain. The related cobalt minerals erythrite (*q.v.*) and cobaltite were probably also used in the seventeenth and eighteenth centuries (Mühlethaler and Thissen, 1993).

Perhaps the best historical description of the preparation of smalt comes from the works of Kunckel (1689), superintendent of a Saxonian glassworks in the late seventeenth century. He explains how cobalt ore was roasted to remove the arsenic it contains, then sieved, mixed with pulverised stones, moistened and packed in barrels for sale. To produce smalt the product was broken up and mixed with sand and potash, then heated until it fused and melted. The vitrified mass was then removed and plunged into water to make it friable, then sieved, ground and washed. Finally it was packed into barrels marked according to colour grade – the best being a deep violet-blue, the cheapest a pale powder blue.

It is interesting that descriptions of the manufacture of smalt always cite potash as a flux. Potash glasses are less stable than soda glasses and this has affected the stability of the pigment, as noted above. It is unusual in glassmaking areas such as Venice and Egypt, for example, that sodium was not used as a flux, being abundant from seaweed and other natural sources such as at Wadi Natrun. Further research is required in this area.

Riederer points out that there were cobalt-containing glasses in antique times in Mesopotamia, Egypt, Greece and within the Roman Empire, but since usually their copper content was much higher, he assumed that the cobalt found in these glasses was mixed to the glass unintentionally (Riederer, 1968). In contrast, Mühlethaler and Thissen see it as well established that 'cobalt ores were used for colouring glass in Egyptian and classical times' (Mühlethaler and Thissen, 1993); they also refer to the fact that in Iran there were important sources of cobalt ore which were known by Persian potters and enamellers. However, it now seems to be generally acknowledged that smalt was probably not a European invention and that it was certainly available before the sixteenth century, the date to which various modern authors have previously suggested its invention (for example, see the earlier occurrences of the pigment as listed by Mühlethaler and Thissen). Riederer also cites numerous sources that mention zaffer or smalt, from Abbott Suger of St Denis in 1144 and a Persian source of 1301 onwards. In Germany the cobalt containing pigment was probably used before the sixteenth century (Riederer, 1968), in Italy it was little used in the fourteenth and fifteenth centuries but became a substitute for ultramarine and azurite (*qq.v.*) in the seventeenth century. In the Netherlands smalt was made from the sixteenth century and in England there is proof for its production in the early seventeenth century (Mühlethaler and Thissen, 1993).

Riederer thereafter discerns a general decrease in application, first in Italy and then in the Netherlands. Mühlethaler and Thissen regard the invention of Prussian blue, the discovery of synthetic ultramarine and of Thénard's blue (*qq.v.*) as the reason for the decline in usage of smalt (Mühlethaler and Thissen, 1993), although examples continue, such as specimens contained in the Hafkenscheid Collection (Pey, 1987). The pigment is currently available.

Pliny used the term *saphirus* to describe blue glass (*Natural History*, 77 AD). During the mediaeval period the German term *saferglas* was the general term for blue glass. However, while at first blue glass only meant blue copper glass, later glass coloured with roasted cobalt ores was also included.

Associated terms for smalt include: *azûr à poudrer, azurblau, azure, bleu d' émail*, blue sand, Bohemian blue, Dumont's blue, Dutch ultramarine, émail, enamel blue, eschel blue, Isenburg blue, *Kaiserblau*, *Königsblau*, powder blue, royal blue, Saalfeld blue, *Sachsischblau*, saffer blue, Saxon blue, Saxony blue, Schneeberg blue, Silesian blue, starch blue, *streublau*, Swabian blue and violet blue. Salter (1869) indicates that powder blue was a form used as a washing blue, blue sand for ceramics and Dumont's blue and royal blue as artists' grades. Mühlethaler and Thissen, citing Winckler, also mention the related terms *couleur* and *eschel* (also *sumpfeschel*); these were, it seems, part of the Saxonian quality designations, although Riederer implies that it was a more general German grading system.

Harley (1982) states that smalt or the knowledge of it may have come from the Near East in the Middle Ages and that it may have been an Italian invention made from glass from Germany and not a German invention as has been previously supposed. Coffignier (1924) believes that smalt was also produced in ancient China.

The terms *smalto* and *smaltino* found in early Italian literature should not automatically be inferred as smalt; these terms might refer to a vitrified pigment such as described by Vitruvius which was composed of sand, copper and potassium nitrate (Merrifield, 1849). Moreover, while 'smalt' commonly refers to this blue cobalt-based pigment, other colours also appear to have been marketed under the name, notably greens, reds, violets and yellows (as in 'smalt green', etc.); these were presumably glass, but opacified with different compounds. Kunckel (1689) uses the term smalt for all pigments that can be melted onto something, giving recipes for preparing different coloured smalts for goldsmiths: an opaque white smalt, a turquoise-coloured smalt, several blue smalts (one a mixture with zaffera and copper), three green smalts, three black smalts, two purple smalts and a yellow smalt (the relevant chapter is based on the sixth book of Neri's *L'Arte Vetraria*). Another Venetian glassmaker's notebook, *The Darduin Manuscript* (1644), gives numerous recipes for coloured smalts, black, green, peacock, white, turquoise, and yellow, as well as opaque smalts.

Reviews of smalt as a pigment are given by Riederer (1968) and Mühlethaler and Thissen (1993).

Cobalt group; Azurite; Erythryte; Ultramarine; Glass; *Azûr à poudrer*; *Azurblau*; *Azure*; *Bleu d'émail*; *Dumont's blue*; *Dutch ultramarine*; *Émail*; *Enamel blue*; *Kaiserblau*; *Königsblau*; *Powder blue*; *Prussian blue*; *Royal blue*; *Sachsischblau*; *Saffer blue*; *Saxon blue*; *Saxony blue*; *Smaltite*; *Starch blue*; *Streublau*; *Thénard's blue*; *Violet blue*

Beckmann (1846) I, 483 ff.; Coffignier (1924) 374–375; Darduin MS (1644) 122–145; Harley (1982) 53–56; Kunckel (1689) 121–128; Merrifield (1849) ccvi–ccvii; Mühlethaler & Thissen (1993); Palomino (1715–24); Pey (1987); Plesters (1969); Pliny (1st cent AD/Rackham, 1952) XXXVI.xxvii.68; Riederer (1968); Salter (1869)

SMALT GREEN

Green
Synonym, variant or common name

See: smalt.

SMALT RED

Red
Synonym, variant or common name

See: smalt.

SMALT VIOLET

Purple
Synonym, variant or common name

See: smalt.

SMALT YELLOW

Yellow
Synonym, variant or common name

See: smalt.

SMALTITE

White
Generic compound

Smaltite, also known as skutterudite or tin white cobalt, is a cobalt arsenate mineral with composition $(Co,Ni)As_{3-n}$, in which the cobalt content exceeds that of nickel; iron is a common impurity. It occurs as metallic silver-white cubes or with massive form, often with pink surfaces caused by oxidation (cobalt bloom) to erythrite (*q.v.*). Smaltite is named after its discovery at Skutterud (Norway) and its use in the production of smalt (*q.v.*). If forms in hydrothermal veins associated with cobalt deposits in areas such as Cobalt (Ontario, Canada), Freiberg (Germany), Andalusia (Spain) and Cornwall (England).

Mühlethaler and Thissen (1993) mention the use of smaltite in the manufacture of smalt pigment; it should not of course be confused with the pigment itself.

Erythrite; Smalt
Mühlethaler & Thissen (1993)

SMARAGD GREEN

Green
Synonym, variant or common name

Smaragd means 'emerald' in German. The term emerald green in both German and French refers to the hydrated chromium oxide, viridian (*q.v.*). This differs from the general meaning in English where emerald green (*q.v.*) typically refers to copper acetate arsenite (Fiedler and Bayard, 1997). A sample labelled *smaragd groen*, in a collection of paint samples dating to 1921 from the Dutch firm Claus and Fritz, has been shown to be composed primarily of viridian (Laar and Burnstock, 1997).

Chromium oxide hydrate; *Emerald green*; *Viridian*
Fiedler & Bayard (1997); Laar & Burnstock (1997)

SMITHSONITE

Variable
Generic compound

Smithsonite is a zinc carbonate mineral with composition $ZnCO_3$, also known as zinc spar or calamine. It was named after the English mineralogist J. Smithson (1765–1829) by Beudant in 1832 after its discovery in Mendip Hills (England). Smithsonite is occasionally found as rhombohedral crystals but it usually forms with botryoidal, reniform or granular habit. It varies in colour as the zinc in the structure is often partly replaced by iron and manganese. Thus smithsonite may be blue, pink, purple, yellow, orange, white, grey, brown or red, although it is more commonly known as a green or blue-green mineral. It has a unique wax-like lustre. It forms from the weathering of zinc sulfide deposits, particularly by the oxidation of zinc sulfide minerals such as sphalerite (*q.v.*). It is often found in association with hydrozincite, aurichalcite, cerussite, dolomite and calcite (*qq.v.*); it may alter to form limonite and hemimorphite or it may be replaced by quartz (*qq.v.*; Rutley, 1988). Noted localities for smithsonite are Cornwall and Derbyshire (England), Saxony (Germany), Attica (Greece), Tuscany (Italy), Durango (Mexico), Tsumeb mine (Namibia), Siberia (Russia) and Bisbee (Arizona, USA).

Listed in the *Colour Index* under CI 77950.

Zinc group; Aurichalcite; Calcite; Cerussite; Dolomite; Limonite; Quartz; Sphalerite; Zinc carbonate
Colour Index (1971) 77950; Rutley (1988) 295–296

SMOKE BLACK

Black
Synonym, variant or common name

Smoke black is a flame carbon. It is the literal translation of the French term *noir de fumée*, said in various sources (for example, Watin, 1785) to be specifically that 'gathered from the combustion of pitch and tar'.
See: lamp black.

Carbon-based blacks group; *Lamp black*
Watin (1773/edition of 1785) 35

SMYRNE LAKE

Red
Synonym, variant or common name

According to the discussion of madder lakes in Osborn (1845), 'At the French colorman's you will see these lakes labelled *Smyrne Lakes.* This is, because the best and most costly madder (*q.v.*) came to France from *Smyrna*. The name rests, but as is the case with certain wines, it probably has little business there.'

Madder
Osborn (1845) 20

SNOW WHITE

White
Synonym, variant or common name

According to Riffault *et al.* (1874), zinc oxide prepared by combustion of metallic vapours in air gives half the product as an 'exceedingly light' product called snow white; the remainder was more dense and called zinc white (*qq.v.*). Heaton (1928) lists the term snowflake white as then current, describing the composition as being a 'pure quality of lead white' (*q.v.*).

Blanc de neige; *Lead white*; *Schneeweiss*; *Zinc oxide*; *Zinc white*
Heaton (1928) 384; Riffault *et al.* (1874) 182

SNOWSHOE YELLOW

Yellow
Synonym, variant or common name

Maerz and Paul (1950) list snowshoe yellow as a synonym for Indian yellow.

Indian yellow
Maerz & Paul (1950) 'snowshoe yellow'

SOAPSTONE

Variable
Synonym, variant or common name

According to Hopkins (1914) 'Soapstone is properly applied to an impure form of steatite which contains varying amounts of chlorite, tremolite, pyroxene, magnetite, pyrite, quartz, and carbonates of calcium and magnesium. Its impurity is due to the fact that it is usually derived from the alteration of a basic, igneous rock, often pyroxenite. In common parlance this is the most widely used term, and is applied to any soft rock which can be cut readily . . . [T]he composition of soapstone necessarily has a wide range of variation.' Therefore, closely allied to the magnesium silicate hydroxide mineral talc and the form variant steatite, Patton (1973e) describes soapstone in a pigmentary context as 'a talclike material of variable composition containing sufficient impurities to prevent its use in applications requiring white color or chemical purity'. Normally used in the massive form for carving, etc., some use in powdered form for paint appears to have occurred.
See: talc and steatite.

Magnesium silicates group
Hopkins (1914) 193; Patton (1973e)

SODA GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

SODALITE

Variable
Generic compound

Sodalite is a cubic sodic aluminosilicate mineral with composition $Na_8Al_6Si_6O_{24}Cl_2$, from which the name is derived. It is the main member of the sodalite group of minerals which also includes lazurite, haüyne (*qq.v.*) and nosean. It is distinct from the other members of the group as it contains essential chlorine. The sodalite minerals are feldspathoids, meaning that they are chemically and structurally similar to the members of the feldspar group (*q.v.*), but differ in that they have a lower SiO_2 content. Sodalite varies in colour from pink, yellow, blue, green, grey to colourless and commonly occurs with granular or massive form; well-formed rhombic dodecahedral crystals may be found although these are less common. Sodalite forms in alkaline igneous rocks and in metasomatised limestones where the contact intrusion is also alkaline; in the latter case it may be found in association with haüyne, lazurite and calcite (*q.v.*); it is also found as a component in lapis lazuli (*q.v.*; Deer *et al.*, 1992; Rutley, 1988). Notable occurrences of sodalite are found at Mt Vesuvius (Italy), Maine and Arkansas (USA), Smaland (Sweden), Siberia (Russia), Quebec (Canada) and Illimaussauq (Greenland). Hackmanite is a variety of sodalite which is tenebrescent, appearing pink on a freshly fractured surface and fading on exposure to light; the colour returns after time when the mineralis kept in darkness or when it is irradiated (Kirk, 1955). This variety has been found in areas such as Mont St-Hilaire, Canada (Peterson, 1983) and Rio de Janeiro, Brazil (Klein and Montavano, 1985).

Although sodalite is not considered to have been used as a pigment in its own right, its formation in close association with lazurite means that it may be expected to occur as a minor constituent in some lapis lazuli samples (Plesters, 1993).

Feldspar group; Silicates group; Calcite; Haüyne; Lazurite; *Lapis lazuli*
Deer *et al.* (1992) 496–502; Kirk (1955); Klein & Montavano (1985); Peterson (1983); Plesters (1993); Rutley (1988) 434–435

SODIUM CARBONATES GROUP

White
Group term

Both natural and synthetic sodium carbonates have been identified in a pigment context. Those considered here are: chalconatronite and its synthetic analogue ($Na_2Cu(CO_3)_2.3H_2O$), sodium carbonate (Na_2CO_3), sodium hydrogen carbonate ($NaHCO_3$) and trona ($Na_3CO_3HCO_3{\cdot}2H_2O$).

The minerals chalconatronite and trona have been identified as pigments (Banik, 1989; Magaloni, 1996; Wainwright *et al*., 2002), while the synthetic form of chalconatronite has been synthesised by Scott (2002) from a Chinese recipe cited by Needham. Sodium hydrogen carbonate is known to be a component of so-called 'laundry blueing' along with, typically, synthetic ultramarine (see: laundry blue; Odegaard and Crawford, 1996). Finally, sodium carbonate is frequently cited as a precursor compound in numerous syntheses of pigments and may, conceivably, be found as a relict phase if incomplete washing has taken place; this is yet to be confirmed, however.

Chalconatronite; Sodium hydrogen carbonate; ultramarine; Trona; *Laundry blue*
Banik (1989); Magaloni (1996); Odegaard & Crawford (1996); Scott (2002) 118; Wainwright *et al.* (2002)

SODIUM HYDROGEN CARBONATE

White
Generic compound

Sodium hydrogen carbonate is likely to occur as a coincidental compound in various pigments although no specific instances seem to be known. However the English firm of Reckitt and Sons produced the laundry product *Reckitt's blue* from 1852, which was originally a combination of synthetic ultramarine (*q.v.*) and sodium hydrogen carbonate (sodium bicarbonate). Use of Reckitt's blue and other laundry blueings is documented in a number of ethnographic contexts such as artefacts from Papua New Guinea (Hill, 2001) and Australian rock art (Chippindale and Taçon, 1998).

Ultramarine; *Laundry blue*
Chippindale & Taçon (1998); Hill (2001)

SODIUM SILICATE ALUMINATE

White
Generic compound

Patton (1973d) describes 'sodium silico aluminate' as an ultrafine, synthetic, precipitated pigment formed by reacting specific aluminium salts with alkali silicates. He gives a typical formula as being $9Na_2O.67SiO_2.12Al_2O_3$. In characterising the pigment Patton differentiates gel and amorphous forms, where the gels are flocculated as a dense network of interconnected particles while the precipitated type comprises colloidal groupings of individual particles that appear as open-packed, isolated aggregates; sodium silicate aluminate is described as a functional form of this latter, precipitated, type. Among other applications, the fine particle size leads to this pigment being used as a partial replacement for titanium dioxide white (*q.v.*).

Titanium dioxide white
Patton (1973d)

SOLATRO

Red
Synonym, variant or common name

A recipe is given in the Paduan MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century; cf. Merrifield, 1849) for a red pigment derived from 'solatro': '100. *To make crimson from the* '*solatro Indiana*' The ripe solatro, being bruised, must be boiled with any quantity of water, gum Arabic and roche alum, over a slow fire, until the water is reduced to 2 thirds; it must then be left to clear, and the sediment must be dried in the shade and then ground.'

'Solatro Indiana' is most probably *Solanum indiana* L. About 1700 *Solanum* species exist in the world, including some of the most common garden plants such as the potato *S. tuberosum* L. and the aubergine (eggplant), *S. melongena* L. Another *Solanum* species, *S. nigrum* L. (commonly known as 'black nightshade') is used to give a green colour; for more information, see: nightshade.

Nightshade
Merrifield (1849) 694

SOLFERINO

Red
Synonym, variant or common name

Mayer (1991) states that solferino was a red-mauve magenta-based lake, named from the site of the battle in Italy.
See: magenta

Magenta
Mayer (1991) 57

SOLID YELLOW

Yellow
Synonym, variant or common name

Solid yellow is listed as a synonym for lead antimony oxide (*q.v.*; Wainwright *et al*., 1986).

Lead antimony oxide
Wainwright *et al.* (1986)

SOLUBLE BLUE

Blue
Synonym, variant or common name

Mayer (1991) has this as a water-soluble form of Prussian blue (*q.v.*); it may, however, be a reference to the so-called 'soluble' form of Prussian blue, which is not actually water-soluble.

Hexacyanoferrate group; *Prussian blue*
Mayer (1991) 57

SOMBRA DE VIEJO

Brown
Synonym, variant or common name

According to Palomino in *El museo pictórico y la escala óptica* (1715–24), this is a brown earth, dark in tone and somewhat roughly divided. The term literally means 'old man's earth', having been discovered 'in these provinces' by an old man (cf. & tr. Veliz, 1986).

Earth pigments group
Palomino (1715–24); Veliz (1986) 213, n.10

SOOT

Black
Synonym, variant or common name

See: lamp black.

SOPHORA YELLOW

Yellow
Synonym, variant or common name

A yellow colour produced from the pistils and stamens of the flowers of *Sophora japonica* L. (Leguminosae; distribution: China, Korea), which is also called the pagoda tree and *Huai* in Chinese (Mabberley, 1998). According to Yü (1955) a lighter yellow-green is produced from the unopened flowers than that from flowers which have already opened. The flowers are scalded in boiling water and then moulded into cakes. This preparation is used in China as a wash applied ‘over malachite in order to improve its adherence to the surface’. The dyestuff contains *Kaempferol* (*q.v.*).

Kaempferol; Malachite
Mabberley (1998) 671; Yü (1955/trans. Silbergold & McNair, 1988) 13

Soranjidiol

Red-Orange-Yellow
Generic compound

The anthraquinone compound soranjidiol, 1,6-dihydroxy-2-methylanthraquinone, is found as a component in roots of all *Rubia* species, *Morinda citrifolia* L. as a glycoside (and also possibly *M. umbellata* L.) and various *Coprosma* species (Schweppe, 1992). It is therefore a constituent of madder (*q.v.*) dyes. It is designated by the *Colour Index* as CI 75390.

Anthraquinones group; Madder
Colour Index (1971) 75390; Schweppe (1992) 205

Sorgho red

Red
Synonym, variant or common name

According to Salter (1869), ‘there was found to be a carmine colouring matter in most parts of the Chinese sorgho, chiefly in the unpressed stem. The red, which is extracted in an impure state, is dissolved in weak potash-ley, thrown down by sulphuric acid, and washed with water.’ It was apparently used in Austria and Germany as a wool and silk dye; Salter did not believe it to have been used as a pigment in Britain. Salter was probably referring to *Sorghum vulgare* Pers. var. Durra Hubbard et Rehd. (Graminaceae), also known as Guinea corn; this produces a red dye, listed in the *Colour Index* as CI Natural Red 32.

Colour Index (1971); Salter (1869) 176–177

Spaans groen

Green
Synonym, variant or common name

See: Spanish green.

Spalt

Brown
Synonym, variant or common name

See: spaltam.

Spaltam

Brown
Synonym, variant or common name

Deriving from the Latin *aspaltum*, in English documentary sources spalt(h)am or spalte referred to asphalt (*q.v.*). For example, accounts of 1532 for Hampton Court Palace, UK, refer to the purchase of ‘2 lb. of spaltam’ (Law, 1885; cf. *OED*, 2002). Harley (1982) mentions two sources of c. 1600; MS Sloane 6284 lists spalte with blacks, while Hilliard (1624) suggests its use for shadowing colours which are brown or blackish. In Spanish and Portuguese sources of the seventeenth century, such as the *Arte Poetica* of Nunes (1615) and Pacheco’s *Arte de la Pintura* (1638), the equivalent term used is *espalto*. Nunes advises its use with a little oil for darkening skin tones while Pacheco includes it among pigments used for producing the *bosquexo* (an underpainted sketch) in flesh tones.

Asphalt
Harley (1982) 151; Hilliard (1624/Thornton & Cain, 1981), 94; Law (1885) I, 363; MS Sloane 6284 (nd) f. 109^{v}; Nunes (1615) 57; *OED* (2002) ‘Spaltam’; Pacheco (1638) 78

Spanish black

Black
Synonym, variant or common name

According to various English sources such as Terry (1893) and Heaton (1928), this is a cork char. Mayer (1991) also indicates that it could be slate black (*q.v.*).

Carbon-based blacks group: Chars sub-group; Slate black
Heaton (1928) 384; Mayer (1991) 57; Terry (1893) 26

Spanish blue

Blue
Synonym, variant or common name

Hispaniense, generally translated as ‘Spanish blue’, is described by the classical author Pliny (77 AD). It is perhaps Egyptian blue (*q.v.*), although Pliny’s description implies that it is naturally occurring rather than a synthetic compound.

Egyptian blue
Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii.161–163

Spanish brown

Brown
Synonym, variant or common name

Harley (1982) found that the term Spanish brown (also ‘*almagro*’) was used in seventeenth century British sources for a burnt ochre (*q.v.*). She also specifically notes letters patent granted in 1626 covering the Forest of Dean, Gloucestershire, England, that gave control over ‘grinding and makeing that Redocker or Red Earth called Almagro and of refining, washing, deviding from gravell or sande the burnte Ocker digged in the fforeste of Deane called Spanish Browne’, also adding that ‘At one time some red and brown ochres had been imported from Spain, and, because the names were familiar to English artists, they were retained even when the pigments were produced in England. Spanish brown persisted as a colour name well into the eighteenth century, when Dossie (1764) found it necessary to point out that it was not Spanish but English’.

White (1986) on the other hand states that Spanish brown, as well as Spanish juice or Spanish liquorice, was obtained as a gum from rhizomes of *Glycyrrhiza glabra* L. (Leguminosae), the extract being more commonly known simply as liquorice. In fact many *Glycyrrhiza* species provide local sources of liquorice, *G. glabra* itself being naturalised in the Mediterranean and central Asia with cultivation in Russia, Spain and the Middle East. Liquorice – also called ‘*Glycyrrhiza*’ – contains saponins and various oligoglycosides such as the immensely sweet glycyrrhizin (typically 6–14%) and asparagine. Dossie describes Spanish juice as being ‘the succulent part of the liquorice root’, adding that it is prepared by boiling the root in water, straining and then evaporating it until dry.

Spanish brown is also noted as a synonym for the humic earth known as Vandyke brown (*q.v.*; Feller and Johnston-Feller, 1997).

Humic earth; *Almagra*; *Burnt ochre*; *Burnt umber*; *Vandyke brown*
Dossie (1764) I-130; Feller & Johnston-Feller (1997); Harley (1982) 119–120; White (1986)

SPANISH GREEN

Green
Synonym, variant or common name

Boltz (1549) refers to this as synonymous with Greek green ('*Griechisch grien*'). However, he mentions honey in the recipe and recent work by Banik (1989) indicates that this is likely to produce a different form of verdigris (*q.v.*).
See: *viride Hispanicum* for more information.

Verdigris; *Viride Hispanicum*
Banik (1989); Boltz von Ruffach (1549/Benziger, 1913) 75

SPANISH JUICE

Brown
Synonym, variant or common name

See: Spanish brown.

SPANISH LIQUORICE

Brown
Synonym, variant or common name

See: Spanish brown.

SPANISH OCHRE

Orange
Synonym, variant or common name

According to Carlyle's survey of nineteenth century British documentary sources, Spanish ochre was a synonym for Mars orange (*q.v.*), a synthetic iron oxide pigment (Carlyle, 2001). Salter (1869) however explicitly links it to a burnt yellow or Roman ochre (*q.v.*). It should also be noted that there were commercially important deposits of a red ochre (*q.v.*) known as Spanish red.

Iron oxides and hydroxides group; *Mars orange*; *Red ochre*; *Spanish brown*; *Spanish red*; *Yellow ochre*
Carlyle (2001) 498; Salter (1869) 255

SPANISH OXIDE

Red
Synonym, variant or common name

According to Heaton (1928), Spanish oxide was a then-current term for a 'natural oxide of iron from Spain', presumably that known otherwise as Spanish red rather than S. ochre (*qq.v.*).

Spanish ochre; *Spanish red*
Heaton (1928) 384

SPANISH RED

Red
Synonym, variant or common name

A variety of red ochre (*q.v.*) that Fairholt (1854) defines as 'an ochre resembling Venetian red, but slightly yellower'. It is presumably properly that derived from the commercially important deposits of red ochre that occur in the vicinity of Malaga, Spain.

Hematite; *Red ochre*
Fairholt (1854)

SPANISH WHITE

White
Synonym, variant or common name

The term Spanish white does not generally appear to relate to a place of origin or manufacture (although Riffault *et al.*, 1874, do, however, state that this refers to place of preparation), and it appear to have been applied to a number of pigments historically. According to Tingry (1804), this was a pure clay; however he further states that 'chalk was attempted to be sold in its stead'. Harley (1982) on the other hand found that it could be applied to bismuth white (*q.v.*; probably bismuth chloride oxide and/or bismuth nitrate) as well as chalk with alum and lead white (*q.v.*). Dossie (1764) states that this is a solution of chalk and alum. Heaton (1928) describes Spanish white as an old name for Paris white (chalk) in lump form and Terry (1893) states that this is 'carefully prepared' whiting. It is not clear whether the transliteration '*Blanc d'Espagne*' referred to the same range of possibilities or was restricted to 'bismuth white' alone.

Calcite; Calcium carbonate, calcite type; Chalk; *Bismuth white*; *Blanc d'Espagne*; *Lead white*; *Paris white*; *Satin white*
Dossie (1764) I-137; Harley (1982) 165, 173; Heaton (1928); Riffault *et al.* (1874) 54; Terry (1893) 246; Tingry (1804) 286–287

SPATH PESANT

White
Synonym, variant or common name

Spath pesant was an historical term for the mineral baryte (*q.v.*; Feller, 1986).

Baryte
Feller (1986)

SPERTINIITE

Blue-Green
Generic compound

Spertiniite is a copper hydroxide mineral with composition $Cu(OH)_2$. It was named after the Canadian geologist F. Spertini and occurs as pale blue or blue-green platy crystals, or as botryoidal or encrusting masses. Spertiniite forms in the oxidising zones of copper ore deposits and is known from localities such as Mine Jeffrey (Quebec, Canada), Bisbee (Arizona, USA) and Saxony (Germany) (Grice and Gasparrini, 1981).

The natural mineral form of spertiniite is not known to have been identified in a pigment context. However, it is known that the synthetic form, copper hydroxide (*q.v.*), can be reproducibly synthesised via one route in the non-commutative titration of aqueous copper chloride with aqueous sodium hydroxide solutions. Thus, observation of copper hydroxide in a pigment context most likely relates to the synthetic form. Scott (2002), for example, states that this form of copper hydroxide frequently occurs as a component of historical recipes for light blue pigments.

Copper group; Copper oxides and hydroxides group; Copper hydroxide
Grice & Gasparrini (1981); Scott (2002) 98

SPHALERITE

Brown
Generic compound

Sphalerite is a cubic resinous zinc iron sulfide mineral of composition (Zn,Fe)S. It is commonly black, brown or yellow but may be red, green or white, depending on the Zn:Fe ratio. Matraite (*q.v.*) is the pure form of ZnS. Sphalerite crystals are often tetrahedral or dodechedral in form with curved faces, although sphalerite can also occur with massive, fibrous or botryoidal form. Named in 1847 by Glocker from the Greek *sphaleros* meaning 'treacherous' on account of its common misidentification as galena (*q.v.*). Sphalerite is common worldwide in metalliferous veins and massive sulfide deposits which are associated with hydrothermal or metasomatic activity (e.g. Santander, Spain; Tri-State Field, Mississippi Valley, USA; Broken Hill, Australia; Derbyshire and Cornwall, England). It is historically known as zinc blende or blackjack and is almost always found in association with galena, pyrite, fluorite, calcite and quartz as well as occasionally with baryte (*qq.v.*). It is the low temperature form of wurtzite (*q.v.*) and is the most common of the zinc sulfide minerals. It commonly alters to the zinc carbonate mineral smithsonite (*q.v.*). There are many common names for sphalerite including 'black jack', 'blende', 'false galena', 'ruby zinc' and 'zinc blende'.

The synthetic form of sphalerite, zinc sulfide (*q.v.*), was introduced as a pigment in 1852 although it was not widely used due to the grey cast apparently caused by traces of iron sulfide. A purer product known as '*Sachtolith*' was marketed from 1927; when zinc sulfide is precipitated with barium sulfate, lithopone (*q.v.*) is produced (Heaton, 1928).

Iron group; Zinc group; Zinc sulfides group; Baryte; Calcite; Fluorite; Galena; Matraite; Pyrite; Quartz; Smithsonite; Wurtzite; Zinc sulfide; *Lithopone*
Glocker (1847); Heaton (1928) 89

SPHERULITIC MALACHITE

Blue-Green
Synonym, variant or common name

The occurrence of a spherulitic form of malachite – that is, a naturally occurring malachite (*q.v.*) with very fine rounded particle morphology – is open to question and is probably predicated on the assumption that the synthetic analogue was not used at the time and place of the works where it was found. FitzHugh, for example, encountered a green copper containing pigment on Ukiyo-e Japanese paintings which, while giving an XRD pattern of malachite, did not have either the typical angular morphology of the mineral or the wholly spherulitic form of the synthetic analogue (FitzHugh, 1979). Subsequently Smith *et al.* (1981) noted a possible use of this pigment in the late fifteenth century painting by Francesco del Cossa of *S. Vincent Ferrer* (National Gallery, London) and in their discussion of that occurrence state that there were two possible explanations: (a) that it was an interaction between malachite and the paint medium and, (b), that it was simply a synthetically produced compound (copper carbonate hydroxide, malachite type, also known as green verditer). Of these possiblities they come firmly down on the side of the latter, noting the characteristic optical morphology of radiating aggregates of needle-like particles within each spherulite and the presence of twinning.

Copper carbonates group; Copper carbonate hydroxide, malachite type; Malachite; *Green verditer*
FitzHugh (1979); Smith *et al.* (1981)

SPINCERVINO YELLOW

Yellow
Synonym, variant or common name

See: giallo santo.

SPINEL BLACK

Black
Synonym, variant or common name

Iron chrome spinels of composition $CuFe_{0.5}Cr_{1.5}O_4$ give black pigments. Spinels are actually magnesium aluminates generally with a cubic crystal structure; they vary according to their iron and chrome content (Buxbaum, 1998). See: spinel pigments for further information. A black synthetic analogue of the spinel mineral jacobsite has been found in an Etruscan context (Schweizer and Rinuy, 1982).

Jacobsite; *Spinel pigments*
Buxbaum (1998) 101; Schweizer & Rinuy (1982)

SPINEL PIGMENTS

Variable
Synonym, variant or common name

From a purely mineralogical point of view spinel is magnesium aluminate ($MgAl_2O_4$), with a cubic crystal structure. The name 'spinel' derives from the Latin '*spinella*' ('little thorn') referring to the spine-shaped octahedral crystals.

However, the mineral also lends its name to a group of compounds which share the same crystal structure, and contain varying amounts of chromium and iron in place of aluminium. In terms of pigments, the principal members are those known as cobalt blue, cobalt green, zinc iron brown and spinel black. All are characterised by good temperature stability, a property which has led to their use, among other things, as ceramic pigments. The main compounds are cobalt aluminium oxide (cobalt aluminate) $CoAl_2O_4$ (CI 77346/Pigment Blue 28), a reddish blue; cobalt aluminium chromium oxide $Co(Al,Cr)_2O_4$ (CI 77343/Pigment Blue 36), a greenish blue; cobalt nickel zinc titanium oxide $(Co,Ni,Zn)_2TiO_4$ (CI 77377/Pigment Green 50), a green; copper chromium manganese oxide $Cu(Cr,Mn)_2O_4$ (CI 77428/Pigment Black 28), a black; copper chromium iron oxide $Cu(Fe,Cr)_2O_4$ (CI 77429/Pigment Black 22), a black; iron zinc oxide $ZnFe_2O_4$ (CI 77496/Pigment Yellow 119), a light to medium brown. These have been classed in the pigment industry under the term 'mixed metal oxide pigments' (although this has now been superseded by the phrase 'complex inorganic colour pigments'), a grouping which further includes compounds with rutile, hematite and bixbyite structures (Buxbaum, 1998). Most of these are used in ceramics rather than as painting pigments, the principal exception being cobalt aluminium oxide, otherwise commonly known as cobalt blue.

Cobalt aluminium oxide; *Cobalt blue*; *Cobalt green*
Buxbaum (1998) 99–105; *Colour Index* (1971)

SPOONER'S CHROME

Yellow
Synonym, variant or common name

According to Mierzinski (1881) old forms of this pigment consisted of chrome yellow (*q.v.*) and alum (a hydrous potassium aluminium sulfate). This composition is the same as that given for French chrome yellow and Baltimore chrome yellow (*q.v.*) by the same source.

Lead chromate(VI); *Baltimore chrome yellow*; *Chrome yellow*
Mierzinski (1881) 134

SPRUCE OCHRE

Yellow
Synonym, variant or common name

Spruce ochre (or 'oker') was an historical term for a variety of yellow ochre. Field (1835) comments that it is a dark yellow […] much employed and affords useful and permanent tints. The name apparently relates to the source of the pigment, 'spruce' being an old form of 'Prussia' or 'Prussian', for example: Abbot (1599; cf. *OED*) states, 'on the East & North Corner of Germany lyeth a country called Prussia, in English Pruthenor Spruce'.

Yellow ochre
Abbot (1599) 69; Field (1835) 80; *OED* (2001) 'Spruce'

SPRUCE OKER

Yellow
Synonym, variant or common name

See: spruce ochre.

STANNIC OXIDE

White
Synonym, variant or common name

See: cassiterite and tin(IV) oxide.

STARCH

White
Generic compound

The term starch is used to describe a biopolymer system comprising predominantly two polysaccharides – amylose and amylopectin – which are made of glucose monomers. Starches are found in a very diverse array of plants, primarily in storage organs such as tubers and seeds. It is synthesised in specialised plastids known as amyloplasts and chloroplasts. Starch is formed by a complex biological pathway involving photosynthesis but much of this route remains unknown. However, once produced, starch is held in granular storage bodies which are usually deposited in the plastids of most higher plant species, it being the main energy storage system in most plants. The smaller of the two polysaccharides which make up starch, amylose, is a linear molecule comprising (1–4) linked alpha-D-glucopyranosyl units. There is a small degree of branching by (1–6) alpha linkages. The larger of the two components, amylopectin, is highly branched with a much greater molecular weight. This structure contains alpha-D-glucopyranosyl units linked mainly by (1–4) linkages (as amylose) but with a greater proportion of (1–6) linkages, which gives a large highly branched structure. Amylopectin has been found to form the basis of the structure of starch granules, essentially because the short branched (1–4) chains are able to form helical structures which crystallise.

Starch is not infrequently mentioned as an addition to paint, either as an adulterant or extender, or as a substrate for dyestuffs. It can be derived from various plant sources such as wheat (*Triticum aestivum* and *T. durum*), potato (*Solanum tuberosum*) and rice (*Oryza sativa*). The so-called 'Paduan' MS *Ricette per Far Ogni Sorte di Colore* (late sixteenth or early seventeenth century/cf. and tr. Merrifield, 1849) describes the use of flour as a lake substrate: '*98. To make fine lake* Take lime water in which brazil wood has been infused, and add it to the flour, so that it may become thick, and when the whole is well mixed, let the flour sink to the bottom, make it into a small loaf, dry it in an oven not too hot, then grind it up, and with lime water, make it into pellets, and let them dry in the shade.' Carlyle (2001) found various mentions of starch used not directly as a pigment, but to gelatinise oil paint; for example, she notes Field's comments that 'Indeed starch, as prepared by the laundress, has been lately recommended with high encomiums for this purpose' (Field, 1841/cf. Carlyle, 2001). Bachhoffner, writing around that time, states that 'starch . . . prepared for the laundress, is more frequently obtained from potatoes . . . and previous to drying is coloured faintly blue by smalt' (*q.v.*; Bachhoffner, 1837). In yet another context Standage mentions that sometimes starch coloured blue with iodine was used to adulterate Prussian blue (*q.v.*; Standage, 1887/cf. Carlyle, 2001). Moffatt *et al.* (1997) have noted the presence of starch in blue colours on Naskapi artefacts, indicative of the use of laundry blue (*q.v.*).

Laundry blue; *Prussian blue*; *smalt*
Bachhoffner (1837) 127; Carlyle (2001) 110, 477; Field (1841) 350; Merrifield (1849) II, 694; Moffatt *et al.* (1997); Standage (1887) 29

STARCH BLUE

Blue
Synonym, variant or common name

Starch blue occurs as a synonym for smalt (*q.v.*), it having been used historically as a laundry blue mixed with starch (for example, see: Carlyle, 2001).

Smalt; *Laundry blue*
Carlyle (2001) 110, 478

STEATITE

White
Generic variety

Steatite refers to a particularly massive form of the magnesium silicate hydroxide mineral talc and is considered a purer grade of the related material soapstone (*qq.v.*), the latter perhaps only containing 50% talc. According to Patton (1973e), to qualify as a steatite-grade talc, it must contain less than 1.5% CaO, 1.5% Fe_2O_3 and 4% Al_2O_3.

Magnesium silicates group; Talc; *Soapstone*
Patton (1973e)

STEEL BLUE

Blue
Synonym, variant or common name

Steel blue has been used as a term for certain paler grades of Prussian blue (*q.v.*; Berrie, 1997). Mayer, the English translator of Zerr and Rübencamp (1908), also suggests that 'steel blue' could be applied generally to products which did not show the characteristic metallic lustre of the pigment, 'bronze blue' to those that did.

Prussian blue
Berrie (1997); Zerr & Rübencamp (1906/1908) 173

STEINBÜHL YELLOW

Yellow
Synonym, variant or common name

Steinbühl yellow (*Steinbühlergelb*) is given by Rose (1916) as a synonym for baryta yellow (barium chromate). Kühn and Curran (1986), while confirming the relationship to barium chromate, also state that *Steinbühler Gelb* was applied to calcium chromate (*qq.v.*) in Germany. The term has also been associated with ultramarine yellow (*q.v.*).

Calcium chromates group; Barium chromate(VI); *Baryta yellow*; *Ultramarine yellow*
Kühn & Curran (1986); Rose (1916) 270

STEINER LAKE

Red
Synonym, variant or common name

According to Schweppe and Winter (1997, citing Seufert, 1955), Steiner lake was an inexpensive madder lake of less brilliant colour prepared from inferior quality madder (*q.v.*).

Madder
Schweppe & Winter (1997); Seufert (1955) 65, 229

STELLERITE

White
Generic compound

Stellerite is an orthorhombic hydrated calcium aluminosilicate mineral with composition $Ca_2Al_4Si_{14}O_{36}.14H_2O$. It forms a solid solution series with the monoclinic mineral stilbite, $Ca_2NaAl_5Si_{13}O_{36}.16H_2O$, with which it is usually found in association, although stellerite is less common (Fridriksson *et al.*, 2001). They both belong to the zeolite group of minerals on account of their crystal structure (Pechar and Mattern, 1986). Stellerite commonly occurs as vitreous tabular crystals or spheres of radiating crystals (stellate) which are usually colourless or white but may be tinted pink, red, orange and yellow-brown. It was discovered by Morozewicz in 1909 and is actually named after Georg Wilhelm Steller (1709–46), a German explorer and the discoverer of the Commander Islands in the Bering Sea. Stellerite is found in basalt rocks which have undergone low-grade metamorphism often by hydrothermal action (such as at Nuequen, Argentina (Vattuone *et al.*, 2001), Commander Islands, Bering Sea, Russia and Iceland), in unaltered amygdales (cavities in igneous rocks which have become filled with different minerals at a later geological period) and veins in basalts (such as in Nova Scotia, Canada; e.g. Pe-Piper, 2000) and in fissures in granite (for example, in Switzerland).

Stellerite – and the hexagonal sodium-rich zeolite mineral gmelinite (*q.v.*) – have been identified as minor phases mixed with celadonite in green earth (*qq.v.*) used as a pigment on wall paintings in Cyprus (Kakoulli, 1997).

Aluminium group; Calcium group; Silicates group; Celadonite; Gmelinite; Green earth; Stilbite
Fridriksson *et al.* (2001); Kakoulli (1997); Pechar & Mattern (1986); Pe-Piper (2000); Vattuone *et al.* (2001)

STIBNITE

Grey
Generic compound

Stibnite is an antimony sulfide mineral with composition Sb_2S_3. It commonly occurs as grey or black acicular or bladed flexible crystals which have a metallic lustre and striated surfaces (although granular forms are also found). The crystals are often curved due to twinning and are relatively soft. Stibnite forms primarily in low temperature hydrothermal veins where it is often found in association with quartz, baryte and calcite (*qq.v.*). It commonly oxidises to form the antimony oxide minerals valentinite, kermesite and senarmontite (*qq.v.*; Rutley, 1988; Dana, 1855). Stibnite occurs worldwide in metal deposits in localities such as Turhal, Turkey (e.g. Gokce and Spiro, 1991) as well as Cornwall (England), Saxony (Germany), Attica (Greece), Durango (Mexico) and Quebec (Canada). The name stibnite comes from the Greek, *stimmi* or *stibi*, 'antimony', thence to the Latin, *stibium*. Also from the Greek *anthemon*, 'flower' in allusion to the form of crystal druses. Synonyms include antimonite, antimony glance, grey antimony and stibium. Stibnite has also been produced artificially by heating a sealed tube containing a solution of antimony with ammonium sulfocyanate, or by passing hydrogen sulfide at red heat over antimony compounds.

Richter (1988) mentions a number of related German terms: *Antimonglanz* ('antimony shine'), *Grauspiessglanz* ('grey sword glint') and *Spiessglanz* ('sword glint'), a term used in baroque times; all three relate to the appearance of the antimony sulfide crystals. Richter also reports that the pigment was found in an altarpiece by Tilman Riemenschneider and Martinus Schwartz dating from 1490. The artists used the stibnite sprinkled as little particles in the rocky background landscape, together with particles of ground brass foil. Richter assumes that the artists obtained the antimony sulfide from natural deposits in the Harz mountains or in Westfalia in Germany. Furthermore, Richter also mentions a technical guide for artists of 1719 that precisely describes this use by Johann Melchior Croeker. Stibnite has additionally been identified in the grey colours of certain paintings by Correggio (Ferretti *et al.*, 1991) and has been found in a number of early sixteenth century northern Italian paintings at the National Gallery, London; it was observed that when finely ground the dry pigment does not look metallic, but a dark grey.

Antimony group; Antimony sulfides group; Baryte; Calcite; Kermesite; Orpiment; Quartz; Senarmontite; Valentinite
Croeker (1719/edition of 1753); Dana (1855) 33; Ferretti *et al.* (1991); Gokce & Spiro (1991); Richter (1988); Rutley (1988) 246

STIL DE GRAIN

Yellow
Synonym, variant or common name

A French term for the yellow flavinoid dyestuff derived from various plants *Rhamnus* species. It is also a term for the yellow lake pigment made from this dyestuff. Watin (1785) describes this as 'made of a decotion of *graine d'Avignon,* which comes from a tree called noirprun (*Rhamnus cathartica* L.) mixed with a little *alun de glace*, a sort of chalk or white marne from Champagne. The berry should be chosen with a golden yellow colour, which gives a jonquil colour and can be varied depending on the amount of white which is mixed with it. Yellow stil de grain made of Avignon berries charged with alum gives a 'transparent pretty yellow'. Osborne (1845) quotes 'a writer [who] says that the *stils de grain*, composed of the oxide of lead and the Avignon berry, are of more solidity. Brown (*or* English) *Stil de grain* is prepared with a calcareous or marly earth, alum, and a decoction of Avignon berries: a treacherous pigment, like the yellow stil.'

Watin also states that *stil de grain* could be made with weld (*q.v.*; *Reseda luteola*) or from a '*graine* called *graine d'Ahoua* which comes from the Orient via the *Companie des Indes.* This is superb in painting, as beautiful as orpiment, holds up much better and has none of the inconveniences.' Merrifield (1849) additionally states that this term refers to those pigments not only pure yellow in colour, but to those inclined to green. This is generally true of the berries of the various Rhamnus plants as the colour depends on the ripeness of the berry at the time of harvesting.

The Brussels manuscript (1635, cf. Merrifield) describes a stil de grain made from earth mixed with white flowers which, according to a note in the margin are '*fleurs de geniste*' (*Genista tinctoria*, 'dyer's broom').
See: rhamnus.

Flavonoids group; Orpiment; Rhamnus; Weld; *Dutch pink*; *English pink*; *French pink*
Merrifield (1849) clxiv; Osborn (1845) 52; Watin (1773/edition of 1785) 27–28

STINKSPAT
Purple
Synonym, variant or common name

Stinkspat was a German term for an intensely blackish purple type of fluorite known as antozonite (*qq.v.*; Richter *et al.*, 2001).

Antozonite; Fluorite
Richter *et al.* (2001)

STOLZITE
Variable
Generic compound

Stolzite is a tetragonal lead tungstate mineral with composition $PbWO_4$, also known as lead wulframate (Plakhov *et al.*, 1971). It forms as yellow, green, red-brown, green-brown, yellow-brown or grey tabular, prismatic or pseudo-cubic crystals which fracture conchoidally. Stolzite is polymorphous with the monoclinic form raspite (*q.v.*), although the stability fields of these phases are not well constrained. Stolzite is commonly found with raspite and occurs in hydrothermal veins associated with ore deposits such as at Broken Hill, Australia (Bywater, 1983) as well as Salzburg (Austria), Cornwall (England), Arizona (USA) and Tsumeb mine (Namibia). It is also found in some metamorphic rocks in association with scheelite, muscovite, albite and quartz (*qq.v.*; for example, at Chalkidiki, northern Greece; Kilias and Konnerup-Madsen, 1997).

Riffault *et al.* (1874) have described how a white synthetic form of lead tungstate (*q.v.*) has been produced as a pigment, although it is unknown what crystal system the synthetic form takes; it is sometimes called tungsten white, although this term may also be used to refer to barium tungstate (*qq.v.*). Lead tungstate is listed as a pigment by various other nineteenth and twentieth century sources such as Salter (1869) who calls this tungsten white or tungstate of baryta, and Bersch (1901); a fuller description of this is given in the entry for lead tungstate.

Lead group; Tungsten group; Albite; Barium tungstate; Lead tungstate; Muscovite; Quartz; Raspite; Scheelite; Tungsten white
Bersch (1901) 128; Bywater (1983); Kilias & Konnerup-Madsen (1997); Plakhov *et al.* (1971); Riffault *et al.* (1874) 159–160; Salter (1869) 414–415

STONE BLUE
Blue
Synonym, variant or common name

Stone blue is listed as a synonym for indigo (*q.v.*) by Schweppe (1997).

Indigo
Schweppe (1997)

STONE GREEN
Green
Synonym, variant or common name

Stone green is listed as a synonym for green earth (*q.v.*) by Mayer (1991).

Green earth
Mayer (1991) 57

STONE OCHRE
Yellow-Brown
Synonym, variant or common name

Field (1835) implies stone ochre was frequently similar to, and confused with, Oxford and Roman ochres (*qq.v.*). Moreover, he states that 'True stone ochres are found in balls or globular masses of various sizes in the solid body of stones, lying near the surface of rocks among the quarries of Gloucestershire and elsewhere. These balls are smooth and compact, in general free from grit, and of a powdery fracture. They vary exceedingly in colour, from yellow to brown, murrey, and gray, but otherwise do not differ from ordinary ochres.'

Ochre; *Oxford ochre*; *Roman ochre*
Field (1835) 79–80

STREUBLAU
Blue
Synonym, variant or common name

The German term *Streublau* may be directly translated as 'strewing blue'. Strewing was a method of using smalt (*q.v.*) for which this is a synonym, it being a particularly coarse grade (Riederer, 1968; Mühlethaler and Thissen, 1969).

Smalt
Mühlethaler & Thissen (1969); Riederer (1968)

STRONTAINE YELLOW
Yellow
Synonym, variant or common name

A term for strontium chromate(VI) (*q.v.*) used by Birren (1965; cf. Kühn and Curran, 1986), who notes that the pigment was present in the palettes of Bonnard and Matisse.

Strontium chromate(VI); *Strontium yellow*
Birren (1965) 67–68; Kühn & Curran (1986)

STRONTIAN WHITE
White
Synonym, variant or common name

See: strontium white.

STRONTIAN YELLOW
Yellow
Synonym, variant or common name

A term used by, for example, Salter (1869) and Heaton (1928) for a strontium chromate (*q.v.*) pigment.
See: strontium yellow.

Strontium chromate(VI); *Strontium yellow*
Heaton (1928) 384; Salter (1869) 113–114

STRONTIANITE
White
Generic compound

Strontianite is a strontrium carbonate mineral with ideal composition $SrCO_3$, although some calcium and/or barium may also be present (Rutley, 1988; Speer and Hensley-Dunn, 1976). It is a comparatively rare carbonate mineral and is named after its type locality of Strontian (Scotland) from where it was first described by Sulzer in 1790 (Dana, 1932). Strontianite occurs most commonly with fibrous, granular or massive form although individual prismatic or acicular crystals are found. It is a white mineral when pure, but can have a variety of colours, pale green, yellow, pink, grey, depending on the presence of minor impurities. Strontianite occurs as nodules in limestone (*q.v.*), where it may form from the alteration of celestite (*q.v.*), or as fibrous masses in low temperature hydrothermal veins in limestones (e.g. Westphalia, Germany; Attica, Greece; Sao Paulo, Brazil; Colorado, USA). Strontianite is often found in association with galena, baryte, calcite and aragonite (*qq.v.*; Rutley, 1988), and is also known to occur as discreet domains in coral skeletons (Allison *et al.*, 2000; Greegor *et al.*, 1997). The principal occurrence of strontianite in a pigment context, however, appears to be as a trace component of calcium sulfate evaporite deposits of gypsum and anhydrite (*qq.v.*).

The presence of a white strontium-bearing pigment was identified using micro-PIXE analysis by Olsson *et al.* (2001) on a nineteenth dynasty Egyptian papyrus, although the exact nature of the mineral was not determined in that study. Strontianite has, however, been observed in the calcium sulfate ground of Giotto's *Crucifix* in Santa Maria Novella, Florence (Matteini *et al.*, 2002).

Strontium group; Anhydrite; Aragonite; Baryte; Calcite; Celestite; Galena; Gypsum; Limestone.
Allison *et al.* (2000); Dana (1932) 532; Greegor *et al.* (1997); Matteini *et al.* (2002) 390; Olsson *et al.* (2001); Rutley (1988) 299–300; Speer & Hensley-Dunn (1976)

STRONTIUM CHROMATE(VI)

Yellow
Generic compound

Strontium chromate(VI), $SrCrO_4$, is a yellow pigment now listed by the *Colour Index* as CI Pigment Yellow 32 (CI 77839). It is synthesised by mixing solutions of neutral alkali chromate (commonly potassium chromate) and strontium chloride, and the resultant precipitate is washed thoroughly before it can be used as a pigment. According to Gentele (1860), who referred to it only as an additive in other yellow mineral colours, strontium chromate is 'a very pale yellow, similar to the barium chromate' (*q.v.*).

Strontium chromate(VI) is also known as strontium yellow, ultramarine yellow (Bouvier, 1910) and lemon yellow (*qq.v.*), although the latter terms are also applied to other pigments. Birren (1965) refers to the pigment as strontaine yellow and Kühn and Curran (1986), citing Bennett (1963), indicate that a product containing strontium yellow was known in France as citron yellow (*q.v.*). Bouvier also states that a mixture of strontium chromate and Prussian blue was called green cinnabar, and that strontium (or cadmium) chromate mixed with chromium oxide was known as Behrendt green (*qq.v.*).

Strontium chromate(VI) pigments have been used by many artists. For example, in the review by Kühn and Curran, Birren is cited as reporting the use of strontaine yellow by both Bonnard and Matisse, while Moreau-Vauthier (1923) reported that strontium yellow had been used by artists such as Cormon, Chabas, Domergue and Doigneaw.

Gettens and Stout (1966), citing Eibner (1909), report that strontium chromate may develop a green colour due to the formation of chromium oxide. It was reported as unsatisfactory when used in watercolours due to its great hiding power (Winsor and Newton, 1910). In modern applications, strontium chromate is used as corrosion inhibitor (Kühn and Curran).

Chromates group; Chromium oxides and hydroxides group; Zinc chromates group; Barium chromate(VI); Cadmium chromate; Chromium oxide; Prussian blue; *Behrendt green*; *Citron yellow*; *Green cinnabar*; *Lemon yellow*; *Strontium yellow*; *Ultramarine yellow*
Bennett (1963); Birren (1965) 67–68; Bouvier (1910) 48, 63; *Colour Index* (1971) 77839; Eibner (1909); Gentele (1860); Gettens & Stout (1966) 159–160; Kühn & Curran (1986); Moreau-Vauthier (1923); Winsor & Newton (1910)

STRONTIUM GROUP

Variable
Group term

There are a small number of both natural and synthetic compounds comprising the strontium group. Of these, strontium chromate(VI) has the widest use as a pigment and is commonly known as strontium yellow (*q.v.*). The compounds included here are:

Carbonates: strontianite ($SrCO_3$).
Chromates: strontium chromate(VI) ($SrCrO_4$).
Phosphates: goyazite ($SrAl_3(PO_4)_2(OH)_5.H_2O$).
Sulfates: celestite and strontium sulfate ($SrSO_4$).

Strontium is also found as a substituting element in apatite group minerals and gypsum (*qq.v.*), and has been identified as a trace element in certain green earth samples (see green earth, burnt; *q.v.*). Fiedler and Bayard (1986) have also reported the presence of strontium in cadmium sulfide group (*q.v.*) pigments and the use of strontium in the precipitation of pigments belonging to the azo group (*q.v.*) has also been noted. Finally, strontium uranium oxide (strontium uranate) has also been proposed as a pigment.

Apatite group; Azo pigments group; Cadmium sulfides and selenides group; Chromates group; Uranium group; Celestite; Goyazite; Green earth, burnt; Gypsum; Strontianite; Strontium chromate(VI); Strontium sulfate; Strontium uranium oxide
Fiedler & Bayard (1986)

STRONTIUM SULFATE

White
Generic compound

Strontium sulfate, $SrSO_4$, apparently as its mineral analogue celestite, has found limited use as a pigment, apparently in the late nineteenth and early twentieth centuries (Zerr and Rübencamp, 1906; Heaton, 1928). For more information, see celestite.

Strontium group; Celestite; *Strontium white*
Heaton (1928) 105–106; Zerr & Rübencamp (1906/1908) 85

STRONTIUM URANIUM OXIDE

Yellow
Generic compound

See: uranium group.

STRONTIUM WHITE

White
Synonym, variant or common name

Heaton (1928) lists strontian white as a then-current term for a pigment composed of strontium sulfate (*q.v.*).

Strontium sulfate
Heaton (1928) 384

STRONTIUM YELLOW

Yellow
Synonym, variant or common name

Strontium yellow corresponds with strontium chromate(VI), and also known as lemon yellow (*qq.v.*) as reported by Gettens and

Stout (1966) and Harley (1982), other term variants for Strontium yellow include Strontaine yellow and Strontian yellow.

According to Bouvier (1910; cf. Kühn and Curran, 1986), a mixture of strontium yellow (or cadmium yellow) and chromium oxide was known as the pigment Behrendt green (*qq.v.*).

Cadmium yellow; Chromium oxide; Strontium chromate(VI); *Behrendt green*; *Lemon yellow*
Bouvier (1910) 63; Gettens & Stout (1966) 97; Harley (1982) 103; Kühn & Curran (1986)

SUBLIMED WHITE LEAD

White
Synonym, variant or common name

Toch (1916) describes sublimed white lead as 'an amorphous white pigment possessing excellent covering and hiding power … very uniform and fine in grain'. He goes on to explain how it was prepared as a direct furnace product derived from the sublimation of the lead sulfide mineral galena (*q.v.*). At the time he was writing in the US this pigment was, apparently, of major economic significance with 65% of manufacturers using it and some 8000 tons being consumed. Toch also gives an analysis indicating the pigment contained 75% lead sulfate, 20% lead oxide and 5% zinc oxide, though he also observes that 'it is held by many that the lead oxid (*sic*) of sublimed lead is really an oxy-sulphate … a basic sulphate of lead'. Heaton (1928), writing a few years later in the UK, merely states that 'sublimed white lead' was a name commonly applied to basic lead sulfate (lead oxide sulfate).
See: lead sulfates group.

Lead sulfates group; Galena; Lead oxide sulfate; Zinc oxide; *Lead white*
Heaton (1928) 81–83; Toch (1916) 35–37

SUCKER FISH ROE

Yellow
Synonym, variant or common name

According to Turner (1894), a yellow paint used on Naskapi artefacts was derived from the eggs of sucker fish. The development of such a colour from sucker fish roe has been demonstrated by Burnham (1992) and tentatively identified as a yellow proteinaceous colour on Naskapi artefacts by Moffatt *et al.* (1997).

Burnham (1992); Moffatt *et al.* (1997); Turner (1894)

SUGAR HOUSE BLACK

Black
Synonym, variant or common name

Toch (1916) mentions sugar house black briefly with other carbon-based blacks, describing it as a by-product of sugar mills; he implies that it was a low-grade material.

Carbon-based blacks group
Toch (1916) 97

SULFITE WHITE

White
Synonym, variant or common name

A lead sulfite hydroxide, $3PbSO_3.Pb(OH)_2$, is listed by Brochwicz *et al.* (1993).
See: lead sulfates group.

Lead sulfates group
Brochwicz *et al.* (1993)

SULFOPONE

White
Synonym, variant or common name

According to Zerr and Rübencamp (1906), Steinau patented a product similar to lithopone (*q.v.*), made from calcium sulfide and zinc sulfate. It was said to be softer and smoother than lithopone.

Lithopone
Zerr & Rübencamp (1906/1908) 124

SULFUR

Yellow
Generic compound

Elemental sulfur may occur in a number of crystalline and non-crystalline forms, both natural and synthetic in origin. Of these the most important are the amorphous and orthorhombic (S_8) forms. Sulfur is commonly associated with volcanic deposits, particularly during the late stages of vulcanicity around hot springs and pools where it is associated with travertine (*q.v.*; a form of limestone), siliceous sinter and borates. It is also found in association with gypsum in sedimentary rocks and particularly with black shales where it is a product of an anaerobic environment and found associated with pyrite (*qq.v.*). It is also found associated with aerially weathered pyrite (and other similar sulfides) where the rate of oxidation is increased due to the presence of thiobacteria. In these cases it is associated with a range of iron sulfate compounds as well as sulfuric acid.

Orthorhombic sulfur (S_8) has been identified among ancient Persian pigments from Persepolis and Pasargade by Stodulski *et al.* (1984). There was also historically some speculation that sulfur was responsible for the colour of Naples yellow (*q.v.*; Pomet, 1694).

Gypsum; Pyrite; Travertine; *Naples yellow*
Pomet (1694) 93; Stodulski *et al.* (1984)

SULFUR GROUP

Yellow
Group term

Elemental sulfur (*q.v.*) is known to occur as a solid yellow material with two principal forms likely to be encountered in a pigment context – the amorphous type and the orthorhombic type (S_8). Sulfur is also used as a starting product in the synthesis of many pigments such as mosaic gold and Paris blue (*qq.v.*). More typically sulfur occurs within pigments as the sulfate or sulfide, of which there are many examples. The reader is referred to the following subgroups and links therein:

Sulfates: aluminium, barium, calcium, chromium, copper, iron, lead and mercury.
Sulfides: antimony, arsenic, cadmium (sulfides and selenides), copper, iron, lead, mercury, tin and zinc.

Sulfur is also present in natural materials aerinite, asphalt and shungite (*qq.v.*), and as the radical species S^{2-} and S^{3-} it is responsible for the blue colour of lazurite (*q.v.*; Clark and Franks, 1975).

Aluminium sulfates group; Antimony sulfides group; Arsenic sulfides group; Barium sulfates group; Cadmium sulfides and selenides group; Calcium sulfates group; Chromium sulfates group; Copper sulfates group; Copper sulfides group; Iron sulfates group; Iron sulfides group; Lead sulfates group; Lead sulfides group; Mercury sulfates group; Mercury sulfides group; Tin sulfides group; Zinc

sulfides group; Aerinite; Asphalt; Lazurite; Shungite; Sulfur; *Mosaic gold*; *Paris blue*
Clark & Franks (1975)

SULPHOINDIGOTIC ACID
Blue
Synonym, variant or common name

See: indigo carmine.

SULPHURET OF CADMIUM
Yellow
Synonym, variant or common name

Stromeyer, shortly after his discovery of the element cadmium, suggested the use of cadmium sulfide (*q.v.*) under the name sulphuret of cadmium as an artists' pigment (Stromeyer, 1819; cf. Fiedler and Bayard, 1986).

Cadmium sulfide
Fiedler & Bayard (1986); Stromeyer (1819)

SUN YELLOW
Yellow
Synonym, variant or common name

Sun yellow was a synonym for a nickel titanium yellow pigment (de Keijzer, 1989a).

Nickel titanium yellow
Keijzer (1989a)

SUNFLOWER BLUE
Blue
Synonym, variant or common name

A reference to sunflower blue is contained in de Massoul's *Treatise on the Art of Painting* (1797; cf. Harley, 1982); it is essentially synonymous with turnsole (blue; *q.v.*).

Turnsole
Harley (1982) 62; Massoul (1797)

SUSANNITE
White
Generic compound

See: lead sulfates group.

SWEDISH BLACK
Black
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77268/Pigment Black 8), this is a carbon char made from birch bark (*Betula* spp.).

Carbon-based blacks group; Carbon-based blacks group: Chars sub-group
Colour Index (1971) 77268

SWEDISH GREEN
Green
Synonym, variant or common name

Fiedler and Bayard (1997) associate Swedish green with Scheele's green (copper arsenite). The Swedish chemist Carl Wilhelm Scheele both discovered and produced the green pigment which bears his name and as the pigment was first manufactured in Sweden the colour was also associated with that country. Mayer (1991) on the other hand links Swedish green to the term cobalt green (*q.v.*).
See: Scheele's green.

Cobalt green; *Scheele's green*
Fiedler & Bayard (1997); Mayer (1991) 58

SWISS GREEN
Green
Synonym, variant or common name

This is listed by Fiedler and Bayard (1997) as one of the names applied to either Scheele's and/or emerald green (*qq.v.*). However, it is also described by Boltz (1549) as being made from sap green tempered with *weinstein* water (calcium hydrogen tartarate).

Emerald green; *Sap green*; *Scheele's green*
Boltz von Ruffach (1549/Benziger, 1913) 82; Fiedler & Bayard (1997)

SYNTHETIC ULTRAMARINE
Blue
Synonym, variant or common name

See: ultramarine.

SYRICUM
Red-Orange
Synonym, variant or common name

Pliny (77 AD) names two pigments which were blends of other reds, namely *sandyx* which is a mixture of white lead (*cerussa*) and red ochre (*qq.v.*) which was then roasted and used for painting flesh tones, and *Syricum* ('red undercoat') which was a mixture of sandyx and red ochre. This latter was used primarily as a preparation for the higher quality sinoper or minium (*qq.v.*; FitzHugh, 1986).

Lead(II,IV) oxide; Lead white; Minium; *Red ochre*; *Cerussa*; *Sandyx*; *Sinoper*
FitzHugh (1986); Pliny (1st cent AD/Rackham, 1952) XXXV.xxiv

T

Talc

White

Generic compound

Talc is a magnesium silicate hydroxide sheet silicate mineral with ideal composition $Mg_6Si_8O_{20}(OH)_4$, although minor Fe, Mn, Ca and Al may be present. It is a very soft mineral with a greasy feel and occurs with massive form, often with a foliaceous structure, or as compact white or pale green granular masses. Its similarity to mica group (*q.v.*) minerals means that it is often included with them; several polytypes of talc have been reported (for example, one-layered triclinic, 1Tc; two-layered monoclinic, 2M; and two-layered orthorhombic, 2O) which are attributable to small changes in orientation of the constituent SiO_4 tetrahedra (Akizuki and Zussman, 1978; Gruner, 1934). Talc forms most commonly from the low-grade metamorphism of siliceous dolomites, often in association with calcite, anthophyllite, tremolite and chlorite group minerals (*qq.v.*); it also forms from the hydrothermal alteration of ultrabasic rocks where it is found with serpentine and olivine group minerals, and magnetite (*qq.v.*). Patton (1973e) also lists a number of minerals commonly associated with talc in nature such as serpentine, anthophyllite, diopside, tremolite, chlorite, calcite, magnesite, dolomite and quartz (*qq.v.*). Talc is a relatively common mineral worldwide and is found at localities such as Gran Paradiso (Italy), Trimouns (France), Tyrol (Austria), Malangen (Norway), Bavaria (Germany), Irkutsk (Russia), San Andreas (California), Rowe (Massachusetts, USA) and Waratah (Tasmania). Massive and dense varieties of talc are known as steatite or soapstone (*qq.v.*) and are often used as ornamental stone for sculpture and jewellery.

The English word 'talc' (1582) derives from mediaeval French *talc* and probably from Spanish *talco* and mediaeval Latin *talcum*; these in turn from the Arabic *talq* and the Persian *talk*. The English *talcum* (1558) derives directly from the mediaeval Latin *talcum*, a word used for any of various shiny minerals – 'A name applied by the Arabs and mediæval writers to various transparent, translucent, or shining minerals, as talc proper, mica, selenite, etc.' (*OED*, 2002). Other terms used for this mineral include agalite and mussolinite, while talc is commonly sold under the name French chalk in Britain and the US.

Hameau *et al.* (2001) identified talc powder as a minor pigment with hematite, ochre, burnt bone, clay group minerals and bauxite (*qq.v.*) in samples from post-glacial paintings in southern France. It has also been noted as a (probably) incidental component of pigments at Qutan Temple, Qinghai, China (Wang *et al.*, 1993a,b). Tingry (1804) mentions the use of talc as a base for carmine (*q.v.*) for cosmetic rouge; this mixture was termed Briançon chalk. However, despite this limited indication of the occurrence of talc as a paint component historically, the principal usage is of relatively modern date. There are earlier references to the use of 'talc' in Dossie's *Handmaid to the Arts* (1764), though this may in fact have been, *sensu lato*, a form of calcium sulfate (*q.v.*) instead of the magnesium silicate mineral now meant *sensu stricto* (Bristow, 1996a); Dossie does, however, write of the adulteration of lead white with powdered talc, making future analytical identifications of interest. According to Patton, there has also been ancient use of the compacted forms of talc known as soapstone or steatite. However, modern use in paints may be traced back to talc mining that began in the US in the latter part of the nineteenth century with the first commercial talc mine being opened in New York in 1878. This location has since developed into the most productive source of talc in the world. Twentieth century use of this material cannot be underestimated, Patton noting 'Talc is probably used in a wider variety of organic coatings than any other single [paint] extender' (Patton, 1973e).

Magnesium group; Magnesium silicates group; Mica group; Sheet silicates group; Silicates group; Anthophyllite; Calcite; Chlorite; Diopside; Dolomite; Magnesite; Pyrophyllite; Quartz; Steatite; Tremolite; *Asbestine*; *Soapstone*

Akizuki & Zussman (1978); Bristow (1996a); Dossie (1764) 133; Gruner (1934); Hameau *et al.* (2001); *OED* (2002) 'Talc'; Patton (1973e); Tingry (1804) 333; Wang *et al.* (1993a); Wang *et al.* (1993b)

Tannin black

Black

Synonym, variant or common name

According to Terry (1893) 'Tannin black is proposed to be made by exhausting the tannin from refuse leather and tanning agents, and adding alum and sulphate of iron. The colour is blue-black, weak, and unstable.'

Tannins group

Terry (1893) 26

Tannins group

Black-Brown

Group term

Tannins are one of the many types of secondary compounds found in plants. They are characterised by:

1. Oligomeric compounds with multiple structure units with free phenolic groups.
2. A molecular weight ranging from 500 to >20,000.
3. Solublity in water (with the exception of some high molecular weight structures).
4. An ability to bind proteins and form insoluble or soluble tannin-protein complexes.

Tannins are usually subdivided into two groups, *hydrolysable tannins* (HTs) and *proanthocyanidins* (PAs; sometimes called condensed tannins). This latter group are now classed under the Flavonoids.

HTs are molecules with a polyol (generally D-glucose) as a central core. The hydroxyl groups of these carbohydrates are partially or totally esterified with phenolic groups like gallic acid ('gallotannins') or ellagic acid ('ellagitannins'). Two additional classes of hydrolysable tannins are sometimes also defined: taragallotannins (gallic acid and quinic acid as the core) and caffetannins (caffeic acid and quinic acid as the core). In gallotannins the phenolic groups that esterify with the core are sometimes constituted by dimers or higher oligomers of gallic acid (where each single monomer is called galloyl). Each HT molecule is usually composed of a core of D-glucose and 6 to 9 galloyl groups. In nature, there is an abundance of mono- and di-galloyl esters of glucose (molecular weight about 900). However, they are not considered to be tannin; rather, at least 3 hydroxyl groups of the glucose must be esterified to exhibit a sufficiently strong binding capacity to be classified as a tannin. In ellagitannins the phenolic groups consist of hexahydroxydiphenic acid, which spontaneously dehydrates to the lactone form, ellagic acid. HTs are hydrolysed by mild acids, mild bases, hot water and enzymes to yield carbohydrate and phenolic acids. Under the same conditions, proanthocyanidins (PAs) do not hydrolyse.

PAs are more widely distributed than HTs. They are oligomers or polymers of flavonoid units (that is, flavan-3-ol) linked by carbon—carbon bonds not susceptible to cleavage by hydrolysis. PAs are more often called *condensed tannins* due to their condensed chemical structure. (However, HTs also undergo condensation reaction. The term condensed tannins is therefore potentially confusing.) The term proanthocyanidins is derived from the acid catalysed oxidation reaction that produces red anthocyanidins upon heating PAs in acidic alcohol solutions. The most common anthocyanidins produced are cyanidin (flavan-3-ol, from procyanidin) and delphinidin (from prodelphinidin). PAs may contain from 2 to 50 or greater flavonoid units; PA polymers have complex structures because the flavonoid units can differ for some substituents and because of the variable sites for interflavan bonds. Anthocyanidin pigments are responsible for the wide array of pink, scarlet, red, mauve, violet and blue colours in flowers, leaves, fruits, fruit juices and wines. Depending on their chemical structure and degree of polymerisation, PAs may or may not be soluble in aqueous organic solvents (Hemingway and Karchesy, 1989; Haslam, 1989).

Hydrolysable tannins group; Proanthocyanidins group
Haslam (1989); Hemingway & Karchesy (1989)

TENORITE

Black
Generic compound

Tenorite is a black copper(II) oxide mineral with composition CuO. Named after the Italian botanist M. Tenor (1781–1861), tenorite occurs most commonly as a dull, earthy black powder or as botryoidal concretions; it may also occur as scales or flakes, or in massive form. Tenorite is a secondary mineral and forms in the oxidising zone surrounding copper deposits (such as in Cornwall, England; Bisbee, Arizona, USA; Baha, Mexico; Burra-Burra mine, South Australia; Salzburg and Tyrol, Austria; Harz and Saxony, Germany), often in association with chrysocolla (*q.v.*) and other secondary copper minerals. It is also known as black copper oxide, melaconite and melanochalcite, and is relatively rare in comparison to the copper(I) oxide mineral, cuprite (*q.v.*).

According to Scott (2002), the earliest example for the use of tenorite as a pigment was in black eye paints from Medun, Egypt, dated from the third dynasty (c. 2649–2575 BC). Partington (1935), referring to an early work by Petrie in 1913, reported that these eye paints were made from the roasting of malachite to form tenorite, though they were more commonly lead- or manganese-based and made from the roasting of galena or pyrolusite. Scott comments that although this was the earliest reference to tenorite as a pigment, its use was probably always restricted due to the greater importance of malachite as a copper ore. Gutscher *et al.* (1989) observed from their analysis of wall paintings and further experiments that tenorite may form as the alteration product of azurite in an alkaline environment; hence, caution should be exercised when identifying this compound in order to determine whether tenorite is the original pigment or a degradation product. Tenorite may be found in Egyptian blue samples when excess copper has been used in the starting materials (Jaksch *et al.*, 1983).

The *Colour Index* (1971) lists copper oxide as CI 77403/ Pigment Black 15, though principally referring to synthetic analogues and chromatically related copper chromates.

Copper oxides and hydroxides group; Copper(II) oxide
Colour Index (1971) 77403; Gutscher *et al.* (1989); Jaksch *et al.* (1983); Partington (1935); Scott (1997); Scott (2002) 95

TERRA ALBA

White
Synonym, variants or common name

Terra alba commonly applied to a finely pulverised and pure form of gypsum, although some sources also state that it can refer to kaolin (*qq.v.*), the term deriving from the Latin *terra*, meaning 'earth' and *alba*, 'white'. Heaton (1928), for example, gives this as a term for a pigment compounded from gypsum, linking it also with the term mineral white, a synthetically produced calcium sulfate (*qq.v.*); it is, however, unclear whether he is actually distinguishing natural and synthetic pigments here.

Calcium group; Calcium sulfates group; Gypsum; Kaolin; *Mineral white*
Heaton (1928) 384

TERRA COTTA

Red
Synonym, variant or common name

A compound material designed to imitate the colour of terracotta clay. According to Mayer (1991) *terra cotta* is a mixture of burnt umber, a 'natural red iron oxide' and chalk in varying proportions; further, baryte, zinc oxide or lithopone can replace the chalk (*qq.v.*).

Baryte; Chalk; Zinc oxide; *Burnt umber*; *Lithopone*
Mayer (1991) 58

TERRA DI BOCCALI

White
Synonym, variant or common name

See: *terra di Cava*.

TERRA DI CAVA

White
Synonym, variant or common name

According to Merrifield (1849), *terra di Cava*, *terra di Boccali*, or *terretta*, was a white earth (*q.v.*) used by potters. It is also mentioned in the so-called *Volpato* MS and in Baldinucci's *Vocabulario Toscano dell'arte del disegno* (1681), and is said to have been employed in the priming for oil paintings.

White earth
Baldinucci (1681)167; Merrifield (1849) clii

TERRA DI COLONIA

Brown
Synonym, variant or common name

Terra di colonia was a term associated with Vandyke brown (*q.v.*; Feller and Johnston-Feller, 1997).

Humic earth; *Vandyke brown*
Feller & Johnston-Feller (1997)

TERRA DI SIENA

Brown
Synonym, variant or common name

Synonymous with Sienna (*q.v.*). According to Harley, sienna was mentioned in English documentary sources from the mid-eighteenth century under the name *Terra di Siena*, unburnt or burnt; it was not until the nineteenth century that the anglicised and abbreviated forms of 'raw sienna' and 'burnt sienna' (*q.v.*) became common (Harley, 1982).

Sienna; *Burnt sienna*
Harley (1982) 90–91

TERRA DI SIENNA

Red-Brown
Synonym, variant or common name

See: sienna.

TERRA DI VERONA

Green
Synonym, variant or common name

Terra di Verona ('Verona earth') was a variety of green earth (*qq.v.*) from the noted source near Verona (Grissom, 1986).

Green earth; *Verona earth*
Grissom (1986)

TERRA MERITA

Yellow
Synonym, variant or common name

This term is the Latin name for turmeric (*q.v.*), *Curcuma longa L.* Tingry describes *terra merita* as 'the root of a plant of the family of the *canna Indica*', adding that it was much used in dyeing as well as varnishing 'only under the form of a tincture' (Tingry, 1804). According to Osborn '*Terra-merita* is a vegitable color, produced by the decoction of an Indian root (*curcuma longa*)' (Osborn, 1845). It is clearly based on extraction of turmeric.

Turmeric
Osborn (1845) 52; Tingry (1804) 369

TERRA OLEANA

Yellow
Synonym, variant or common name

See: bixa.

TERRA OMBRE

Brown
Synonym, variant or common name

Synonym for 'raw' umber (*q.v.*; Mayer, 1991).

Umber
Mayer (1991) 58

TERRA ROSA

Red
Synonym, variant or common name

According to Church (1901) *terra rosa* was a synonym for red ochre (*q.v.*); he states that 'The terra rosa of Italy owes its pinkish red hue to ferric oxide, but it is probably often, if not always, an artificial product.' Mayer (1991) associates terra rosa exclusively with the term Venetian red (*q.v.*).

Iron oxides and hydroxides group; *Red ochre*; *Venetian red*
Church (1901) 183; Mayer (1991) 58

TERRA SIGILLATA

Variable
Synonym, variant or common name

As an alternative to herbal remedies, naturally occurring minerals were used in the treatment of internal disorders. Clay from certain sources, traded in the form of tablets stamped to indicate their origins, were known as *terra sigillata* – literally, 'sealed earth'. Some examples of specific types are those from Lemnos, *terra lemnia*, from Malta, *terra melitensis*, and from Esztergom in Hungary, which was known as *terra strigonensis*. Colours of these earths range from white through yellow to red.
See: Lemnian earth.

Lemnian earth

TERRE DE LINNA

Yellow-Brown
Synonym, variant or common name

Fishwick (1795–1816) mentions *Terre de linna*; it appears to be an earth pigment of specific source although no further details are given.

Earth pigments group
Fishwick (1795–1816) 41

TERRE VERTE

Green
Synonym, variant or common name

See: green earth.

TERRENE WHITE

White
Synonym, variant or common name

Field (1835) classed various pigments such as calcium carbonate, calcium sulfate, white clay, (egg)shell white and bone white (*qq.v.*) as 'Terrene' whites. Salter (1869) elaborates on this, stating that these are available 'under equivocal names, among which are Morat or Modan white, Spanish white, Troys or Troy white, Rouen white, China white, and Satin white'.

Calcium carbonates group; Bone, calcined; Calcium sulfates group; Eggshell; *Shell white*
Field (1835) 71; Salter (1869) 79–80

TERRETTA
White
Synonym, variant or common name

See: terra di Cava.

TESSIE DU MOTAY'S BLUE
Blue
Synonym, variant or common name

Bersch (1901) describes Tessie du Motay's blue as prepared from 10 parts sodium tungstate, 8 parts 'tin crystals', 5 parts 'yellow prussiate' and 1 part of iron(III) chloride; these are dissolved separately and mixed. The precipitate is washed and exposed to light in thin layers, with the blue colour developing over a period of a few days. According to the discoverer, the pigment consists of a compound of tungsten oxide with 'a double cyanide of iron and tin'.

Hexacyanoferrate group; Tin group; Tungsten group
Bersch (1901) 239

THALLIUM CHROMATE
Red-Orange-Yellow
Generic compound

Salter (1869) describes the synthesis of thallium orange, red and yellow (*qq.v.*) pigments, in which starting materials of potassium dichromate and thallium oxide or metallic thallium and chromic acid are used; in the former combination, the colour of the yellow-orange precipitate can be varied to redder shades by the addition of nitric acid. The pigments produced by these synthesis methods are likely to be thallium chromates, although the exact stoichiometries are not known. Several thallium chromate compounds exist in the chemical literature, such as $Tl_2(CrO_4)_3$ and Tl_2CrO_4 (Carter and Margulis, 1972; Riou *et al.*, 1986). Although Salter states that 'the present scarcity of the metal renders the colours produced from it mere scientific curosities', thallium was still being considered as a basis for pigments by Bersch (1901), some 30 years later.

Chromates group; Thallium group; *Thallium orange*; *Thallium red*; *Thallium yellow*
Bersch (1901); Carter & Margulis (1972); Riou *et al.* (1986); Salter (1869) 122, 177, 259–260

THALLIUM GROUP
Variable
Group term

Bersch (1901) discusses thallium pigments, but dismisses their use on cost grounds, implying that they were not employed. However, Salter (1869) does list thallium chromates under thallium orange, thallium yellow and thallium red. Those compounds of interest are $Tl_2[CrO_4]_3$ and Tl_2CrO_4.

Thallium chromate; *Thallium orange*; *Thallium red*; *Thallium yellow*
Bersch (1901); Salter (1869) 122, 177, 259–260

THALLIUM ORANGE
Orange
Synonym, variant or common name

Salter (1869) states that 'Thallium orange is produced when bichromate of potash is added to a neutral salt of the protoxide of thallium, as an orange-yellow precipitate.' It was clearly a speculative and unproven pigment as far as the author was concerned; the composition is likely to have been a thallium chromate (*q.v.*).

Thallium chromate
Salter (1869) 259–260

THALLIUM RED
Red-Orange
Synonym, variant or common name

Salter (1869) states that 'The orange-yellow precipitate formed by mixing a neutral salt of protoxide of thallium with bichromate of potash, is converted by nitric acid into an orange-red … If the colour be boiled in a large excess of moderately strong nitric acid it is dissolved, yielding magnificent cinnabar red crystals on the solution cooling.' The pigment would thus seem to be thallium chromate (*q.v.*).

Thallium chromate
Salter (1869) 177

THALLIUM YELLOW
Yellow
Synonym, variant or common name

According to Salter (1869) 'The new metal thallium yields in combination with chromic acid two yellow colours, a pale and an orange.' However, he also adds that 'The present scarcity of the metal renders the colours produced from it mere scientific curosities.'

Thallium chromate
Salter (1869) 122

THALO RED ROSE
Red
Synonym, variant or common name

Mayer (1991) lists this as an American proprietary name for a quinacridone red pigment. For quinacridones, see: polycyclic pigments group: quinacridone sub-group.

Polycyclic pigments group: Quinacridone sub-group
Mayer (1991) 58

THÉNARD'S BLUE
Blue
Synonym, variant or common name

At the beginning of the nineteenth century, Thénard showed that by calcining a mixture of aluminium hydrate and acetous cobalt phosphate or acetous cobalt arsenate he obtained more easily a cobalt blue (*q.v.*) pigment of deeper colour than by using cobalt carbonate or cobalt nitrate. His method was to precipitate solutions of cobalt nitrate with the ordinary primary acetous sodium phosphate, wash the purple $CO_3(PO_4)_2$ with water and then mix it with aluminium hydrate (eight times its weight) which was precipitated with ammonia. Afterwards this mixture was brushed onto even boards for the drying process. When it became solid and brittle it would be ground and calcined in a closed clay container for half an hour. Another method is described, which achieved a darker blue, through using sodium arsenate instead of sodium phosphate (Thénard (1803–4)). These formulations are in essence Thénard's blue, although there appears to be a history of using the term simply to mean a cobalt blue. The term Thénard's blue, for example, was still current when Heaton drew up a list of pigment synonyms in 1928, simply listing it as 'cobalt blue'.

Cobalt group; Cobalt aluminium oxide; *Cobalt blue*
Heaton (1928) 384; Thénard (1803–4)

THEODOTEION

Green
Synonym, variant or common name

Described by the classical author Vitruvius (first century BC), *Theodoteion* was a form of the green chalk (green earth, *q.v.*) which he calls *Creta viridis*. He adds that the best form of this came from near Smyrna (western Anatolia) and was called Theodoteion after the man who owned the land on which it was found.

Green earth; *Green chalk*
Vitruvius (1st cent BC/Grainger, 1934) VII.vii.4

THERMAL BLACK

Black
Synonym, variant or common name

Several modern processes for the production of carbon-based blacks (flame carbons; *q.v.*) are based on the thermal decomposition of lower gaseous hydrocarbons in the absence of air. Developed in the 1930s, the thermal black process is still used for the production of pigments. In distinction from other carbon black processes, the method is discontinuous; the reaction furnace is heated to about 1400°C with a mixture of natural gas and air, then the air is switched off. The gas is decomposed, an andothermic process which cools the furnace. This cycle is then repeated. Fine thermal blacks of particle size 120–200 nm and medium thermal blacks of 300–500 nm are typically produced (Buxbaum, 1998).

Carbon-based blacks group: Flame carbons sub-group
Buxbaum (1998) 158–159

THERMATOMIC BLACK

Black
Synonym, variant or common name

Thermatomic black is a variety of gas black (*q.v.*) described by Heaton (1928) as 'of recent introduction', formed by heating gases such as methane and butane at high temperature in the absence of air.

Carbon-based blacks group; *Gas black*
Heaton (1928) 175

THESSIÉ BLUE

Blue
Synonym, variant or common name

See: tungsten oxides and hydroxides group.

THIOINDIGOID RED VIOLET

Red
Synonym, variant or common name

See: polycyclic pigments group: thioindigoid sub-group.

THWAITES YELLOW

Yellow
Synonym, variant or common name

A synonym for cadmium chromate (*q.v.*), this pigment was enthusiastically described in Salter (1869): 'Under this name [Thwaites' Yellow] chromate of cadmium was introduced some few years back. If well prepared it is a fine soft powder of a very vivid light yellow colour … a good sample of cadmium chrome is marked by exceeding beauty, unsurpassed for clearness and purity by any other yellow.' However, in Carlyle's survey of nineteenth century British literature she found little other mention of it (Carlyle, 2001).

Cadmium group; Chromates group; Cadmium chromate
Carlyle (2001) 260, 525; Salter (1869) 122

TIERRA SANTA

Yellow
Synonym, variant or common name

A Spanish term, *tierra santa* is seemingly equivalent to the Italian *giallo santo* (*q.v.*), which Merrifield defines as an organic yellow (that is, a 'lake' pigment; Merrifield, 1849). It is also probably related to the term ancorca (*q.v.*; Veliz, 1986).

Ancorca; *Giallo santo*
Merrifield (1849) clxiv; Veliz (1986) 26, n.4

TIFF

White
Synonym, variant or common name

Synonym for baryte (*q.v.*; Feller, 1986).

Baryte
Feller (1986)

TIMONOX

White
Synonym, variant or common name

Timonox is the name used by the British firm Cookson Lead and Antimony Co. for an antimony oxide-based white pigment which they developed and introduced commercially around 1920 (see, for example, Heaton, 1928).

Antimony oxides and hydroxides group; *Antimony white*
Heaton (1928) 99

TIN CHROMATE

Purple
Generic compound

Two methods of preparation for 'basic tin chromate' are described by Riffault *et al.* (1874). The original method according to Malaguti (reputedly the discoverer) uses 100 parts stannic (tin(IV)) oxide to 2 parts chromium oxide; this is then calcined at dull-red heat. The second method follows an aqueous preparation process for tin chloride which is then calcined with 'nitrate of potassa'. Salter (1869) gives a recipe for tin violet (*q.v.*) involving heating to redness 'chromate of stannic oxide'. The tin chromate commonly encountered in the chemical literature is tin(IV) chromate with composition given as $Sn(CrO_4)_2$ (MacIntyre, 1992).

Chromates group; Tin group; *Tin violet*
MacIntyre (1992) 3089; Riffault *et al.* (1874) 395; Salter (1869) 308

TIN GROUP

Variable
Group term

Both metallic tin and tin compounds have been used as pigments. Tin has been used in the manufacture of bronze colours and mosaic silver (*qq.v.*), while powdered tin has been used to imitate gold with the aid of a yellow lacquer applied over the surface (for example, Thompson, 1956). The following tin compounds are also known in a pigment context:

Oxides and Hydroxides: cassiterite (SnO_2); chromium tin oxide; cobalt tin oxide ($CoSnO_3$); copper tin hydroxide ($Cu[Sn(OH)_6]$);

copper(II) tin oxide; copper tin oxide hydrate ($CuSnO_3.nH_2O$); lead antimony tin oxide ($Pb(Sb_x,Sn_{1-x})O_3$); lead tin oxide (Pb_2SnO_4); lead silicon tin oxide ($Pb(Si,Sn)O_3$ and $PbSn_{1-x}Si_xO_3$ where x is ~¼); romarchite (SnO); tin(IV) oxide (SnO_2).
Chromates: tin(IV) chromate ($Sn(CrO_4)_2$).
Tungstates: tin tungstate ($SnWO_4$) – see tungsten group.
Sulfides: berndtite (SnS_2); herzenbergite (SnS); ottemannite (β-Sn_2S_3); tin(II) sulfide (SnS); tin(II,IV) sulfide (β-Sn_2S_3); tin(IV) sulfide (SnS_2).

Of these, the lead tin oxides are of principal importance in lead tin yellow (*q.v.*) pigments. Although Pb_3SnO_4, Pb_2SnO_3, $PbSnO_2$ and $PbSn_6O_7$ compounds have also been described in the literature (Fournier and Kohlmuller, 1970), they have not been mentioned in a pigment context; their synthesis conditions are radically different from those used in the preparation of lead tin yellow pigments based on Pb_2SnO_4 (lead tin yellow, type I). Tin(IV) oxide, commonly used in tin white (*q.v.*) and in the preparation of lead tin yellow, is reported to have three polymorphs – tetragonal, hexagonal and orthorhombic (Winchell, 1931). The most stable of these is the tetragonal form, which occurs as the mineral cassiterite and it is this structure type which appears to occur in pigments. Of the tin sulfide compounds, the tin(IV) sulfide (berndtite-type) is of greatest importance as the pigment mosaic gold (*q.v.*), although tin sulfides may also be found in cadmium sulfide pigments.

Tin may also occur in Egyptian blue, introduced with copper from bronze to the precursor materials.

Cadmium sulfides and selenides group; Tin sulfides group; Tungsten group; Berndtite; Cassiterite; Chromium tin oxide; Cobalt tin oxide; Copper tin oxide; Herzenbergite; Lead antimony tin oxide; Lead tin oxide; Lead tin silicon oxide; Ottemannite; Romarchite; Tin chromate; Tin(IV) oxide; Tin(IV) sulfide; *Bronze colours*; *Egyptian blue*; *Lead tin yellow*; *Mosaic gold*; *Mosaic silver*; *Tin white*
Fournier & Kohlmuller (1970); Thompson (1956); Winchell (1931) 191

TIN PINK

Red
Synonym, variant or common name

According to Salter (1869), this pigment was prepared by 'igniting strongly for some hours a mixture of stannic oxide, chalk, chromate of potash and a little silica and alumina, a dingy red mass is obtained, which acquires a beautiful rose-red colour on being washed with water containing hydrochloric acid'. Tin pink is probably synonymous with 'mineral lake' and 'potter's pink' (*qq.v.*; Mayer, 1991). Salter appears to have considered it superfluous.

Mineral lake; *Potter's pink*
Mayer (1991) 54; Salter (1869) 177

TIN SULFIDES GROUP

Variable
Group term

There are a number of tin sulfide compounds, notably the minerals berndtite (tin(IV) sulfide, SnS_2), herzenbergite (tin(II) sulfide, SnS), ottemannite (tin(II,IV) sulfide, β-Sn_2S_3; *qq.v.*) and their synthetic analogues. From analyses of material from paintings, the tin sulfide pigment known as 'mosaic gold' appears to take the berndtite structural form (Smith *et al.*, 1981; Speleers, 1999).

Tin(II) sulfide is a grey-black cubic or monoclinic compound of formula SnS with a melting point of 882°C and a boiling point of 1230°C and can be made by heating tin and sulfur together. Above 265°C it slowly decomposes to tin(IV) sulphide and tin metal.

Tin(IV) sulfide (berndtite-type or mosaic gold) is a bronze or golden yellow hexagonal crystalline compound (SnS_2). It decomposes at 600°C and can be prepared by the reaction of hydrogen sulfide with a soluble tin(IV) salt or by the action of heat on thiostannic acid, H_2SnS_3.

For a fuller discussion of the issues concerning the use of tin sulfide in the contect of painting, see the entry for mosaic gold.

Tin group; Berndtite; Herzenbergite; Ottemannite; *Mosaic gold*
Smith *et al.* (1981); Speleers (1999)

TIN VIOLET

Purple
Synonym, variant or common name

Tin violet is listed by Salter (1869), who explains that 'By heating chromate of stannic oxide to bright redness, a dark violet mass is obtained.' The author considered it 'better adapted to enamel painting than to the palette'.

Tin chromate
Salter (1869) 308

TIN WHITE

White
Synonym, variant or common name

Much of the early history of the use of tin compounds as white pigments occurs in the context of glass and ceramic opacifiers. It may be traced from ninth century AD Iraq, through the Near East (tenth century) and via North Africa to Spain by the thirteenth century.

The earliest explicit example of a recipe for a paint pigment, called here *ceruse* (this term was imprecise, for a fuller discussion see the entry for ceruse), appears to be that quoted by Harley (1982) from an English MS of about 1500 AD (Clarke MS 1710); the process was identical to that used to prepare lead white (*q.v.*), but thin sheets of tin were substituted. On the assumption that the chemistry is broadly similar to that of lead in this context, we might anticipate the production of a tin carbonate or carbonate hydroxide; however, as Turgoose (1985) has shown, tin corrosion products tend to be tin(IV) species. Gettens (1964) notes that tin seldom survives in archaeological sites because of the transformation of tin to a mix of stannous and stannic oxide by direct intercrystalline oxidation (SnO and SnO_2) or to a loose powdery grey tin, commonly referred to as 'tin pest', by allotropic modification.

As mentioned by Harley (1982), in the seventeenth century, Van Dyck tried tin white in oil, reporting that it had insufficient body and was only suitable for manuscript illumination. She further reports that Mytens found that it blackened in sunlight and spoiled lead white, was useless in oil and distemper if exposed to air. Guyton de Morveau (1782) included tin white among the pigments he tested as substitutes for lead white; he concluded that it was unsuitable, tending to yellow or blue. Field (1835) considered that it resembled zinc white in many respects, but dried badly, with even less body and colour in oil. The term was still a current one for Heaton (1928), who lists the composition as 'oxide of tin' (that is, probably tin(IV) oxide, *q.v.*).

Tin white has been briefly reviewed by Darrah (1995), who also reports identifying the pigment in several sixteenth century Jain miniatures.

Tin(IV) oxide; *Ceruse*
Darrah (1995); Field (1835) 70; Gettens (1964); Guyton de Morveau (1782); Harley (1982) 172–173; Heaton (1928) 384; Turgoose (1985)

TIN(IV) OXIDE
White
Generic compound

Tin(IV) oxide is known in three crystal phases, the most stable being the tetragonal form, which occurs naturally as the mineral cassiterite (*q.v.*). According to Winchell (1931), hexagonal and orthorhombic phases of tin(IV) oxide have also been produced.

Normally used as a component for making certain pigments such as lead tin yellow and Cerulean blue (*qq.v.*), it may therefore be found as a free agent where an excess was employed. It was also used as a base for 'tin' lakes; Saunders and Kirby (1994) state that 'There is little evidence for the availability of any tin-containing cochineal lake before the very late eighteenth or early nineteenth century.' Otherwise, discussion of tin oxide is generally in the context of opacifiers for ceramic glazes.

Cassiterite; *Cerulean blue*; *Lead tin yellow*; *Stannic oxide*
Saunders & Kirby (1994); Winchell (1931) 191

TIN(IV) SULFIDE
Yellow
Generic compound

See: tin sulfides group and mosaic gold.

TIN-COPPER GREEN
Green
Synonym, variant or common name

See: copper tin oxide.

TITAN YELLOW
Yellow
Synonym, variant or common name

'Titan yellow' is a commercial name for a nickel titanium yellow pigment (de Keijzer, 1989a).

Nickel titanium yellow
Keijzer (1989a)

TITANIUM BARIUM WHITE
White
Synonym, variant or common name

Laver (1997) lists a number of commercial products available since the 1920s compounded of barium sulfate and titanium(IV) oxide. Heaton (1947; cf. Feller, 1986) describes early forms of titanium dioxide white formed on a base of synthetic barium sulfate ('blanc fixe').

Barium sulfate; *Titanium dioxide white*
Feller (1986); Heaton (1947) 91–96; Laver (1997)

TITANIUM BROWN
Brown
Synonym, variant or common name

Titanium brown is derived from the titanium ore ilmenite (de Keijzer, 1990); the brown color is attributable to the high iron content.

Ilmenite
Keijzer (1990)

TITANIUM DIOXIDE WHITE
White
Synonym, variant or common name

Titanium dioxide white is a collective term for various titanium dioxide pigments, notably the rutile and anatase forms of titanium(IV) oxide. However other white titanium-bearing compounds have been used as pigments (see: titanium white) as have various composite pigments based on titanium dioxides. Titanium dioxide white pigments in the common sense are the products of twentieth century technology and, while titanium is abundant in nature, the element was not known until the late eighteenth century. The mineral anatase (TiO_2) is not known to have been used in artists' materials, essentially because it is rare, but rutile, on the other hand, may have been and it is therefore important to distinguish it from synthetic analogues; references to titaniferous pigments in paints can be found in the patent literature of the nineteenth century. However, colours made with ground rutile are never the brilliant white of the synthetic pigment – the natural product tends to range from yellow through red-brown to almost black. It was also difficult to grind.

Although titanium oxides were produced in the laboratory in the period after the discovery of the element in the late eighteenth century, it was not until the twentieth century that its possibilities as a pigment were realised. To date, there appears to be no evidence of the use of this synthetic product in paintings until the time of the commercial development that subsequently took place. Before 1916, when these pigments were being produced in small experimental batches, there was a limited amount of field-testing by artists but this appears to be very rare and limited only to those in some way connected with the researchers. Once larger quantities became available after World War I, it was incorporated into ready-made paints; in Europe the first paint formulation using titanium dioxide was registered in 1919 in Norway. The paint industry remained sceptical into the 1920s of the claims made for these pigments and the general public seem to have been unaware of them. It is not surprising therefore that artists' colour makers were slow to incorporate titanium dioxide whites in their formulations. Even a company in Norway who introduced it to their commercial paints in 1919 did not add it to their line of artists' colours. Some supply of anatase occurred in France from the mid-1920s but it was not until the 1930s that artists' manuals indicate a degree of acceptance.

Commercial production of titanium dioxide whites is carried out under several methods, primarily by (1) hydrolysis of aqueous solutions (the 'sulfate process'); (2) vapour phase oxidation of titanium tetrahalides (the 'chloride process'); (3) precipitation from aqueous solutions of tetrahalides by addition of a base (Kampfer, 1973). It is the sulfate and chloride processes which are generally used commercially. The sulfate process uses the ore ilmentite (*q.v.*; iron titanium oxide, $FeTiO_3$) which is dissolved in sulfuric acid, whereby ferric iron and titanium sulfates form. Scrap iron is added and ferrous sulfates (copperas) is formed and removed. The titanium salts are hydrolysed in the presence of titania (TiO) and hydrated titanium dioxide forms. This is washed, calcined and ground to produce the pigment. The chloride process uses the ore rutile (TiO_2) as the starting raw material. This method was introduced in Germany in the 1950s. Rutile is mixed with coke and heated to 900°C, at which temperature chlorine is introduced, forming titanium tetrachloride gas. This is condensed and then reheated to 1500°C in the presence of oxygen, whereby titanium dioxide is formed (see Kampfer, 1973) for further discussion of the techniques).

Numerous commercial products contain titanium dioxide whites, either as the principal component or as an admixture; examples given by Laver (1997) include Chinese white, flake white, iridescent white, isolating white, *Permalba white,* permanent white, *Super Hiding white*, *Superba white*, *Supra white*, *Titanox*, texture white, underpainting white, utrecht white and zinc white. Brachert (2001) also lists *Titanweiss*, *Rutilweiss*, *Abdeckweiss* and *Blinkweiss* as synonyms for titanium dioxide whites.

The most complete recent discussion of the use of titanium dioxide white pigments in the context of artists' materials is probably that by Laver though numerous other authors have discussed the history (for example, de Keijzer, 1989b); for a more general discussion, refer to texts such as Kampfer (1973) or Buxbaum (1998).

Titanium group; Titanium oxides and hydroxides group; Anatase; Copperas; Ilmenite; Rutile; *Chinese white*; *Flake white*; *Permalba white*; *Permanent white*; *Titanium white*; Titanox; *Zinc white*
Brachert (2001) 248; Buxbaum (1998) 43; Kampfer (1973); Keijzer (1989b); Laver (1997)

TITANIUM GREEN

Green
Synonym, variant or common name

The various sources which describe titanium green indicate that it was a titanium hexacyanoferrate(II) compound. Salter (1869) lists the term, providing the following description of its preparation by 'adding yellow prussiate of potash to a solution of titanic acid in dilute hydrochloric acid, and heating the mixture to ebullition rapidly. The dark green precipitate is washed with water acidulated with hydrochloric acid, and dried with great care, since it decomposes at temperatures above 100°.' Riffault *et al.* (1874) describe preparation of a similar compound, but starting with rutile (*q.v.*); this involved melting at red heat 500 parts powdered rutile with 1500 parts purified potassa. The melted mass was saturated with hydrochloric acid, filtered and the clear liquid precipitated with a solution of potassium ferrocyanide. The precipitate when washed and dried was titanium green. Also described by Terry (1893) as 'an excellent dark green pigment, though rather costly', that author repeating a similar procedure to that given by Riffault *et al*. mentioned above.

Hexacyanoferrate group; Rutile
Riffault *et al*. (1874) 159–160; Salter (1869) 290; Terry (1893) 135

TITANIUM GROUP

Variable
Group term

Titanium forms a variety of oxide compounds and is a common trace element in a wide range of minerals. The largest source of titanium is the mineral ilmenite (*q.v.*) and the most important titanium-containing pigments are, of course, the titanium(IV) oxide whites which have been reviewed by Laver (1997); see the entry for titanium dioxide white. The titanium compounds discussed here are the oxides: anatase (TiO_2); barium titanate ($BaTiO_3$); barium titanate yellow ($2NiO.3BaO.17TiO_2$); brookite (TiO_2); ilmenite ($FeTiO_3$); iron titanate ($FeTiO_3$); lead titanate ($PbTiO_3$); potassium titanate ($((K_2O)_{1/x}(TiO_2)_4)$); rutile (TiO_2); titanium(IV) oxide, rutile type (TiO_2); titanium(IV) oxide, brookite type (TiO_2); titanium(IV) oxide, anatase type (TiO_2); titanomagnetite ($Fe_3O_4.Fe_2TiO_4$); zinc titanate ($ZnTiO_3$; Zn_2TiO_4; $Zn_2Ti_3O_8$).

As pigments, many titanium oxide compounds (barium titanate, zinc titanate, potassium titanate, titanium lithopone and titanium phthalate) fall under the collective term 'titanium white' (*qq.v.*), although the synthetic forms of rutile and anatase (titanium(IV) oxide) have been the most extensively used in this context. Laver also mentions titanium silicate as a form of titanium white. Further titanium minerals include pseudobrookite (Fe_2TiO_5), ferropseudobrookite ($FeTi_2O_5$), ilmenite ($FeTiO_3$), and ulvöspinel (Fe_2TiO_4). Titanium oxide minerals may also be components of bauxite (*q.v.*). Buxbaum (1998) describes the use of the spinel minerals, Mg_2TiO_4 and Zn_2TiO_4, to produce cobalt green (*q.v.*) pigments. Further cobalt green pigments are produced by replacing magnesium with nickel (approximately $[Ni,Co,Zn]_2TiO_4$), as listed in the *Colour Index* (1971) CI 77377/Pigment Green 50, or with lithium ($Li_2(Co,Ni,Zn)Ti_3O_8$). However, of more general interest are nickel rutile yellow, $(Ti_{0.85}Sb_{0.10}Ni_{0.05})O_2$ (CI 77788/Pigment Yellow 53) and chromium rutile yellow, $(Ti_{0.90}Sb_{0.05}Cr_{0.05})O_2$ (CI 77310/Pigment Brown 24) (*qq.v.*).

Titanium oxides and hydroxides group; Anatase; Barium titanate; Brookite; Ilmenite; Iron titanate; Lead titanate; Potassium titanate; Rutile; Titanomagnetite; Zinc titanate; *Cobalt green*; *Titanium lithopone*; *Titanium phthalate*; *Titanium white*
Buxbaum (1998) 43, 100–101; *Colour Index* (1971) 77310, 77377, 77788; Laver (1997)

TITANIUM LITHOPONE

White
Synonym, variant or common name

Laver (1997) mentions titanium lithopone as a possible form of 'titanium white'. So-called 'titanated lithopones' were also available (Stieg, 1985).

Titanium group; *Lithopone*; *Titanium white*
Laver (1997); Stieg (1985)

TITANIUM OXIDES AND HYDROXIDES GROUP

White
Group term

In terms of pigments, the principal members of this group are the synthetic titanium(IV) oxide pigments of the rutile and anatase types (*qq.v.*) – a third form, brookite, also exists. There is a further group of synthetic secondary and tertiary oxides: potassium titanate ($((K_2O)_{1/x}(TiO_2)_4)$), barium titanate ($BaTiO_3$), a barium nickel titanate ('barium titanate yellow', $2NiO.3BaO.17TiO_2$), iron titanate ($FeTiO_3$), lead titanate ($PbTiO_3$), zinc titanate (three forms: $ZnTiO_3$, Zn_2TiO_4 and $Zn_2Ti_3O_8$), titanium antimony chromium oxide ($(Ti_{0.90}Sb_{0.05}Cr_{0.05})O_2$) and titanium antimony nickel oxide ($(Ti_{0.85}Sb_{0.10}Ni_{0.05})O_2$). Titanium oxide also occurs in nature as the minerals anatase, rutile, brookite, ilmenite and titanomagnetite (*qq.v.*), as well as pseudobrookite (Fe_2TiO_5), ferropseudobrookite ($FeTi_2O_5$) and ulvöspinel (Fe_2TiO_4) (Laver, 1997; Buxbaum, 1998).

There are no titanium hydroxides of interest as pigments.
See: titanium group.

Titanium group; Anatase; Brookite; Ilmenite; Iron titanate; Lead titanate; Potassium titanate; Rutile; Titanomagnetite; Zinc titanate; *Barium titanate yellow*; *Titanium dioxide white*
Buxbaum (1998) 51, 100–101; Laver (1997)

TITANIUM(IV) OXIDE, ANATASE TYPE

White
Generic compound

See: anatase and titanium oxides and hydroxides group.

TITANIUM(IV) OXIDE, BROOKITE TYPE
White
Generic compound

See: brookite.

TITANIUM(IV) OXIDE, RUTILE TYPE
White
Generic compound

See: rutile and titanium oxides and hydroxides group.

TITANIUM PHTHALATE
White
Generic compound

Laver (1997) mentions titanium phthalate as a possible form of 'titanium white' (*q.v.*).

Titanium group; *Titanium white*
Laver (1997)

TITANIUM RED
Red
Synonym, variant or common name

Titanium red was reportedly derived from the titanium ore ilmenite (*q.v.*; de Keijzer, 1990).

Ilmenite
Keijzer (1990)

TITANIUM SILICATE
White
Generic compound

Laver (1997) mentions titanium silicate as a possible form of 'titanium white' (*q.v.*).

Silicates group; Titanium group; *Titanium white*
Laver (1997)

TITANIUM WHITE
White
Synonym, variant or common name

According to Laver (1997), titanium white has been applied to any white pigment containing titanium. These may include barium titanate, zinc titanate, potassium titanate (*qq.v.*), titanium lithopone, titanium phthalate and titanium silicate. Titanium dioxide white is also a titanium white. Furthermore, the name permanent white (*q.v.*) has been applied to these (and other) compounds.
See: titanium dioxide white and titanium oxides and hydroxides group.

Titanium oxides and hydroxides group; Potassium titanate; Zinc titanate; *Permanent white*; *Titanium dioxide white*
Laver (1997)

TITANIUM YELLOW
Yellow
Synonym, variant or common name

According to de Keijzer (1990) titanium yellow was derived from the titanium ore ilmenite (*q.v.*). However, Hackman (1973) lists titanium yellow as a synonym for nickel titanate yellow.

Ilmenite; *Nickel titanate yellow*
Hackman (1973); Keijzer (1990)

TITANOLITH
White
Synonym, variant or common name

According to Mayer (1991), *Titanolith* is a trade name for a composite material based on 25% titanium white and 75% blanc fixe (*qq.v.*) or other inert pigment.

Blanc fixe; *Titanium white*
Mayer (1991) 58

TITANOMAGNETITE
Black
Generic variety

The iron titanium oxides of interest form a ternary system with FeO, Fe_2O_3 and TiO_2 as the end-members. The most interesting minerals in this system are wüstite ($Fe_{1-x}O$), magnetite (Fe_3O_4), hematite (α-Fe_2O_3), maghemite (γ-Fe_2O_3), pseudobrookite (Fe_2TiO_5), ferropseudobrookite ($FeTi_2O_5$), ilmenite ($FeTiO_3$) and ulvöspinel (Fe_2TiO_4). There are three fundamental solid-solution series in this system: the magnetite-ulvöspinel series (titanomagnetites) with an inverse spinel structure, the rhombohedral hematite-ilmenite series (titanohematites) and the orthorhombic pseudobrookite-ferropseudobrookite series. Of these, the titanomagnetites are the most important. Titanomagnetites can be oxidised or reduced by a variety of processes; most naturally occurring titanomagnetites are slightly oxidised towards the titanohematite line (Nagata, 1961).

Titanomagnetite has been identified as occurring with Egyptian blue (*q.v.*) by Jaksch *et al.* (1983).

Iron group; Iron oxides and hydroxides group; Titanium group; Titanium oxides and hydroxides group; Hematite; Ilmenite; Maghemite; Magnetite; *Egyptian blue*
Jaksch *et al.* (1983); Nagata (1961)

TITANOX
White
Synonym, variant or common name

Titanox has been used as a trade name for various titanium dioxide white (*q.v.*) pigments produced by the Kronos company. The original manufacturers of titanium dioxide pigments were the Titanium Pigment Corporation of Niagara Falls, New York and the Titan Co. AS of Norway, who simultaneously began commercial production around 1916. The National Lead Company (today, NL Industries) acquired both companies. In 1989, NL Industries reorganised itself such that Kronos became a separate company. Before 1989, Kronos sold its Kronos titanium dioxide grades branded as either 'Titanox' or 'Kronos' in different areas of the world; since the grades were interchangeable, the company decided to adopt the Kronos brand name exclusively, though the company still maintains the rights to the Titanox brand name. Kronos, or 'Cronus', was one of the Titans of Greek myth.

Titanium dioxide white

TOBACCO JUICE
Brown
Synonym, variant or common name

Dossie lists tobacco juice among various organic browns such as Spanish juice (derived from liquorice; see: Spanish brown) and asphaltum (see asphalt), although he does not describe it (Dossie, 1764).

Asphalt; *Spanish brown*
Dossie (1764) I-130

Todorokite

Black
Generic compound

Todorokite is a calcium-bearing hydrated manganese oxide (Mn_2, Ca, Mg) ($Mn_3O_7.H_2O$), frequently identified as pyrolusite (Ford, 2001). Todorokite typically accumulates in cave deposits as black coatings on cave walls and stream beds. It is a common constituent of black manganese oxide earths. Identifications of this mineral and the associated birnessite (*q.v.*) in wad-based pigments may be forthcoming.

Manganese oxides and hydroxides group; Birnessite; Wad
Ford (2001)

Toluidine red

Red
Synonym, variant or common name

Toluidine red, CI Pigment Red 3 (*Colour Index*, 1971), is by volume one of the 20 largest organic pigments in the world. A β-naphthol azo pigment (*q.v.*), it is diazotised 2-nitro-p-toluidine coupled with alkaline β-naphthol, and was first synthesised in 1904 by Meister Lucius and Bruning (Herbst and Hunger, 1997; de Keijzer, 1999). It is used extensively in conjunction with molybdate red (*q.v.*).

Associated commercial names include *Harrison red*, *Helio Fast Red* (Toch, 1916), *Spectrum red* and *Winsor red* (Winsor & Newton).

Azo pigments group: β-Naphthol sub-group; *Harrison red*; *Molybdate red*; *Naphthol red*; *Spectrum red*
Colour Index (1971); Herbst & Hunger (1997) 279–280; Keijzer (1999); Toch (1916) 69–70

Transparent brown

Brown
Synonym, variant or common name

According to Mayer, transparent brown is calcined green earth (*q.v.*; Mayer, 1991).

Green earth
Mayer (1991) 59

Transparent copper green

Green
Synonym, variant or common name

Transparent copper green is usually considered a synonym for copper resinate (for example: Kühn, 1993a), but it could refer equally to any copper green glaze.

Kühn (1993a)

Transparent oxide of chromium

Green
Synonym, variant or common name

See: viridian.

Transparent white

White
Synonym, variant or common name

According to Doerner (1935), transparent white referred to aluminium hydroxide (*q.v.*). Patton (1973i) on the other hand indicates more specifically that it was ‘a basic aluminium sulfate prepared as a precipitate from solutions of aluminium sulfate and sodium carbonate’ which he otherwise calls light alumina hydrate.

Aluminium oxides and hydroxides group; Aluminium sulfates group
Doerner (1935) 59; Patton (1973i)

Trapilo blue

Blue
Synonym, variant or common name

Trapilo (or trapito) blue is a Spanish term which literally means ‘blue from little rags’. Veliz (1986) identifies it as the pigment known in English as turnsole – an organic pigment derived from the ‘turnsole’ plant *Chrozophora tinctorum*. This pigment was stored in the form of dyed cloths which were wetted in order to extract the colour for use.
See: turnsole.

Veliz (1986) 26, n.13, 27, 117

Travertine

White
Generic variety

Travertines are freshwater limestones, composed of calcium carbonate, either in the form of calcite or aragonite (*qq.v.*). Specifically the term refers to banded, decorative varieties of the stone (unbanded freshwater limestones are called tufa or calcareous tufa) and they should not be confused with the superficially similar rock alabaster (*q.v.*) composed of hydrated calcium sulfate. Characteristically, travertines and tufas form in warm climates in limestone regions and are the reprecipitation of dissolved calcium carbonate from bedrock. They may also be associated with hot springs as in Pammukkale in Turkey and in volcanic regions. Similar materials are speleothems, also known as flowstones, stalactites and stalagmites that form in limestone caves. The decorative travertines from the hot spring deposits of western Anatolia are sometimes referred to as Phrygian Marble. Travertine deposits are extensive in the victinity of Rome where it is widely used as a building stone. Travertines and associated deposits are usually pure white at the time of formation but rapidly weather to a yellow-brown colour. When crushed they will be white.

Travertines are not widely recognised as pigment sources but it is mentioned as being used as a substrate for dyes including brazilwood in the manuscript of Jehan Le Begue: ‘*Tavertinus albus color, seu lapis qui apte rubificatur, si in ligno braxilii, cum urina, vel lexivio, et alumine misceatur.*’ (‘Travertine is a white colour which can be reddened if it is mixed in the wood of Brazil with urine, lexcivius’, and alum.)’ (1431, Clarke MS 2790, cf. Merrifield, 1849). Merrifield also states that travertine was ‘… frequently mixed with transparent vegetable colours to give them body’, adding that it was occasionally used as a white pigment (the travertine from Tivoli being particularly suitable) and that it was used by painters to give a body to lakes made from *verzino* (brazilwood). The Bolognese MS (Clarke MS 160) also mentions powdered travertine, in a recipe to make the yellow pigment known as *arzica.*

Calcium carbonates group; Alabaster; Aragonite; Brazilwood; Calcite; Limestone; *Arzica*
Merrifield (1849) clii, 37

Tremolite

White
Generic compound

Tremolite, $Ca_2Mg_5Si_8O_{22}(OH)_2$, is a calcium-rich member of the amphibole group (*q.v.*) of minerals. It occurs as white acicular or fibrous crystals in certain metamorphic rocks (Rutley, 1988). It is stated by Patton (1973e) to be a mineral commonly associated with talc (*q.v.*). Adverse health effects have been noted from the presence of tremolite in modern household whitewash used in Greece (Berger *et al*., 2001).

Amphibole group; Silicates group; Talc
Berger *et al*. (2001); Patton (1973e); Rutley (1988) 389–390

Tridymite
White
Generic compound

Tridymite is a silicon dioxide mineral with composition SiO_2. It is polymorphous with quartz and cristobalite (*qq.v.*) and has two structural forms itself: the monoclinic α-tridymite (or low tridymite) form, and the hexagonal β-tridymite (or high tridymite) form. Tridymite is the polymorph of SiO_2 stable above 870°C (α- and β-quartz being stable below this temperature) and inverts to cristobalite above 1470°C; β-tridymite is the polymorph produced upon heating of quartz, with α-tridymite forming preferentially upon cooling (Deer *et al*., 1992; Tuttle and Bowen, 1958; Grant, 1967). The open channel structure of tridymite allows access for impurities that may also distort the structure between monoclinic and hexagonal. Tridymite occurs metastably at room temperature as spherules or as small platy hexagonal crystals that may be twinned to give wedge-shaped crystals or six-rayed trillings or triplets; this crystal habit has resulted in the mineral being named after the Greek word *tridymos* meaning ‘three twins’. Tridymite is found in rapidly cooled acid igneous rocks (such as obsidian), and in high temperature contact metamorphosed impure limestones (Deer *et al*., 1992). Tridymite is found at localities such as the San Juan Mountains (Colorado, USA), Mule Springs (Oregon, USA), Eifel District (Germany), Vesuvius (Monte Somma, Italy), Cerro San Cristobal (Mexico) and Kumamoto (Japan).

The relatively high temperature of formation of tridymite means that it may form during heating of other silicate minerals. Tridymite is mentioned as a phase found in Egyptian blue (*q.v.*) by Colinart *et al*. (1998).

Silicates group; Cristobalite; Quartz; *Egyptian blue*
Colinart *et al*. (1998); Deer *et al*. (1992) 457–472; Grant (1967); Tuttle & Bowen (1958)

Tripoli
White
Synonym, variant or common name

The term tripoli is used to denote fine-grained silicas (*q.v.*) as a class, being supposedly derived from the term tripolite; Patton (1973a) states that this is because of a superficial resemblance of such silicas to the diatomaceous silica called tripolite that comes from Tripoli in Libya.

In a discussion of the white pigment *Paraetonium* (*q.v.*), the classical author Pliny (77 AD) also mentions a similar material coming from Cyrene (modern Shahhat, Libya) and which could plausibly be interpreted as tripoli. Cyrene was a colony formed by Greeks from Thera and was one of the principal cities in the Hellenic world. It was Romanised and remained a great capital until a devastating earthquake in 365 AD.

Silica; *Paraetonium white*
Patton (1973a); Pliny (1st cent AD/Rackham, 1952) XXXV.xviii

Tripotassium hexanitrocobalt(III)
Yellow
Generic compound

See: potassium hexanitrocobalt(III).

Trippkeite
Blue-Green
Generic compound

Trippkeite is a copper arsenate mineral with composition $CuAs_2O_4$ (Sarp and Cerny, 2001). It forms as green-blue prismatic crystals in arsenic-bearing copper deposits such as those in the Atacama desert (Chile) from where it was first reported by vom Rath in 1880; it has also been found in the copper mines of Roua (Alpes-Maritimes, France) where it is associated with other copper minerals brochantite, malachite and cuprite (*qq.v*).

Although trippkeite has not been encountered as a pigment to date, Scott (2002) has pointed out that its synthetic analogue may occur as a relict phase from one of the many preparations routes of Scheele’s green (*q.v.*).

Arsenic group; Copper arsenite group; Copper group; Brochantite; Cuprite; Malachite; *Scheele’s green*
Sarp & Cerny (2001); Scott (2002) 309–310

Trisulphide of arsenic
Yellow
Synonym, variant or common name

See: orpiment.

Trona
White
Generic compound

Trona is an hydrated sodium carbonate mineral with composition $Na_3CO_3HCO_3.2H_2O$. It was named in 1773 by Bagge after the Arabic word for native salt, *tron* derived from *natrun*; it is also known as *urao*. Trona is white or colourless when pure but may be tinted light grey, brown or yellow. It commonly forms as soft white fibrous, columnar or powdery masses, or as prismatic or tabular crystals, often infilling fractures. It is soluble in water and is often subject to dehydration or further hydration. Large deposits of trona form from the evaporation of saline solutions in non-marine settings (usually in lacustrine environments); smaller deposits are found as effluorescent crusts on mine or cave walls, or in soils in arid climates (Rutley, 1988; Dana, 1932). It is often found in association with halite, gypsum, sodalite, calcite, galena, fluorite (*qq.v.*), natron and thenardite, and alters to nahcolite, $NaHCO_3$. Trona is found at Vesuvius (Italy), Fezzan (Libya), Mt St Hilaire (Quebec, Canada), Mono Lake and Death Valley (California, USA), Lake Magadi (Kenya), Lake Natron (Tanzania) and the Jequetepeque Valley (northern Peru).

Trona has been identified by Sánchez-Moral *et al*. (2002) with thernardite and gypsum in the effluorescence crusts on the cave paintings of Galdar (Canary Islands). It has also been found as a phase in certain South American (Argentinian) rock art pigments by Wainwright *et al*. (2002).

Sodium carbonates group; Calcite; Fluorite; Galena; Gypsum; Halite
Dana (1932) 530; Rutley (1988) 306; Sánchez-Moral *et al*. (2002); Wainwright *et al*. (2002)

Troy white
White
Synonym, variant or common name

Troy white is probably an anglicised form of Troyes white, a white chalk from Troyes in France. It appears, however, to have been used as a general term for chalk (*q.v.*). Dossie (1764), for example, mentions that Troy white is a mixture of chalk and alum, as well as being synonymous with the term spanish white (*q.v.*).

Chalk; *Satin white*; Spanish white *Troyes white*
Dossie (1764) 137–138

TROYES WHITE

White
Synonym, variant or common name

Troyes white is a white chalk from the region of Troyes in France. Since Troyes is in the Champagne region, it is therefore also synonymous with Champagne chalk. This name appears to have been adapted to Troy white as a general term for chalk (Riffault *et al*., 1874).

Chalk; *Troy white*
Riffault *et al*. (1874) 53–54

TRUE CHROME GREEN

Green
Synonym, variant or common name

True chrome green was used as a term for chromium oxide (*q.v.*) by Field (1835) who considers it a 'native' (or natural) colour, free of lead and therefore stable.

Chromium oxide
Field (1835) 129

TUNGSTATE GROUP

Variable
Group term

See: tungsten oxides and hydroxides group.

TUNGSTEN BLUE

Blue
Synonym, variant or common name

Tungsten blue is mentioned by Salter (1869) as 'an oxide formed by the action of various deoxidising agents on tungstic acid … is opaque, and of a blackish indigo-blue colour'. Although he adds that there was little to recommend it as a pigment, later authors include it; according to the *Colour Index* (1971; CI 77901), 'commercial Tungsten blue' is composed of the 'blue oxide and blue hydroxide' while synthesis is by adding aqueous ammonium chloride to hot aqueous potassium tungstate, the dried precipitate then being heated to redness in a hydrogen atmosphere. Bersch (1901) describes the product as 'a deep blue powder of velvety appearance'. Rose (1916) gives the formula as W_3O_8, using the names tungsten blue, tungsten oxide, mineral blue and blue carmine (*qq.v.*) for this pigment; he adds that it is a coarse powder that turns blue from grinding, employed for watercolour and oil painting.

Tungsten group; Tungsten oxides and hydroxides group; *Blue carmine; Mineral blue;*
Bersch (1901) 238–239; *Colour Index* (1971) 77901; Rose (1916) 378; Salter (1869) 233

TUNGSTEN GROUP

Variable
Group term

Tungsten compounds are not widely used as pigments, despite the strong coloration of the naturally occurring ores. Deposits are not abundant and the commonest-occurring ore, wolframite (Fe,Mn)WO_4, is found in association with tin ores but was not easily separated from them until the late nineteenth century. The tungstates are the most commonly encountered tungsten pigments, although the obscure Tessie du Motay's blue (*q.v.*) may be a tungsten hexacyanoferrate compound. For a fuller discussion see the tungsten oxides and hydroxides group entry.

Tungsten oxides and hydroxides group; *Tessie du Motay's blue*

TUNGSTEN OXIDES AND HYDROXIDES GROUP

Variable
Group term

The following tungsten oxides and tungstates are known. Although naturally occurring materials have not yet been recognised as pigments, synthetic analogues have been documented (*Colour Index*, 1971).

Oxides and hydroxides: tungsten (IV) oxide WO_2; tungsten (VI) oxide WO_3 and tungstite (WO_3 or $WO_3.H_2O$); tungsten oxide (W_3O_8).

Tungstates: barium tungstate ($BaWO_4$); cadmium tungstate ($CdWO_4$); scheelite and calcium tungstate ($CaWO_4$); cobalt tungstate ($CoWO_4$); raspite, stolzite and lead tungstate ($PbWO_4$); tin tungstate ($SnWO_4$); wolframite (Fe,Mn)WO_4.

Barium, cadmium, calcium, cobalt, lead and tin tungstates are known or reported to have been used as pigments, with the minerals scheelite (calcium tungstate), raspite and stolzite (lead tungstates, *qq.v.*) associated as natural analogues. Barium tungstate is tungsten white, calcium tungstate is tungsten yellow and tungsten blue (*qq.v*) is W_3O_8 (Rose, 1916; *Colour Index*, 1971). Tin tungstate is also known as Thessié blue. Tungstite or tungstic ochre ($WO_3 - WO_3.H_2O$) is an earthy deposit associated with the surface weathering of tungsten-rich ore deposits. It is a bright yellow or yellow-green colour (Rutley, 1988) and is potentially a component of yellow ochre, although identifications have not been made. Tessie du Motay's blue (*q.v.*), according to Bersch (1901), consists of a compound of tungsten oxide with 'a double cyanide of iron and tin'. Tungsten (and molybdenum) may also substitute for vanadium in yellow bismuth vanadate (*q.v.*) pigments.

Tungsten group; Barium tungstate; Bismuth vanadate; Cadmium tungstate; Calcium tungstate; Cobalt tungstate; Lead tungstate; Raspite; Scheelite; Stolzite; *Tessie du Motay's blue*; *Tungsten blue*; *Tungsten white*; *Tungsten yellow*
Bersch (1901) 239; *Colour Index* (1971); Rose (1916) 378; Rutley (1988) 491

TUNGSTEN WHITE

White
Synonym, variant or common name

Salter (1869) indicates that this pigment was 'tungstate of baryta' (*q.v.*). While he also states that it had been 'very recently' introduced in France by M.E. Rousseau and was being prepared on a large scale, Carlyle (2001) in her survey of British nineteenth century sources found little other mention of it. Riffault *et al.* (1874) on the other hand describe the preparation of lead tungstate (*q.v.*), providing instructions as follows: sodium tungstate was dissolved in the smallest possible quantity of boiling water and another hot concentrated solution of lead acetate added while a precipitate forms. The basic lead tungstate formed was then treated with nitric acid or acetic acid to make the acid tungstate.

Tungsten group; Tungsten oxides and hydroxides group; Barium tungstate; Lead tungstate
Carlyle (2001) 518; Riffault *et al.* (1874); Salter (1869) 414–415

TUNGSTEN YELLOW

Yellow
Synonym, variant or common name

According to the *Colour Index* (1971; CI 77250), tungsten yellow is calcium tungstate, $CaWO_4$ (*q.v.*). Its preparation has been described, for example, by Zerr and Rübencamp (1906) as a mineral analogue, scheelite also exists. Other terms for tungsten yellow include *giallo di tungsteno* and *wolframgelb*; it was also sold commercially under the name *jaune minéral* (Mierzinski, 1881).

Tungsten group; Calcium tungstate; Scheelite; *Jaune minéral*
Colour Index (1971) 77250; Mierzinski (1881); Zerr & Rübencamp (1906/1908) 155

TURACINE

Red
Synonym, variant or common name

Salter (1869) gives the following description of Turacine: 'An interesting account has lately been given by Professor Church of a new animal pigment, containing copper, found in the feathers of the violet plantain-eater and two species of Turacus, natives respectively of the Gold Coast, the Cape, and Natal. *Turacine*, the name proposed for it, is noticed here only because it is the first animal or vegetable pigment, with copper as an essential element, which has been hitherto isolated. It is a copper complex uroporphyrin-III extracted by solution in an alkali, and precipitation by an acid, and is changed on long exposure to air and moisture to a green hue. As the entire plumage of a bird yields not more than three grains of pigment, turacine must be looked upon as a mere curiosity.'

Salter (1869) 165

TURBITH MINERAL

Yellow
Synonym, variant or common name

According to Harley (1982) the term 'turbith mineral' probably derives from the seventeenth century use of basic sulfate of mercury as an emetic, since there was another emetic called 'turbith' which was prepared from the East Indian jalap tree *Ipmoea turpethum*. The de Mayerne MS (c.1620, BL MS Sloane 2052) was the first documentary mention of basic mercury sulfate (mercury oxide sulfate) being used as a pigment that Harley encountered, although the *Oxford English Dictionary* (2002) lists references to 'turbith minerall' from 1616 for medicinal use (Bullokar, 1616). Robert Dossie (*Handmaid to the Arts*, 1764) recommended its use, describing the preparation of it by heating equal quantities of mercury and sulfuric acid in a retort until the mercury is reduced to a white mass, which was then powdered and washed until it turned yellow.

Carlyle (2001) found that turbith mineral was rarely mentioned by late eighteenth and early nineteenth century documentary sources although, for example, *A Practical Treatise* of 1795 and the *Compendium* of 1808 through to Salter (1869) and Scott Taylor (1885) list it and Field's *Practical Journal 1809* (cf. Harley) has a sample of it. An equivalent term – mercury yellow – is given by Heaton as late as 1928, though as an obsolete or rarely used pigment.

Various alternate spellings exist such as turbith, turpith and turpeth (*OED*) and it is reasonably clear from the contexts, particularly where there are descriptions of the preparation, that these refer to a sulfate of mercury. Confusingly however, turpeth is listed in modern mineralogical texts such as Hey (1993) as a synonym for calomel, which is mercury chloride – a white compound.

Queen's yellow is also synonymous with turbith mineral, presumably paralleling the use of the term 'king's yellow' for orpiment (*qq.v.*).

Mercury sulfates group; Orpiment; *King's yellow*; *Queen's yellow*
Bullokar (1616); Carlyle (2001) 530; *Compendium* (1808); Dossie (1764) I-107; Field (1809); Harley (1982) 94–95; Heaton (1928) 382; Hey (1993); MS Sloane 2052 (nd); *OED* (2002) 'Turbith'; *Practical Treatise* (1795); Salter (1869); Scott Taylor (1885) 199

TURCHINO

Blue
Synonym, variant or common name

Turchino was considered by Merrifield (1849) to be a carbonate of copper said to have been imported into Italy by the Turks. It was also mentioned as *turquin* in the so-called Brussels MS translated by Merrifield where it is described as a *blue frit*. Turchino is also refered to in Sir Joshua Reynolds' manuscript notes, where it clearly refers to a Prussian blue pigment (*q.v.*; Kirby Talley, 1986).

Copper carbonates group; *Prussian blue*
Kirby Talley (1986); Merrifield (1849) cc–ccii; 804

TURGITE

Red
Generic variety

Turgite, also known as 'iridescent hematite', is a tarnish or weathering product of hematite (*q.v.*) and has a general formula $2Fe_2O_3.nH_2O$; the precise formula is poorly understood. Turgite is highly iridescent showing a wide range of interference colours; however, it is red when powdered. It has a bright metallic lustre. Turgite occurs in thin films or as encrusting, earthy masses coating minerals and rock surfaces, or as a minor component of limonite and of red and yellow ochres (*qq.v.*). It is not known to have been used as a pigment but may occur as a secondary product of some hematite paints.

Church (1901) writes that a 'very fine natural red' comes from Krasso in the Banat, Hungary. '[C]alled turgite, it has the formula $2Fe_2O_3.H_2O$. It has same hue as synthetic Venetian Red [*q.v.*].'

Iron oxides and hydroxides group; Hematite; Limonite; Ochre; *Red ochre*; *Venetian red*; *Yellow ochre*
Church (1901) 179

TURKEY BERRIES

Yellow
Synonym, variant or common name

Yellow lake pigments based on dye derived from *Rhamnus* species, presumably from those indigenous to the historical territories of Turkey. Bristow (1996b) cites the records of the English firm of Berger where 'Turkey berries' (from Îzmir – formerly Smyrna – or Aleppo) and 'Persian berries' were used for production of Dutch pink (*q.v.*) and brown pink; he tentatively identifies the plant source as *R. sacatalis*, *R. amygdalinus* and/or *R. oleiodes*. However, see the entry for *Rhamnus* for a fuller discussion.

Flavonoids group; Dutch pink; Rhamnus
Bristow (1996b)

TURKEY BROWN

Brown
Synonym, variant or common name

See: umber.

TURKEY MADDER

Red
Synonym, variant or common name

Turkey madder appears to refer to the roots of madder (*q.v.*; *Rubia* species) exported from Turkey; Salter (1869) describes it thus: 'Madder roots in the unground state are imported from the Levant, and called Turkey roots. Good qualities of Turkey madder yield near sixty per cent of extractive matters, a term that includes everything removable by water and dilute alkalis.'

Madder
Salter (1869) 139

TURKEY RED

Red
Synonym, variant or common name

Heaton (1928) describes Turkey red pigments as lighter shades of synthetically produced iron oxides obtained by calcination of iron salts at low to medium temperatures.

Iron oxides and hydroxides group
Heaton (1928) 384

TURKEY UMBER

Brown
Synonym, variant or common name

Term used in some sources such as Heaton (1928) equivalent to Cyprus umber.
See: umber.

Umber
Heaton (1928) 384

TURKISH GREEN

Blue-Green
Synonym, variant or common name

Several German sources (Mierzinski, 1881; Rose, 1916) provide similar information on Turkish green, to the effect that in 1859 Salvétat drew attention to a colour basically used for painting of porcelain but which could also be useful for other types of painting. The colour is made by calcining a mixture of cobalt carbonate, aluminium hydrate and chrome oxide. In 1860 Koechlin recommended the colour produced by mixing 30 parts cobalt carbonate, 40 of aluminium hydrate and 20 chrome oxide; in 1906 Zerr and Rübencamp recommended proportions of 30 parts cobalt carbonate, 60 of aluminium hydrate (as a soft powder) and 30 of chrome oxide hydrate, or a sodium precipitate of the mixed solution of sulfates from cobalt, aluminium and chrome. Turkish green is synonymous with turquoise green as the two words are the same in German, the name being variously translated. Wehlte (1975) has also called this *chromblaugrün* (cf. Newman, 1997).

The *Colour Index* (1971) gives Turkish green as a synonym under CI 77343; their formulation is to produce a chromium oxide-aluminium oxide-cobalt oxide compound by 'igniting a mixture of aluminium hydroxide, chromium oxide and cobalt carbonate at white heat'.

Pamer (1978) has identified chromium cobalt aluminium oxide in samples of modern acrylics labelled cerulean blue (*q.v.*), but this appears to be otherwise rare (Newman) and a colour of this composition has been found in a painting of 1862 by Schleich the Elder in the Schlach Gallerie, Munich (Kühn, 1969).

Aluminium group; Chromium group; Cobalt group; *Cerulean blue*; *Turquoise green*
Colour Index (1971) 77343; Kühn (1969); Mierzinski (1881) 427; Newman (1997); Pamer (1978); Rose (1916) 289; Salvétat (1859); Wehlte (1975); Zerr & Rübencamp (1906/1908) 241

TURMERIC

Yellow
Generic compound

Turmeric is a dye or pigment derived from the roots of *Curcuma longa* L., a perennial herbaceous plant of the ginger family (Zingiberaceae) native to southern India and Indonesia, its roots being washed, peeled, dried and ground to a powder for use. The principal yellow dye present is curcumin (*q.v.*), along with dimethoxycurcumin and bisdimethoxycurcumin. Another species, *C. zedoaria* (Christm.) Roscoe, may also be a source.

Lee *et al.* (1985) have published occurrences of turmeric used as both a dye and a pigment on ethnographic objects from the Santa Cruz Islands. These authors state that: 'The use of turmeric as a pigment and dye appears to be peculiar to the Santa Cruz Islands group and has not been encountered in such a wide ranging manner on other Pacific ethnographic material', although they also mention a bark cloth from Tahiti, a vegetable fibre skirt from Ponape in the Caroline Islands, a canoe crest from the Gilbert Islands and a bark cloth from Rennell Island all dyed with turmeric.

According to Watin (1785), *terra merita* (synonyms: *circuma longa* (*sic*) and *safaran des Indes*) was 'a small root resembling ginger growing in several places in the "Grandes Indes" whence it is imported dry. It should be strong smelling, fresh, heavy, compact, well fed and of a saffron yellow colour. It is used to paint floors.' Tingry notes the use of *Terra merita*, stating that it is the root of a plant of the family of the *canna Indica* (Tingry, 1804); Osborn (1845), however, mentions a 'vegetable color' called Terra-merita based on an extract of turmeric. Dossie mentions zedoary (*q.v.*) wash, which he states is 'stronger than turmeric' and he may in fact be specifically referring to dye from *C. zedoaria* rather than *C. longa* (Dossie, 1764).

Curcumin; *Terra merita*; *Zedoary*
Dossie (1764) I-111; Lee *et al.* (1985); Osborn (1845) 52; Tingry (1804) 369; Watin (1773/edition of 1785) 26–27

TURNBULL'S BLUE

Blue
Synonym, variant or common name

The potassium substituted iron(III) hexacyanoferrate(II) ($KFe^{3+}[Fe^{2+}(CN)_6].nH_2O$) was that known as 'soluble' Prussian blue or Turnbull's blue (Berrie, 1997; Mayer, 1991)

Hexacyanoferrate group; *Prussian blue*
Berrie (1997); Mayer (1991) 59

TURNER'S YELLOW

Yellow
Synonym, variant or common name

See: lead chloride oxide.

TURNSOL BLUE

Blue

Synonym, variant or common name

Numerous mediaeval manuscripts describe blues derived from berries. Boltz (1549) gives a recipe for a blue pigment 'Plo Tornisal' which is made from ripe 'Heidelbeern' (berries of *Vaccinium myrtillus* L., Ericaceae). The so-called *Nürnberg Kunstbuch* (Clarke MS 2320) also gives a recipe for blue from 'heidelper' and a second recipe where 'pyer', a term for 'beeren', here referring to 'attichbeeren', *Sambucus ebulus* L. (Caprifoliaceae; 'dwarf elder berries'), are ground with indigo (*q.v.*) and warmed with strong vinegar and alum. This is then painted out '*streich es denn auf*' which appears to indicate that this is used in a painting context (cf. Ploss, 1962). Schweppe (1992) lists various historical terms for *vaccinium myrtillus* (*V. montanum* Salisb., *V. angulosum* Dulac, *Myrtillus niger* Gilib., *M. Silvatica* Bubani). Cardin (2003) states that *Vaccinium arctostaphylos* L., *V. corymbosum* L., *V. angustifolium* Aiton, and *V. ashei* are also used in the production of dyestuffs, these producing a flavonoid anthocyanins. This should not be confused in this context with the important mediaeval blue dye-source turnsole (*Chrozophoria tinctoria* L.) which lent its name to blues produced from numerous other vegetable sources (Thompson, 1956).
See: turnsole and the flavonoids group.

Flavonoids groups; Vaccinium; *Turnsole*

Boltz von Ruffach (1549/Benziger 1913) 78; Cardon (2003) 200–201; Ploss (1962) 124; Schweppe (1992) 400–401; Thompson (1956) 141

TURNSOLE

Red-Blue

Synonym, variant or common name

Turnsole is a dye of varying colour from red through to blue derived from *Chrozophora tinctoria* (L.) A. Juss. (Euphorbiaceae; formerly *Croton tinctorium* L., *Tournesolia tinctoria* Baillon, or *Heliotropium tricoccum*). The early European manuscripts vary as to whether they classify this pigment as red, blue orpurple, showing an awareness that berries of this plant could produce a red dye when acid, through violet to blue whenalkaline.

The term is clearly derived from the Latin *torna-ad-solem* and *solsquium* (thus the English corruption, *suniskell*) and the Latin-Greek *heliotropum* (for example, Dioscorides' Eliotropum; 1st cent. AD). Merrifield (1849), in her prefatory account of pigments gives a clear description of the terminology given to this plant, explaining how it might be distinguished from other similar plants. From a fourteenth century manuscript (Sloane 1754, Clarke MS 1900) she says, the dye can be deduced as having come from the plant called '*morella*' which grew in 'terra Sancti Egidii'. The so-called Venetian manuscript (Sloane 416, Clarke MS 1770) gives a similar recipe but calls the plant *turnasole*, both plants being described as having three berries. This feature has ensured that it is possible to distinguish between two plants and to determine that the name should bear the adjective tri- as in *tri-coccum. Heliotropum tricoccum, H. minus tricoccum.* These all therefore refer to *Chrozophoria tinctoria.* The Latin name Egidius refers to S. Gilles near Montpellier in the Languedoc where the plant is called *maurelle.*

There has been considerable confusion as to which plant is being described by the term turnsole. Furthermore there are other dye producing plants to which this term has also been applied, notably the dwarf elder plant (see: Turnsol blue) and *Heliotropium minus.* A degree of confusion also exists in the more recent literature also in that turnsole has frequently been confused with the French '*tournesol*', a term which was used for a litmus derived from various lichen species (Diadick Casselman, 2002).

The dye was traditionally used to dye pieces of cloth treated with an alkali, to give a blue or violet colour. Harley (1982), in her survey of seventeenth to nineteenth century British documentary sources adds that these were known in England in the seventeenth century though the plant was grown only in France, Spain and Italy, 'because it needed sunshine'. She is also quite clear that the colour was not used in oil painting and probably little used in water colours by the seventeenth century, although noting that the colour is mentioned in some manuscripts copied from earlier sources, as well as *Limming* (1573). A sample of turnsole exists in the manuscript of de Mayerne (BM MS Sloane 2052). Norgate (early seventeenth century) writes deprecatingly about turnsole around the same time, linking it with others that are '… extraccions from fflowers, Jvoyce of herbes or Rootes, which by reason of theire cheapnis and Communitie are esteemed fitter for those which wash prints, Cartes, Mapps then for Limning.' A curious addition is a comment by the contemporaneous writer Peacham, who describes how turnsole rags might be boiled with vinegar and then tempered with gum, a process which would have caused the dye to revert to a red colour.

Early manuscripts refer to this as *folium*. A possible explanation of the term *folium* has been given by Merrifield (see: folium). Although de Massoul (1797; cf. Merrifield) describes its production in the form of a paste, however many other descriptions show the colour was used in the form of cloths which, having been dyed with the berries, were dried and then soaked in water when required for use. Boltz (1549) refers to this as *Tüchleinplouw.* This has led to the various terms relating to linen cloth or rags. These include Italian *pezzette*, corrupted to *bisetus*, or *biseto folii* and *bezetta seu turnasolis* (Merrifield) and the Spanish *trapilo blue*, which means 'blue from little rags' (Veliz, 1986). The term eventually was applied to any rags dyed with a blue-red dye whether they were produced from *Crozophora* or other sources such as vaccinium, orchil, cochineal or brazilwood. See also: *Cimatura.* The term Folium might also reasonably be explained as a fault in transcribing the term torna-ad soleum, where the s may have been mistaken for an f. Other terms include, dyer's croton, giradol (Spanish) maurelle (French) and lackmuskraut (German).

Cimatura; *Folium*; *Sunflower blue*; *Trapilo blue*; *Turnsol blue*

Boltz von Ruffach (1549/Benziger, 1913) 78; Cennini (c. 1400/Thompson, 1960); Clarke (2001) 132; *Compendium* (1808); Diadick Casselman (2002); Harley (1982) 61–63; *Limming* (1573); Massoul (1797); Merrifield (1849) clxxxviii–cxcvi; MS Sloane 2052 (nd) plate 8; Norgate/Thornton & Cain (early 17th C./1981); Peacham (1612); Veliz (1986) 111, 117; Theophilus (c.12th cent/Hawthorne & Smith 1963) 38–39

TURQUOISE GREEN

Green

Synonym, variant or common name

Turquoise green is a chromium aluminium cobalt oxide (*q.v.*). In German 'Turkish' and 'turquoise' are synonymous, thus Turkish green is synonymous with this colour.
See: Turkish green.

Chromium aluminium cobalt oxide; *Turkish green*

TUSCAN RED

Red
Synonym, variant or common name

Heaton (1928) states that Tuscan red was a synthetic iron oxide pigment of a purple hue with the addition of 'an aniline lake such as magenta' (*q.v.*). Clearly the composition is likely to be quite variable with different red dyes and iron oxide pigment substrates within the lake.

Iron oxides and hydroxides group; Magenta
Heaton (1928) 384

TYRIAN PURPLE

Purple
Synonym, variant or common name

Tyrian purple, also known as Royal or Imperial purple, shellfish purple, Byzantium purple, and Purple of the Ancients, is, arguably, one of the oldest known pigments. The colour is derived exclusively from marine shellfish of the Muricidae and Thaisidae families. Its long history contains many misconceptions and erroneous conclusions. Its chemical composition as 6,6′-dibromoindigotin was only identified in the first half of the twentieth century and the presence of two further components, 6-bromoindigotin and 6,6′-dibromoindirubin, were only identified in 1992 (Wouters and Verhecken, 1991b). The pigments derived from *Murex trunculus* also contain indigo and indirubin. Structure and synthesis of these compounds and the related precursors and transient intermediates have been discussed recently by Cooksey (2001).

This molluscan dye has been known since pre-Roman times and in the Mediterranean region there is evidence of the industry as early as the thirteenth century BC at Sarepta (now Sarafand), Lebanon. This industry was distributed worldwide. Surviving details of the ancient process are insufficient to explain the chemistry involved and this is the subject of continuing speculation. (Bancroft, writing in 1813, states that the accounts of how the colour was obtained are 'from their brevity, better suited to excite than to satisfy, an enlightened curiosity'.) But it is clear that the dye does not exist in the mollusc itself and is generated from precursors, sometimes termed *chromogen*s, contained in the hypobranchial gland (Cooksey).

This '*Purpurissum*' purple was difficult to produce and therefore a highly prized colour. The best and most pure purple was produced organically from shellfish collected offshore from Tyre in Phoenicia and elsewhere in the Mediterranean, and thus gave name to the colour as Tyrian purple, which Vitruvius (first century BC) calls *ostrum* (*q.v.*). Vitruvius tells us that there was a variation in colour from blueish through to reddish purples depending on where the shells were collected; however, Bancroft states that the different species of shellfish used appear to give differing shades and were often mixed to produce other variations. Ostrum's prohibitive expense gave rise to its use primarily for imperial trappings and meant that it was rarely used in painting. However, Vitruvius recommends that if it is used, it should be mixed with honey to prevent it drying out too quickly. Ostrum was probably used mainly for dyeing cloth. Purple from molluscs was also produced in Britain, the process being described by Cole in 1685 (cf. Cooksey) as using the hypobranchial gland of the *Nucella lapillus* (*Dogwhelks*, *Nucella lapillus*, are one of the commonest gastropod molluscs on the coastal North Atlantic, from the Arctic south to Gibraltar and Connecticut; however, they do not seem to be found in the Mediterranean) and the process was also common in South and Central America, here using *Purpura patula pansa* as described by Ulloa in 1744 (Cooksey). These processes were for producing dyed cloth. The source of this colour as a pigment is described by Pliny in the first century AD who says that a purple lake pigment was made by soaking purple dyed cloth in water with chalk (see the entry for *cimatura*). He gives two different genera of shellfish for the production of Tyrian purple: the first, Buccinum, smaller and resembling a hunting horn and the second called Purpura. Bancroft (1813) found in his research that Buccinium appeared to be more widespread, having been found, for example, by Mr William Cole (1683–84) on the coasts of Somerset and South Wales; M. Jussieu (1709) on the French Atlantic coast; M. Reaumur (1710) on the coast of Poitou; and M. Duhamel (1736) in Provence. Furthermore Bancroft cites other writers (Jussieu the Elder, Thomas Gage, Don Antonio Ulloa around 1690) who reported the constant production of purple from Buccinium near Panama and particularly on the coasts of Guayaquil and Guatemala, and Mr John Nicuhoff mentions the abundance of snails in 'the islands over against Batavia' which are used by the Chinese to produce a purple coloured substance used in colouring and the making of ink. Tyrian purple derived from *Nucella lapillus* is currently available commercially.

The terminology for the purple producing molluscs themselves has been confusing in the past. Many names used in the literature are now inaccurate and the following gives the current correct zoological nomenclature:

Cosmopolitan: Rapaninae: *Rapana venosa* (Valenciennes, 1846) (syn: *Rapana thomasiana* Crosse, 1861) (Higo *et al*., 1999).
Mediterranean: Muricinae: *Bolinus brandaris* (Linnaeus, 1758) (Radwin and D'Attilio, 1976), *Phyllonotus trunculus* (Linnaeus, 1758) (Radwin and D'Attilio); Thaidinae: *Stramonita haemastoma* (Linnaeus, 1766) (Sabelli *et al*., 1990).
North Atlantic: Thaidinae: *Nucella lapillus* (Linnaeus, 1758) (Sabelli *et al.*)
Japan: Thaidinae: *Thais (Reisha) clavigera* (Kuster, 1860) (Higo *et al*.); *Thais (Reisha) bronni* (Dunker, 1860) (Higo *et al*.).
Carribean: Thaidinae: *Purpura patula* (Linnaeus, 1758) (Abbott, 1974).
South Atlantic: *Purpura patula pansa* (Gould, 1853) (Abbott).
Indo-Pacific: Rapaninae: *Rapana bezoar* (Linnaeus, 1767) (Higo *et al*.); *Purpura aperta* (Blainville, 1832).

Other molluscs may produce 6,6′-dibromoindigotin; however, this is currently unexplored.

Indigoid group; *Byzantium purple*; *Cimatura*; *Ostrum*
Abbott (1974); Bancroft (1813) 78–94; Cooksey (2001); Higo *et al.* (1999); Pliny (1st cent AD/Rackham, 1952) XXXV.xxxvi; Radwin & D'Attilio (1976); Sabelli *et al.* (1990); Vitruvius (1st cent BC/Grainger, 1934) VII.xiii.3; Wouters & Verhecken (1991b)

TYROL WHITE

White
Synonym, variant or common name

'Tyrol white' was a synonym for the barium sulfate mineral baryte (*q.v.*; Feller, 1986).

Baryte
Feller (1986)

TYROLITE

Green
Generic compound

Tyrolite is a copper arsenate mineral of composition $Ca_2Cu_9(AsO_4)_4(OH)_{10}.10H_2O$. Comparatively rare, it has been identified in two mines in the vicinity of Anarak, central Iran. Tyrolite has been identified among ancient Persian pigments from Persepolis and Pasargadae (Stodulski *et al*., 1984), where it appeared to have been partially calcined.

Copper arsenite group
Stodulski *et al*. (1984)

U

ULMIN

Brown
Synonym, variant or common name

Various formulations are provided under this heading by Terry (1893), the common factor being the likely creation of complex organic residues. The three recipes provided are as follows: '(1) Fused caustic potash is digested in alcohol, and the liquor filtered and heated till a brown powder is thrown down, which is filtered and washed with acidulated water; (2) Waste cotton, peat, or brown coal, heated with an alkali; (3) Farinaceous matters carbonised by mineral acids.'

Terry (1893) 105

ULTRAMARINE

Blue
Generic compound

Ultramarine, a name drived from the Latin *ultra*, 'beyond' and *marinus*, 'sea', is a term of historical importance used since antiquity to refer to a pigment derived from the rock known as *lapis lazuli* (*q.v.*). Additionally, this has now also come to be applied as a term to artificially prepared pigments of similar composition to lazurite, the principle blue mineral found in lapis lazuli. Consequently the qualifications 'natural' and 'synthetic' are frequently employed to differentiate the two types. In this volume lazurite and lapis lazuli are reserved for reference to the naturally-ocurring mineral and rock type, while ultramarine is used for the synthetic product unless otherwise stated.

Ultramarine is essentially a three-dimensional aluminosilicate lattice with a sodalite structure containing entrapped sodium ions and ionic sulfur groups. The presence of two types of sulfur group, S_2 and S_3, provides absorbtion in the ultraviolet and violet (S_2) and green-yellow-orange (S_3), making the compound blue. In its simplest form ultramarine has a basic lattice unit of $Na_7Al_6Si_6O_{24}S_3$. However, various synthetic forms are produced deviating from this; Buxbaum (1998), for example, states that a typical composition would be $Na_{6.9}Al_{5.6}Si_{6.4}O_{24}S_{4.2}$, the product being a stronger, redder shade of blue than the simple type. In violet and pink ultramarines the lattice structure is little changed, but the sulfur chromophores are further oxidised, possibly to S_3Cl^-, S_4 or S_4^-. The sodium can be substituted by other ions such as silver, potassium, lithium or copper to give marked colour changes but these products are apparently of no commercial value. It has further been noted that synthetic compounds derived from china clay (*q.v.*) contain a disordered arrangement of silicon and aluminium ions, while natural minerals are ordered.

The minerals lazurite and haüyne (*q.v.*) are natural forms of this structure and both are members of the sodalite group. Lazurite occurs in several parts of the world, one of the best known being the mine in the Kokcha Valley in Afghanistan, believed to have been the source of most of the natural ultramarine used in Europe during the Middle Ages and the early modern period. For a fuller account of the mineral, associated terminology and usage, see the entry for lazurite.

According to current views on the origin of synthetic ultramarine, the earliest related observation was that by Goethe, who noticed blue deposits on the walls of lime kilns near Palermo, Italy, in 1787. He remarked that the material was used locally as a substitute for lapis lazuli in decorative work, though employment as a pigment was not mentioned (Auden and Mayer, 1962; cf. Plesters, 1993). Similar observations in kilns were made elsewhere around this time, notably by Tassaert with regard to soda kilns of the Saint Gobin, France, glass factory; he sent samples of this material to the chemist Vauquelin in 1814, the latter being able to confirm the similarity to natural ultramarine, publishing his results in 1824. A substantial prize was then offered by the Société d'Encouragement pour l'Industrie Nationale in France for the development of a workable method for producing ultramarine, this being claimed by Jean Baptiste Guimet, the man to whom it was awarded on 4 February 1828. Contemporaneously, C.G. Gmelin, a German chemist, devised a slightly different synthesis route, which he published a month later than Guimet's submission to the Société. An early description of the history and methods involved is given by Mérimée (1830), who details the Gmelin method at some length. Guimet began manufacturing his pigment at Fleurieu-sur-Sâone in 1830, though F.A. Köttig had reputedly already commenced production at the Meissen porcelain works in Germany in 1828, presumably following Gmelin's process (Zerr and Rübencamp, 1908). Plesters states that factories soon sprang up across France and Germany with others following in England, Belgium, Austria and the USA.

Quality in the beginning was perhaps not entirely reliable since Salter (1869) stated that in its early days ultramarine was not produced 'to that state of perfection at which it has now arrived', adding that 'A number of substances such as iron, lime, magnesia, and potash, may be present as impurities and were, in part at least, purposely added to the earlier manufactures; but they are found to be superfluous.' Standage (1892) warned that in mixtures 'only the best of the artificial ultramarines should be used, as inferior specimens are liable to contain superfluous sulphur'.

According to Zerr and Rübencamp, by the early twentieth century there were three chief kinds of ultramarine blue in commercial production – one that they call 'glauber salt or sulphate ultramarine' and low and high sulfur varieties of 'soda' ultramarine.

Modern production of ultramarine utilises relatively cheap starting materials, typically kaolin, a feldspar, anhydrous sodium carbonate, sulfur and a reducing agent such as oil, pitch or coal. The kaolin is first heated to about 700°C to destabilise the kaolinite structure by removing hydroxyl ions as water. The activated clay is then blended with the other raw materials and dry-ground; slight variation in the proportions of the ingredients will modify the colour. This ground mixture is heated to about 750°C under reducing conditions. The sodium carbonate reacts with the sulfur and reducing agent at 300°C to form sodium polysulfide; at higher temperatures the clay lattice is transformed to the sodalite structure, entrapping sodium and polysulfide ions. At this point the material is cooled to about 500°C, air being introduced to cause oxidisation of the polysulfide ions to form the S_2^- and S_3^- free radicals that cause the colour (Buxbaum, 1998). The violet shade is produced by heating blue ultramarine with ammonium chloride at c. 240°C in the presence of air; treating this violet form with hydrogen chloride gas at 140°C gives the pink derivative.

Various associated terms seemingly relate to the discovery by Guimet, such as French ultramarine, F. blue and Guimet's blue; the first two of these frequently appear in English documentary sources, as does occasionally German ultramarine (Harley, 1982) and Gmelin's blue (Heaton, 1928); new blue and factitious u. presumably also refer to the synthesis. Other terms to be found in the literature are brilliant u. (Salter, 1869), laundry blue, lime blue (Heaton, 1928), oriental blue (ultramarine according to Linke and Adam, 1913, a mixture of ultramarine and Prussian blue in the *Colour Index*, 1971), permanent blue and p. mauve (Standage; 1892; Heaton), royal blue (Heaton) and sky blue (Winsor & Newton, cf. Carlyle, 2001). 'Ultramarine' was also used – with qualification – to refer to entirely different pigments, such as cobalt u. and Gahn's u. (which were both cobalt blue) or even other colours, such as *u. yellow*, *Colour Index* designations for ultramarine are CI Pigment Blue 29 for the reddish blue pigment, CI Pigment Violet 15 for the violet and CI Pigment Red 259 for the pink, all additionally being listed under CI 77007.

The pigment has been reviewed by Plesters (1993); other important sources for the history of this pigment include Reckitt (1954).

Lazurite; Sodalite; *Brilliant ultramarine*; *French blue*; *French ultramarine*; *Gahn's ultramarine*; *Guimet's blue*; *Lapis lazuli*; *Laundry blue*; *Lime blue*; *New blue*; *Oriental blue*; *Permanent blue*; *Permanent mauve*; *Reckitt's blue*; *Royal blue*; *Sky blue*; *Ultramarine yellow*
Auden & Mayer (1962); Buxbaum (1998) 123–131; Carlyle (2001) 472–473, 522; *Colour Index* (1971) CI 77007; Harley (1982) 43–46; Heaton (1928); Linke & Adam (1913) 62; Mérimée (1830/trans. Taylor 1839); Plesters (1993); Reckitt (1954); Salter (1869); Standage (1892); Zerr & Rübencamp (1906/1908) 177–200

ULTRAMARINE ASH
Blue
Synonym, variant or common name

Ultramarine ash is 'consistently reported as the last washings of genuine ultramarine' (*q.v.*; Carlyle, 2001). Salter (1869) gives the following description in connection with the preparation of natural ultramarine: 'When well carried out, [the extraction process] perfectly isolates the blue from all extraneous matter, yielding the colour at first deep and rich, then lighter and paler, and lastly of that grey tint which is known by the name of Ultramarine Ash. The refuse, containing little or no blue, furnishes the useful pigment, Mineral Gray.'
See: lazurite and lapis lazuli.

Mineral grey
Carlyle (2001) 478; Salter (1869) 220

ULTRAMARINE BLUE, NATURAL
Blue
Synonym, variant or common name

See: lazurite and haüyne.

ULTRAMARINE BLUE, SYNTHETIC
Blue
Synonym, variant or common name

See: ultramarine.

ULTRAMARINE GREEN
Blue-Green
Synonym, variant or common name

As Salter (1869) states, green ultramarine was 'French or artificial ultramarine before the final roasting. It is a somewhat bright bluish-green, becoming a dull greenish-blue on continued exposure.' According to the *Colour Index* (1971), the synthetic ultramarine blue is made by fusing kaolin, soda ash, Glauber's salt, sulfur, carbon and kieselguhr in the absence of air at red heat for 7–10 hours. This results in the so-called green ultramarine, which is cooled, ground, mixed with 7–10% of sulfur and then 'blued' by heating in a furnace. Hues of the final product vary from pale greenish blue to violet depending on the silica:alumina ratio.

Ultramarine
Colour Index (1971); Salter (1869) 287

ULTRAMARINE RED
Red
Synonym, variant or common name

According to the *Colour Index* (1971), ultramarine red is obtained by treating ultramarine violet (*q.v.*) with gaseous hydrochloric acid at 200°C for four hours or at a higher temperature with gaseous nitric acid. The *Colour Index* further comments that ultramarine red is the acid of which ultramarine violet is the salt.

Ultramarine; *Ultramarine violet*
Colour Index (1971)

ULTRAMARINE VIOLET
Purple
Synonym, variant or common name

Several derivatives can be made of ultramarine (*q.v.*) by substituting various constituent elements. In the case of ultramarine violet, ultramarine blue is mixed with about 2.5–5% ammonium chloride, heated to 200–250°C for four days and exposed to air until the purple colour develops; alternatively ultramarine can be heated with chlorine and hydrochloric acid (Heaton, 1928; *Colour Index*, 1971; Buxbaum, 1998). Ultramarine red (*q.v.*) is produced as a derivative of this pigment.

Listed in the *Colour Index* as CI Pigment Violet 15.

Ultramarine; *Ultramarine red*
Buxbaum (1998) 129; *Colour Index* (1971); Heaton (1928) 155

ULTRAMARINE YELLOW
Yellow
Synonym, variant or common name

Carlyle found a number of references to yellow ultramarine/ultramarine yellow in English nineteenth century sources such as Standage (1887), Seward (1889) and Vibert (1892) identifying it as barium chromate (*q.v.*; Carlyle, 2001); this correspondence is also noted by Heaton in 1928, indicating that it was still an active term at that time. The term is listed in various German texts of the period as well, though it is described variously as barium, strontium or zinc yellows (chromates); an exception among these is Rose, who states that it is incorrect to call barium chromate ultramarine yellow (Jännicke, 1893; Linke and Adam, 1913; Rose, 1916). Other associated terms listed in these latter sources include *Barytgelb* ('baryta yellow'), permanent yellow, lemon yellow and Steinbühl yellow.

However, we should also note that Zerr and Rübencamp (1908) discuss various treatments to ultramarine that cause shade variants (violet, green, pink), remarking that 'On heating red ultramarine above 360°C, or treating it with hydrochloric acid gas as a higher temperature than above mentioned, yellow ultramarine will be very quickly formed.'

Chromates group; Barium chromate(VI); Strontium chromate(VI); Ultramarine; *Baryta yellow*; *Lemon yellow*; *Permanent yellow*; *Steinbühl yellow*; *Zinc yellow*
Carlyle (2001) 522; Heaton (1928) 385; Jännicke (1893) 52–53; Linke & Adam (1913) 43; Rose (1916); Seward (1889) 43; Standage (1887) 34; Vibert (1892) 167; Zerr & Rübencamp (1906/1908) 199

UMBER

Brown
Common generic composite

The name 'umber' is derived from the Latin *ombra* (shadow) and describes simply the colour of a pigment, useful for the rendition of shadows. Subsequently the name umber has been applied to a rock with a significant manganese oxide content but variable composition. Consequently there is a minefield of terminology concerning the description and classification of umber pigments in historical texts which differ, in some cases widely, from the geological classification of the raw material, umber sediments.

Geologically, umbers are very fine-grained sedimentary rocks composed of manganese hydroxides and oxides (primarily the minerals manganite and pyrolusite) plus iron hydroxide (goethite) particles. Manganese compounds should be present in amounts between 5 and 20% and iron oxides typically represent 45–70% of the rock (Ford, 2001; Buxbaum, 1998). As rocks, these are not pure substances and other minerals may be present in varying amounts depending on the mode and environment of formation. In an attempt to clarify this situation, classification based on manganese oxide content is adopted here, thus placing both the pigments and the rock deposits in a group separate and distinct from ochres. The generic and oft used definition that umbers are 'a variety of ochre' is therefore rejected.

Furthermore, geologically, the classification based on manganese oxide content is applied to umber sediments *sensu lato*. Umber *sensu stricto* is applied to rocks forming in a restricted geological environment. They are precipitated in deep marine conditions in areas adjacent to submarine spreading centres (mid-ocean ridges; zones of active volcanicity and ore genesis). Umbers may or may not be silicified and may contain sparse radiolarian (siliceous) microfossils. Silicification is a secondary process caused by the circulation of heated subsurface waters. Preservation of umber on the surface of the earth is dependent on ocean crust being overthrust onto the continents during mountain building processes. It therefore occurs in limited geographical regions. In outcrop it forms often small, localised deposits, ranging from dark brown to greenish brown in colour and finely but distinctly laminated, often disintegrating to a shaly scree deposit. It is soft and leaves a strong, brown streak on any surface. Characteristically, it has low density and although appears compact it is an incredibly absorbent rock. However, porosity will decrease with the increase in the degree of silicification.

The principal source for umber *sensu stricto* is Cyprus. The deposits at Margi are well known (Kaleda and Krylov, 1993; Prichard and Maliotis, 1998; Ravizza *et al.*, 1999). Cyprus-type umbers also occur with extensive deposits throughout the Levant and the Middle East, especially Syria (Parrot and Delaune, 1974). Limited and less well-described deposits are known in Japan (Tazaki *et al.*, 1980) and Ireland (Williams *et al.*, 1997).

Umber *sensu lato* may also be applied to a weathering and alteration product of magnesian limestones and this is particulary known and described with reference to deposits in central England. Fielding (1839) states that umber was found in many parts of England and Wales 'amongst the lead and coal mines' and Church (1901) remarks that English umbers were poor in iron. Here both authors are referring to the wads (*q.v.*) and umbers associated with the lead mineralisation in limestones (Ford 2001; Wedgwood, 1783) particularly in Derbyshire, but also known from Devon and North Wales. These umbers are found in association with dolomitised limestone and it is their formation that Terry (1893) primarily alludes to in his discussion of umber. By definition, these beds yield umbers with the correct manganese oxide and iron oxide ratios and may therefore be geologically defined broadly as umbers. They are gradational with the higher manganese oxide-bearing wads which are worked for black pigments. The geological origin of the 'English-type umbers' is distinctly different from Mediterranean and Middle Eastern umbers and should not be confused with them. Ford (2001) describes the formation of the British umbers and that of the closely associated manganese oxide earth wad, which is black in colour. Similar occurrences are known from Romania and elsewhere; however, the authors are unaware of these deposits being worked for pigments but analyses may be forthcoming.

The Cyprus-type umbers, with their characteristic olive-greenish cast, produce by far the best pigment and particularly popular was that derived from the Margi area, west of Nicosia. Terry (1893) says that this is 'the darkest and richest in colour – a warm violet brown … and commands a higher price in the market [than other umbers]'. De Massoul (1797) also offers praise, though he particularly states Egypt as a source. Church (1901) agrees saying that samples of the pigment were shown in the 1886 Colonial and Indian Exhibition. His own analysis on a 'choice sample' revealed it to contain 19% manganese oxide in the form of hausmannite (*q.v.*).

Terry (1893) writes that umber could be bought either as untreated 'lumps' direct from outcrop, requiring grinding by the purchaser, or in a ground or powdered form. The ground pigment is prepared by washing, levigation and drying but impurities are likely to remain. For Cyprus-type umbers, these may include silica in either the form of quartz or siliceous microfossils (radiolaria) plus a wide variety of iron and manganese oxides and hydroxides. Prichard and Maliotis (1998) have found the Margi umbers to be gold-bearing, though the gold is finely disseminated throughout the material and would only be detected through chemical analyses. The 'English-type' Derbyshire umbers are known to contain trace amounts of quartz, calcite, dolomite, baryte and gypsum and have highly variable manganese oxide contents. Terry (1893) complains that the Derbyshire umbers are 'poor and incline to a reddish tint, besides being gritty'. He also notes that they are 'sometimes adulterated with a little lamp black' to produce a tone similar to that of Cyprus umber.

Further confusion of terminology arises in the similarity of colours produced from umbers and those that are related to Vandyke brown (*q.v.*), derived from hydrocarbon deposits. The description of umber in Tingry (1804) fits more readily to the low-grade brown coal lignite, the pigment called Cologne earth (or 'Cologne umber'), and he does in fact describe this as a bituminous earth. Church (1901) adds that inorganic umbers were occasionally adulterated with 'a ferruginous brown coal'.

Umbers are also known from Ireland. Cyprus-type umbers occur in the north-west of the island in the vicinity of Clew Bay (Williams *et al.*, 1997). However, they are not known to be worked as pigments. The reddish brown Cappagh (or Cappah) brown comes from the south-west of Ireland and is presumably an English-type umber; it is mentioned by various historical sources. This material was, according to Weber (1923), mined in Cork in 1814, and he clearly defines it as an umber in the geological sense, containing manganese and iron oxides. However, he goes on to say that the material 'is today obtained from various sources', implying that a similar colour was made from mixing 'bitumen' with burnt umber and burnt sienna. Terry (1893) mentions, but does not elaborate on, the occurrence of Cornish umber 'of fairly good quality'. These authors are unaware of the geological occurrence of 'true' umber in Cornwall but it cannot be ruled out. Weber (1923) describes Caledonian brown as an umber but gives no provenance. Although Scott Taylor (1885) states that it is a naturally occurring pigment, Church (1901) believes that the original source of the material has been exhausted and that a mixture of burnt sienna and Vandyke brown are sold instead. Portugal is reputed to be a source of umber called Sintra or 'Cintra' umber, according to Nunes (1615; cf. Veliz, 1986); however, both pigments' compositions and provenance are unknown.

Early identified uses of umber come from Ajanta frescos dating from the 200 BC–600 AD (Kahn, 1949). Umber was a standard colour of the eighteenth century palette (Harley, 1982) and was considered to be superior to Cologne earth and Vandyke brown due to its high stability and inertness and its ability as a drier. Numerous other cases could be cited though some exemplars might be given. Umbers have been identified in Vermeer's paintings (Kühn, 1968). Gifford (1983) has identified umbers to have had widespread use in eighteenth century Dutch landscape painting. Gettens and Turner (1951) have identified umbers on nineteenth century 'santos' (religious portraits) from New Mexico. However, the similarities in colour between umber and humic earth-based pigments such as Vandyke brown have led to assumptions made on brown pigments used and no clear identifications in several cases (see Roy, 1999). Importantly Seccaroni (1999a) has identified manganese oxide brown pigments in Correggio's *Allegories of Virtue and Vice* 'absolutely not explained by the composition of *raw* umber'. These pigments are purer forms of manganese oxide indicating that in many cases, naturally occurring umbers have been interpreted as prepared pyrolusite etc. – based pigments, and that these pigments are more widespread than previously realised.

It is now generally accepted that the name umber derives from *ombra* alluding to the suitability of this pigment for the rendering of shadows. However, earlier sources (Tingry, 1804) suggest that the original pigment was derived from Umbria in Italy, a region which is not known as a source for the pigment as described above (the Umbrian *nocera earth* is a humic earth). In its natural state, the terms 'umber' or 'raw umber' are commonly used to describe the pigment. Burnt umber is calcined umber; the colour becomes darker and more red. The name is recorded in some texts as *umbra* (for example, Weber, 1923), while Church (1901) lists *umbraun*. Since the main source of umber was Cyprus, the name 'Cyprus umber' is also common. Many documentary sources list the terms 'Turkish umber' and 'Turkey umber'; Anatolia would not have been distinguished from Cyprus in the eighteenth century, however. A similarly derived name is the 'Levant umber' listed by Church (1901).

Due to its sometimes earth-like appearance, there are many variations on the name umber earth (*terre d'ombre*, *terra d'ombra*, *tierra de sombra*); calcined umber is similarly called burnt umber, *terre d'ombre brulée*, *tierra de sombra tostado* and so forth. Pigments named Kassel (or 'Cassel') umber, Cologne umber and Cassler umbra are synonyms for the lignite-based Vandyke brown and are misnomers as applied to umbers as described above. This terminology is reviewed in Feller and Johnston-Feller (1997).

Iron oxides and hydroxides group; Manganese oxides and hydroxides group; Bayrite; Calcite; Dolomite; Goethite; Gypsum; Hausmannite; Humic earth; Lignite; Magnetite; Ochre; Pyrolusite; Quartz; Wad; *Burnt Sienna*; *Burnt umber*; *Cappagh brown*; *Cologne earth*; *Cyprus umber*; *Raw umber*; *Sintra umber*; *Vandyke brown*

Buxbaum (1998) 84; Church (1901) 227–229, 232–233; Feller & Johnston-Feller (1997); Fielding (1839); Ford (2001); Gettens & Turner (1951); Gifford (1983); Harley (1982) 148–149; Kahn (1949); Kaleda & Krylov (1993); Kühn (1968); Massoul (1797); Nunes (1615); Parrot & Delaune (1974); Prichard & Maliotis (1998); Ravizza *et al.* (1999); Roy (1999); Scott Taylor (1885) 158; Seccaroni (1999a); Tazaki *et al.* (1980); Terry (1893) 105; Tingry (1804) 367; Veliz (1986); Weber (1923) 28, 104; Wedgwood (1783); Williams *et al.* (1997)

URANIA GREEN

Green
Synonym, variant or common name

Listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*).

Emerald green
Fiedler & Bayard (1997)

URANINITE

Black-Brown
Generic compound

Uraninite is a cubic uranium(IV) oxide mineral, named after its composition, UO_2. It has a high density and commonly occurs with black, black-brown or grey botryoidal or dendritic form, with a greasy or sub-metallic lustre; it is also found as aggregates and more rarely as coarse-grained crystals. Uraninite was discovered by Born in 1772 at St Joachimstal, Czech Republic. It forms in high temperature pegmatite rocks and low temperature veins in areas such as Bergen (Germany), Lake District and Cornwall (England), Great Bear Lake (Canada), Minas-Gerais (Brazil), La Rioja (Argentina), Shaba (Congo), Piedmont (Italy), Siberia (Russia), Arizona and New Hampshire (USA). It is the dominant component of pitchblende (*q.v.*; Rutley, 1988) and is also found as detrital material in placer deposits and reworked into conglomerates.

Uranium(IV) oxide is listed in the *Colour Index* (1971) as CI 77915, and uraninite may be the source of uranium for many uranium-based pigments such as uranium brown, green, orange, red and yellow (*qq.v.*).

Uranium group; Pitchblende; *Uranium brown*; *Uranium green*; *Uranium orange*; *Uranium red*; *Uranium yellow*
Colour Index (1971) 77915; Rutley (1988) 195, 274

URANIUM BROWN

Brown
Synonym, variant or common name

Without explaining the detailed composition, Salter (1869) describes uranium brown as having 'A warm rich hue of the utmost intensity.'

Uranium group
Salter (1869) 360

URANIUM GREEN

Green
Synonym, variant or common name

Salter (1869) lists uranium green, describing it as 'an oxide of a deep dull green colour, inclining to olive, and nearly black when in lumps'. It is otherwise obscure and probably rarely if ever used by artists. Compositionally this might perhaps be uranyl uranate (U_3O_8, which is listed in the *Colour Index* (1971) as CI 77919); this occurs naturally in pitchblende (*q.v.*) and was supposedly used as an olive green to grey pigment.

Uranium group; Uranium oxides and hydroxides group; Pitchblende
Colour Index (1971) 77919; Salter (1869) 291

URANIUM GROUP

Variable
Group term

The existence of the element uranium was recognised by Klaproth in 1789, but it was only in 1840 that Peligot isolated the metal itself (*OED*, 2002). The most important ores of uranium are pitchblende or uraninite (*qq.v.*) and various uranium vanadates. Although the main uranium-based pigments are oxide compounds, the compositions of the uranium pigments mentioned by Salter (1869) – such as a 'uranium green' and a 'uranium orange' – are unclear. The uranium compounds included here are the oxides: barium uranium oxide (BaU_7O_2); pitchblende ($UO_2 + U_3O_8$); uraninite (UO_2); uranium(IV) oxide (UO_2).

The *Colour Index* (1971) also lists uranyl uranate (U_3O_8; CI 77919), uranium(VI) oxide (UO_3; CI 77917) and uranium peroxide ($(UO_2)(O_2)(H_2O)_2$; CI 77921). Salter (1869) further refers to a dark red uranium 'persulphomolybdate' pigment. Strontium uranium oxide has also been proposed as a pigment. An ochre (*q.v.*) dominated by yellow uranium(III) oxide (U_2O_3), uranic ochre, has also been mentioned by Hackh (1969).

Barium group; Strontium group; Uranium oxides and hydroxides group; Barium uranium oxide; Ochre; Pitchblende; Strontium uranium oxide; Uraninite; *Uranium brown*; *Uranium green*; *Uranium orange*; *Uranium red*; *Uranium yellow*
Colour Index (1971) 77917, 77919, 77921; Hackh (1969); *OED* (2002); Salter (1869) 123, 171–172

URANIUM ORANGE

Yellow-Orange
Synonym, variant or common name

Listed by Salter (1869), who states that it 'is obtainable by wet and dry methods as a yellowish-red, or, when reduced to powder, an orange-yellow, uranate of baryta. It is an expensive preparation, superfluous as a pigment.'

Uranium group; Barium uranium oxide
Salter (1869) 260–261

URANIUM OXIDE

Variable
Synonym, variant or common name

See: uranium oxides and hydroxides group.

URANIUM OXIDES AND HYDROXIDES GROUP

Variable
Group term

Various uranium oxides are known and have apparently been used as pigments (*Colour Index*, 1971). Uranium(IV) oxide, UO_2, is listed in the *Colour Index* as a black-brown highly non-stoichiometric compound (CI 77915). It occurs naturally as the mineral uraninite (*q.v.*) but is also prepared synthetically by extracting uranyl nitrate with ether, by heating a higher oxide in hydrogen, or by hydrolysing uranium tetrachloride, although its use as a pigment is said to be limited. Uranium(VI) oxide, UO_3 (CI 77917), has been used as a red or yellow pigment and is prepared by heating uranyl nitrate or ammonium diuranate; uranium peroxide, $(UO_2)(O_2)(H_2O)_2$ (CI 77921), has been used as a yellow pigment and is prepared by adding hydrogen peroxide to an aqueous uranyl salt. Uranyl uranate, U_3O_8 (CI 77919), occurs naturally in pitchblende (*q.v.*) with uraninite, and has been used as an olive green to grey pigment. A further natural compound, uranic ochre, is mentioned by Hackh (1969) and is an ochre (*q.v.*) containing yellow uranium(III) oxide U_2O_3. Barium uranium oxide (*q.v.*), BaU_7O_2, and strontium uranium oxide have been used or proposed as pigments.

Uranium group; Barium uranium oxide; Ochre; Pitchblende; Uraninite; *Uranium yellow*
Colour Index (1971) 77915, 77917, 77919, 77921; Hackh (1969)

URANIUM RED

Red
Synonym, variant or common name

According to Salter (1869) uranium red was prepared by 'treating the yellow sulphite of uranium with a prolonged current of sulphuretted hydrogen, and saturating gradually with ammonia, a red finally results'.

Uranium group
Salter (1869) 179

URANIUM YELLOW

Yellow
Synonym, variant or common name

Synonym or common name for a uranium-based pigment of yellow colour (Doerner, 1935); this might be the peroxide ($(UO_2)(O_2)(H_2O)_2$), which is pale yellow, or possibly uranium(VI) oxide (UO_3), which is orange-yellow, or, most probably, barium uranate(IV), which is orange or yellow. According to Salter (1869), uranium yellow 'Can be produced of a pale or orange tint, differing in brightness and depth of colour according to the mode of preparation. It is fairly eligible as a pigment, and far superior to the many fugitive compounds which have from time to time appeared. Being very expensive, however, and not possessing the good qualities of its peers lately introduced, uranium yellow has but little chance of being employed now.' Both Doerner (1935) and Mayer (1991) state that this was a colour used in ceramics.

Uranium group; Uranium oxides and hydroxides group; Barium uranium oxide
Doerner (1935) 62; Mayer (1991) 60; Salter (1869) 123

UTPALA WATER

Yellow
Synonym, variant or common name

According to Sankrityayana (1937), utpala water was used to produce a yellow colour: 'Petals from the utpala flower (?) from Phem-bo and the leaves from the shun tree (?) of Bhutan are combined in a mixture of one to ten and boiled to obtain a yellow (lake?) which is used in the painting the "edges of leaves" ' (cf. Huntington, 1970). Meaning, composition and likely use are obscure.

Huntington (1970); Sankrityayana (1937)

UVATUM

Blue
Synonym, variant or common name

According to Schweppe (1997), uvatum is a term associated with woad (indigoid dyestuff derived from the plant *Isatis tinctoria*; *q.v.*).
See: woad

Indigo; *Woad*
Schweppe (1997)

UZONITE

Red-Orange-Yellow
Generic compound

Uzonite is a yellow monoclinic arsenic sulfide mineral with composition As_4S_5 about which relatively little is known. It was first reported by Popova and Poljakov in 1985 from the Uzon caldera (Kamchatka Peninsula, Russia), after which it is named, and its formation at this locality has been examined by Migdisov and Bychkov (1998). Uzonite was found as soft prismatic crystals and granular deposits in association with pyrite, realgar, orpiment, alacranite, stibnite, cinnabar and native sulfur (*qq.v.*). Uzonite is closely related to the other arsenic sulfide minerals realgar, pararealgar (AsS), orpiment (As_2S_3), alacranite (As_8S_9), duranusite (As_4S) and dimorphite (As_4S_3) and may oxidise to form arsenolite or claudetite (*qq.v.*).

Uzonite is mentioned by FitzHugh (1997) in the context of her review of orpiment and realgar, but is not otherwise considered to occur as a pigment in its own right.

Arsenic group; Arsenic sulfides group; Alacranite; Arsenolite; Cinnabar; Claudetite; Dimorphite; Duranusite; Orpiment; Pararealgar; Pyrite; Realgar; Stibnite; Sulfur
FitzHugh (1997); Migdisov & Bychkov (1998)

V

VACCINIUM

Blue
Common generic composite

The berries of *Vaccinium myrtillus* L. (Ericaceae) are a source of a blue dyestuff. The main colouring compounds are delphinidin-, cyanidin-, petunidin- and malvidin-glycosides (*q.v.*; Schweppe, 1992; Sato *et al*., 2001).
See: turnsol blue.

Delphinidin; *Turnsol blue*
Sato *et al.* (2001); Schweppe (1992) 400–401

VALENTINITE

White
Generic compound

Valentinite is an orthorhombic antimony oxide mineral with composition β-Sb_2O_3. It is polymorphous with the cubic senarmontite, α-Sb_2O_3 (*q.v.*), and is the higher temperature form (White *et al*., 1967). Valentinite occurs as prismatic to fibrous crystals with striated surfaces which radiate out in clusters from a host rock; aggregates and massive forms of this mineral may also be found. It is usually colourless or white but may also be yellow, red or grey. It forms by the oxidation of antimony-rich minerals and for this reason is often known as antimony bloom. Valentinite most commonly forms by the oxidation of the antimony sulfide mineral, stibnite (*q.v.*), and an intermediate oxidation product, kermesite (*q.v.*), is also known. Valentinite is found in localities associated with metal deposits such as Cornwall (England), Tyrol (Austria), Tuscany (Italy), Saxony (Germany), Attica (Greece), Dauphine (France), Djebel-Haminate mine (Algeria), La Paz (Bolivia), Quebec (Canada) and Durango (Mexico).

Valentinite is not known to have been used directly as a pigment. However, synthetic white antimony(III) oxide (Sb_2O_3, so-called antimony white; *qq.v.*) is used as a pigment (*Merck Index*, 1996) and is generally made from roasting stibnite in air (Heaton, 1928). Thus, both valentinite and senarmonite may be found as relicts from the roasting process.

Antimony group; Antimony(III) oxide; Kermesite; Senarmontite; Stibnite; *Antimony white*
Heaton (1928) 99; *Merck Index* (1996) 752; White *et al.* (1967)

VAN DYCK RED

Red
Synonym, variant or common name

According to Schweppe and Winter (1997, citing Seufert, 1955), Van Dyck red was an inexpensive madder lake of less brilliant colour prepared from inferior quality madder (*q.v.*).

Madder
Schweppe & Winter (1997); Seufert (1955) 65, 229

VANADINITE

Red-Orange-Yellow
Generic compound

Vanadinite is a lead vanadate mineral with composition $Pb_5(VO_4)_3Cl$, in which the VO_4 ions may be partially replaced by PO_4 or AsO_4. It occurs most commonly as deep red to orange short hexagonal prismatic crystals (Dai and Hughes, 1989; Rutley, 1988), although yellow or orange-brown acicular crystals, crusts and nodules may also be found. Vanadinite forms in the oxidation zone of lead deposits, usually in arid climates, and is often found in association with pyromorphite and mimetite, to which it is closely related, as well as wulfenite, galena, baryte and limonite and other apatite group minerals (*qq.v.*; Rutley, 1988). Vanadinite was described by Kobell in 1838 and its type locality is Zimapan (Mexico). It is used as a minor ore of lead and is known from localities such as Touissit, Morocco (White, 1984) as well as Tsumeb (Namibia), Bisbee (Arizona, USA), Broken Hill (New South Wales, Australia) and Cumbria (England).

Identification of vanadinite (lead vanadate) has been made during analysis of 22 Greek stèles in the Louvre (Rouveret and Walter, 1998; Walter *et al*., 1998); the normally orange-red to orange-yellow compound had deteriorated in this instance to black.

Vanadium group; Baryte; Galena; Limonite; Mimetite; Pyromorphite; Wulfenite
Dai & Hughes (1989); Rouveret & Walter (1998); Rutley (1988) 339–341; Walter *et al*. (1998); White (1984)

VANADIUM GREEN

Green
Synonym, variant or common name

Salter lists this in his 1869 edition of Field's *Chromatography*; it was evidently a vanadium hexacyanoferrate(II) compound as he states 'Vanadium Green falls when ferrocyanide of potassium is added to vanadic acid dissolved in a strong acid. It is a beautiful green precipitate, but at present simply a curiosity, owing to the rarity of the metal vanadium.' It is otherwise obscure and probably largely unused by artists. However, vanadium, as a transition element, is known to form V^{3+} and V^{5+} compounds; the former would reasonably substitute for the Fe^{3+} ion in iron(III) hexacyanoferrate(II).
See: vanadium group.

Hexacyanoferrate group; Vanadium group
Salter (1869) 291

VANADIUM GROUP

Variable
Group term

The principal members of the group are the vanadate pigments which are a suite of green-yellow to yellow-orange compounds of both natural and synthetic origin.

Oxides (*Vanadates*): bismuth vanadate ($BiVO_4$); clinobisvanite ($BiVO_4$); copper vanadate; dreyerite ($BiVO_4$); lead vanadate ($Pb_5(VO_4)_3Cl$); pucherite ($BiVO_4$); vanadinite ($Pb_5(VO_4)_3Cl$).

A vanadium hexacyanoferrate(II) ($V[Fe(II)(CN)_6]^{4-}$) is also known.

Vanadium affords a number of other coloured compounds which might also conceivably have been tried as pigments. For example, vanadium(V) oxide (V_2O_5) occurs as yellow to rust brown orthorhombic crystals and is used in the production of yellow glass; vanadium(III) fluoride (VF_3) forms an apparently stable greenish yellow powder, the trihydrate of which is dark green; vanadium(III) oxide is black but converts on exposure to air into the blue vanadium(V) oxide; vanadium(III) sulfate is lemon yellow and hydrates on exposure to moisture to a green form, while vanadium oxide sulfate ($VOSO_4$) is used as a textile mordant in the manufacture of coloured glass and for blue and green ceramic glazes (*Merck Index*, 1996).

Hexacyanoferrate group; Bismuth vanadate; Clinobisvanite; Copper vanadate; Dreyerite; Vanadinite; *Bismuth yellow*; *Vanadium green*; *Vanadium yellow*
Merck Index (1996) 10056, 10063

VANADIUM YELLOW

Yellow
Synonym, variant or common name

Heaton (1928) lists vanadium yellow as a by-then obsolete or rarely used pigment based on 'vanadic acid' (said by other sources to be an acid containing a vanadate group, especially HVO_3, H_3VO_4, or $H_4V_2O_7$, not existing in a pure state).

Vanadium group
Heaton (1928) 384

VANDYKE BROWN

Black-Brown
Synonym, variant or common name

The term Vandyke brown has been applied to a variety of compounds or compound groups historically. Church (1901) clarifies the situation in describing the three varieties of pigment which he is aware are referred to as Vandyke brown or 'Cologne earth': 'the first is made by calcining certain ferruginous earths or brown ochres; the second is nothing but a dark brown variety of colcothar; the third is a kind of brown earth containing, along with some iron oxide and hydrate, a good deal of organic substance in the forms of humus or bituminous matter'. The latter kind is most commonly referred to as Vandyke brown (although Church thinks it inferior), and he calls it Vandyke brown B. It is composed of naturally occurring, soft, impure varieties of brown coal or lignite, in effect a humic earth (*qq.v.*). Weber (1923) defines the general composition of Vandyke brown as 80% organic matter and moisture, and 20% mineral matter (iron oxide, alumina, calcium carbonate, silica). The pigment has been extensively reviewed by Feller and Johnston-Feller (1997).

Although Vandyke brown and other names referring to the same or similar materials are well cited and discussed in the historical sources, they have been poorly recognised in modern paint analyses. This is largely because the pigment is difficult to detect by many analytical techniques. Infra-red spectroscopy is, however, reliable. Feller and Johnston-Feller (1997) have used this technique to confirm the presence of humic earth-based pigments in early nineteenth century portraits from the Upper Hudson Valley. From contemporary sources, humic earth browns were well known to occur on the palettes of artists working in the sixteenth and seventeenth centuries (Von Sonnenberg, 1976; Kühn, 1977). Possibly, the earliest known use is from the early sixteenth century in two paintings attributed to Gerard David (c. 1460–1523; Butler, 1976). The pigment remains in use to this day. However, to quote Terry (1893) 'What the original brown used so much by the great Van Dyke [sic] was no one can tell.' Hopefully further analyses are forthcoming. Roy (1999) has identified 'umber or Cassel Brown' in an underdrawing for one of the Van Dycks in the National Gallery, London.

Akin to other hydrocarbon-based pigments, the colour was known to be fugitive on exposure to light and was a poor drier.

Terminology concerning Vandyke brown is confusing and wide, and refers to several different materials including the artificial 'Vandyke browns' developed from mixing earth pigments with black. So-called 'soluble Vandyke brown' was produced by dissolving Vandyke brown in ammonia, which dissolves all organic matter, and the insoluble residue was filtered off and evaporated. This was used as a water stain for woodwork, although by the time of Heaton's writing it had been largely replaced by the dye Bismark brown (Heaton, 1928). Heaton also states that artificial Vandyke brown was made by blending lamp black with a little iron oxide which produced a colour which was permanent but not as brilliant as the natural earth.

Typically the German humic earths are referred to as Cologne earth, Collens earth, Cullen earth, Cassel brown, Cassel earth, Castle earth, *Preto de Frandes* and *Terra di colonia*. The pigment has been called Vandyke brown largely by English and American sources. The umber, Cappagh brown once natural supplies were exhausted (probably in the late nineteenth century), was manufactured by mixing peat with burnt umber and or burnt sienna; this material resembles Vandyke brown both in colour and compositionally. Vandyke brown, as an umbrella term for humic earths and other associated pigments, has been reviewed by Feller and Johnston-Feller (1997).

Humic earth; Lignite; *Cappagh brown*; *Cassel earth*; *Cologne earth*; *Preto de Frandes*; *Terra di colonia*
Butler (1976); Church (1901); Feller & Johnston-Feller (1997); Heaton (1928) 170; Kühn (1977); Roy (1999); Sonnenberg (1976); Terry (1893) 107–108; Weber (1923) 115

VANDYKE BROWN, CALCINED

Black-Brown
Generic compound

Thermally modified form of Vandyke brown (*q.v.*), mentioned by Feller and Johnston-Feller (1997).

Vandyke brown
Feller & Johnston-Feller (1997)

VANDYKE RED

Red-Brown
Synonym, variant or common name

According to Mayer (1991), Vandyke red is a common name for copper ferrocyanide (copper hexacyanoferrate(II), *q.v.*), a pigment also known as Florence brown or Hatchett's brown. Brownish red, reddish violet or reddish brown shades can be made.

Copper hexacyanoferrate(II); *Florence brown*; *Hatchett's brown*
Mayer (1991) 60

VARLEY'S GREEN

Green
Synonym, variant or common name

Field (1835) states that this, like Hooker's green, is similar to a mixed green of Prussian or Antwerp blue and gamboge. The pigment is not mentioned by Field's later editor Salter (1869). It belongs to the category of mixed greens discussed in several nineteenth century sources such as Field (1835).

Hooker's green; *Mixed green*
Field (1835); Salter (1869)

VATERITE

White
Generic compound

Vaterite is a crystallographic and mineral form of calcium carbonate that is rare compared to the other polymorphs calcite and aragonite (*qq.v.*). It is named after the mineralogist Heinrich Vater. Vaterite is known to form in mother-of-pearl (nacre) in molluscs and in lacustrine algal mats as well as being a component of some birds' eggs. There is some historical use of mother-of-pearl (*q.v.*) as a lustre pigment and therefore vaterite may occur in this context.

Calcium carbonates group; Aragonite; Calcite; *Eggshell*; *Mother-of-pearl*

VEGETABLE VIOLET

Purple
Synonym, variant or common name

Mayer (1991) states that this is a bright violet lake pigment based on logwood (dye derived from *Haemotoxylon campechianum*).

Logwood
Mayer (1991) 60

VELVET BLACK

Black
Synonym, variant or common name

According to Beguin's *Dictionnaire* (1978–84), 'Velvet black' was a bone black, supposedly made from the feet of sheep.
See: carbon-based blacks group: cokes subgroup and bone.

Beguin (1978–84)

VELVET BROWN

Brown
Synonym, variant or common name

According to Mayer (1991), velvet brown is a mixture of raw or burnt umber and dark ochre.

Ochre; *Burnt umber*; *Fawn brown*; *Raw umber*
Mayer (1991) 60

VENEDA

Grey
Synonym, variant or common name

Alcherius (fifteenth century, Clarke MS 2970, cf. Merrifield) gives a recipe for veneda: 'To make a colour which is called venede or veneda take black and mix with white lead … or lime.' Theophilus (twelfth century) recommends veneda to paint eyes.

Merrifield (1849) 310; Theophilus (c.12th cent/Hawthorne & Smith, 1963) I.ch.6

VENETIAN EARTH

Yellow
Synonym, variant or common name

See: ancorca.

VENETIAN GREEN

Green
Synonym, variant or common name

Salter (1869), when discussing terms associated with sap green, adds that similar pigments were obtained from coffee berries and named Venetian green or emerald green.

Emerald green; *Sap green*
Salter (1869) 282–283

VENETIAN LAKE

Red
Synonym, variant or common name

Venetian lake is considered by Schweppe and Roosen-Runge (1986) to be a cochineal (*q.v.*) lake prepared by extraction of the dye with alum solution followed by precipitation with soda. Bouvier (1827) describes it as a pure cochineal lake and Salter (1869) lists it under the general heading of 'Cochineal Lakes', though fails to describe it in more detail. Along with similar terms such as Florentine, Parisian and Viennese lake, the name was probably fanciful in derivation. Harley (1982), however, postulates that as the place names attached to the lakes are often ports it is probable that this refers to the place of manufacture, the source material being imported into these ports.

Cochineal; *Florentine lake*; *Parisian lake*; *Viennese lake*
Bouvier (1827) 25; Harley (1982) 134; Salter (1869) 131; Schweppe & Roosen-Runge (1986)

VENETIAN RED

Red
Synonym, variant or common name

According to Church (1901), Venetian red originally 'consisted of a native ferric oxide or red haematite, less purplish in its tints and washes than Indian red'. However, he goes on to say that 'of recent years the name appears to have been transferred to a particular quality of artificial ferric oxide, made by calcining green vitriol'. Heaton (1928) describes it as 'reduced anhydrous iron oxide'. Fuller (1973) is more explicit, stating that it was prepared by calcination of copperas red (*q.v.*; a synthetic iron oxide produced by thermal decomposition of iron(II) sulfate hydrate) with hydrated lime, though he further remarks that at that time it was no longer either popular or economical to produce.

Salter (1869) gives alternate or equivalent names as English red, Prussian red and scarlet ochre, also stating that Spanish red differed little, and Zerr and Rübencamp (1906) give this as a synonym for Indian red (*qq.v.*).

Iron oxides and hydroxides group; *Red ochre*
Church (1901); Fuller (1973); Heaton (1928) 384; Salter (1869) 149–150; Zerr & Rübencamp (1906/1908) 390

VENETIAN WHITE

White
Synonym, variant or common name

According to Salter (1869), this was composed of equal proportions of 'heavy spar' (that is, the barium sulfate mineral baryte) and 'lead carbonate'.

Lead carbonates group; Baryte; Lead carbonate; *Lead white*
Salter (1869) 75

VENICE CERUSE

White
Synonym, variant or common name

See: biacca.

VENICE RED

Red
Synonym, variant or common name

Synonymous with Venetian red (*q.v.*).

VENICE WHITE

White
Synonym, variant or common name

According to Church (1901), Venice white was a combination of lead white and baryte in the proportion of 1:1.
See: biacca.

Baryte; *Biacca*; *Lead white*
Church (1901)

VERDE AZZURO

Green
Synonym, variant or common name

According to Gettens and FitzHugh (1993b) verde azzuro is synonymous with malachite (*q.v.*); however, Martin *et al.* (1995) have found evidence of the use of other 'mineral greens' on fifteenth century paintings. They further comment that copper greens found in Italian paintings of the fifteenth century may have been manufactured, as they have found metallic impurities (tin, zinc) which could indicate a synthetic source for the greens. It is therefore possible that the verde azzuro used by these painters may not have been malachite. Furthermore Martin *et al.* point out that the Bolognese manuscript (fifteenth century, Clarke MS 160; cf. Merrifield, 1849), for instance, explains that to obtain 'natural' verde azzuro one must 'take azure of whatever kind you like in fine powder, and put it to soak in soft water, and add to it so much saffron as it will make it a dark green', azure having been described earlier in the same manuscript as 'nostro azzuro' indicating Lombardian azurite (*q.v.*). Azurite can be thus tranformed into malachite.

Azurite; Malachite; Saffron; *Verdigris*
Gettens & FitzHugh (1993b); Martin *et al.* (1995); Merrifield (1849) 424, 348

VERDE ETERNO

Blue-Green
Synonym, variant or common name

Term associated with verdigris (*q.v.*; Kühn, 1993a).

Copper acetate group; *Verdigris*
Kühn (1993a)

VERDE GRANILLO

Green
Synonym, variant or common name

Verde granillo is mentioned by Carducho (1633) in his *Diálogos*; Veliz (1986) suggests in the notes to her translation that it might either be a granular green pigment such as the mineral chrysocolla or, on the basis that Palomino (1715–24) states it is not a mineral, a synthetic copper pigment such as that known as green verditer (copper carbonate hydroxide; *qq.v.*).

Chrysocolla; Copper carbonate hydroxide, malachite type; *Green verditer*
Carducho (1633); Palomino (1715–24); Veliz (1986) 198, n.10

VERDE VESSIE

Green
Synonym, variant or common name

Verde vessie – literally, 'bladder green' – was synonymous with sap green, a lake pigment traditionally made from dyes derived from the ripe berries of *Rhamnus* species (though some literature references also indicate the use of woad and blue iris).

Watin (1785) states that verde vessie (or *vert de vessie*) is prepared from the Persian or Avignon berries, which he calls *noirprun*. The berries have to be collected when they are black and very ripe, then pressed to form a viscous black liquid. This liquid is evaporated with a gentle heat, then alum dissolved in water added along with lime water, continuing to heat it gently 'until it has the consistency of honey'. The liquid is then suspended in a chimney in pig or beef bladders (from which the pigment gets its name) and left to harden in order to preserve it.
See: sap green.

Flavonoids group; *Sap green*; *Vert de vessie*
Watin (1773/edition of 1785) 29

VERDERAME

Blue-Green
Synonym, variant or common name

The so-called 'Paduan' MS *Ricette per Far Ogni Sorte di Colore* (cf. Merrifield, 1849) provides a recipe for this pigment: '16. *To make a good green of verderame*. Take 10 parts of verdigris, 2 of corrosive sublimate, half part of saffron, quarter of galls of Istria, half of sal ammoniac, grind them up with very strong vinegar … put into glass vase. When vinegar is clear and coloured, let it be decanted and evaporated in a glazed vase. [repeat] … grind up the colour with a little roche alum and a little gum Arabic, so as to make into a cake.'

Saffron; *Verdigris*
Merrifield (1849) II, 660

VERDETE

Green
Synonym, variant or common name

Term associated with verdigris (*q.v.*; Kühn, 1993a).

Copper acetate group; *Verdigris*
Kühn (1993a)

VERDETTO

Green
Synonym, variant or common name

According to authors such as Field (1835), *verdetto* was a green earth of warmer hue. It was also known as holy green.

Green earth
Field (1835) 128–129

VERDETTO DELLA MAGNA

Green

Synonym, variant or common name

Verdetto della magna is given as a term associated with malachite, presumably with the same construction and use as *azzurro della magna*, azurite (Gettens and FitzHugh, 1993b). ‘Della magna’ is probably an Italian corruption of ‘Allemagna’ – ‘German’.

Malachite; *Azzurro della magna*

Gettens & FitzHugh (1993b)

VERDIGRIS

Green

Synonym, variant or common name

The term verdigris has loose definition. It applies to corrosion products formed from copper and copper alloys following exposure to the atmosphere and more particularly to organic acids (particularly acetic and formic acid). Verdigris used as a pigment was generally deliberately manufactured for that purpose by exposing copper plates, strips or foil to organic substances such as vinegar, curdled milk, urine, wine lees and so forth. The green or blue encrustation produced could then have been further refined by dissolution in vinegar and subsequent recrystallisation through evaporation. Given the varieties of recipes used to produce verdigris (see Scott *et al*., 2001a; Scott, 2002) it is not surprising that no strict chemical substance was produced. Verdigris will most typically be a copper acetate compound (*q.v.*) of which there is a large variety; products are likely to be mixtures of these. However, the term might also be applied to various other copper compounds such as carbonates and chlorides. This complexity was clearly appreciated historically and documentary comments indicate that varieties were categorised according to, say, water solubility or suitability for a certain purpose.

It has also been suggested that copper(II) formates may be encountered, but there is little evidence to support their intentional use as pigments. An exception is the work of Pey (1998) who indicates that some of the greens from the Hafkenschied Collection, and particularly a sample labelled ‘Parrot green’ (*q.v.*), may be copper formate-based pigments. Scott *et al.* (2001a) believe that further identifications of similar forms of copper(II) formate-verdigris may be forthcoming.

The copper(II) acetates (ethanoates) are more typical of verdigris pigments. The formulae for the main acetate compounds related to so-called ‘basic verdigris’ are: (1) $[Cu(CH_3COO)_2]_2.Cu(OH)_2.5H_2O$; (2) $Cu(CH_3COO)_2.Cu(OH)_2.5H_2O$; (3) $Cu(CH_3COO)_2.[Cu(OH)_2]_2$; (4) $Cu(CH_3COO)_2.[Cu(OH)_2]_3.2H_2O$ and (5) $Cu(CH_3COO)_2\,[Cu(OH)_2]_4.3H_2O$. Compounds (1) to (3) are blue, (4) is green and (5) is blue-green (Scott, 2002, Kühn, 1993a, Rahn-Koltermann *et al*., 1991 and Gauthier, 1958). Only acetate (3) can exist alone (it is incompatible with the other compounds). Other products are impure mixtures of (1) and (2) or (2) and (4). However, Rahn-Koltermann *et al.* (1991) could not produce compound (2) and suggested therefore that it did not exist. They did, however, produce the additional compound (5), thereby suggesting further compounds may exist with the generalised formulae $[Cu(CH_3COO)_2]_x.[Cu(OH)_2]_y.zH_2O$, where $x = 1$, $y = 3$ and $z = 2$.

A ‘purer’, green compound called ‘neutral verdigris’ is prepared by dissolving the basic acetates above in acetic acid to form (6) $Cu(CH_3COO)_2.H_2O$ (copper(II) acetate hydrate). Other neutral verdigris compounds are the copper(II) acetate $Cu(CH_3COO)_2$ and the copper(I) acetate $Cu(CH_3COO)$. The latter two have less importance as pigments. Compound (6) was generally prepared by dissolving basic verdigris compounds in vinegar (Scott, 2002). Recipes for the manufacture of verdigris by modern and historical methods have been reviewed and recounted in detail by Scott *et al.* (2001a) and Scott (2002).

Other pigments described as verdigris have less expected origins. Scott (2002) cites the work of Laurie (1914) who identified verdigris with azurite (*q.v.*) on the sixteenth–seventeenth century *Coram Rege Rolls*. Scott here concludes that in this case the ‘verdigris’ was formed by dissolving azurite in vinegar. Purinton and Newman (1985) identified antlerite and atacamite (*qq.v.*), both naturally occurring corrosion products of copper in Indian paintings. Although these authors have called these pigments verdigris, it is not clear that they fit into the categories of synthetic pigments described above. Verdigris was used as a raw material for making the green glaze, commonly known as copper resinate.

Verdigris has always been regarded as a fugitive pigment, darkening dramatically from its original bright green or blue. Cennini (c. 1400, Clarke MS 590) writes that ‘it is nice to the eye but it does not last’. However, Woudhuysen-Keller (1995) points out that this is the case in many works of art, but in others it remains untainted and a bright green or blue. She states that preservation of colour depended upon the verdigris being thoroughly embedded in oil or an oil-resin varnish to prevent it coming into contact with the atmosphere and that yellow glazes (themselves sometimes prone to discoloration) would correct the bluish hue of many verdigris pigments. Verdigris was known to be adulterated with saffron to retard corrosion. Such use has been recognised by Barkeshli and Ataie (2002) on sixteenth to nineteenth century Persian and Indian miniatures (but see also Lee *et al*., 1997a). Woudhuysen-Keller and Woudhuysen (1998) have shown that neutral (recrystallised) verdigris was a more stable pigment than basic verdigris when used in oil. They also cite manuscripts suggesting the pigment be adulterated with rue (*Ruta graveolens*) to give a mossy green.

Verdigris has a long history of use. The classical author Vitruvius (first century BC) calls the pigment *aeruca*, as does Pliny (77 AD). The latter considers the compound primarily for medicinal uses and quotes from Theophrastus (c. 315 BC) in saying it was made from copper soaked in wine lees.

Olsson *et al.* (2001) have identified verdigris among pigments used in thirteenth century BC Egyptian papyri. Verdigris was in common usage as a pigment for easel paintings throughout the thirteenth to nineteenth centuries, generally going out of use in the early twentieth century. Notable occurrences of verdigris pigments in works of art have been reviewed by Kühn (1993a). More recent identification of the pigment includes its appearance on a fourteenth century Icelandic manuscript (Best *et al*., 1995) and the fifteenth century German manuscript of Barlaam and Josephat (in this instance, basic verdigris; Scott *et al*., 2001b). Verdigris has been detected on a *Virgin and Child* from the School of Durer (Ackroyd *et al*., 2000).

Various synonyms for verdigris have been used, based on either the methods of preparation or from regions that were known as centres of manufacture. The classical authors use the term *aeruca* or *aerugo*, i.e. ‘copper rust’. Merrifield (1849) lists names used in mediaeval manuscripts as *viride salsum*, *viride Hispanicum*, *viride Rothomagense* and *viride Graecum*. The latter, 'green of Greece' is probably the derivation of the modern 'verdigris' via *verd/vert de Grèce*. Harley (1982) adds *viride aeris*, 'copper green'. The pigment derived from the manufacturing process producing basic verdigris (also 'crude verdigris'), centred in the South of France and the Rhone Valley, was according to Merrifield called *verdete* and *cardenillo* by the Spanish. However, these pigments are more often described as being 'from Montpellier, Grenoble, Marseille etc.' Neutral verdigris, also called crystallised, distilled or purified verdigris, was frequently known as *verde eterno*. Woudhuysen-Keller and Woudhuysen (1998) cite the term *Flores Veneres* from a sixteenth century recipe for producing a blue verdigris. Bersch (1901) adds 'German' and 'Swedish' verdigris, these only differing from ordinary verdigris in the use of pure acetic acid.

Copper acetate group; Copper carbonates group; Copper group; Copper formate group; Copper halides group; Antlerite; Atacamite; Azurite; Rue; Saffron; *Crystallised verdigris*; *Distilled verdigris*; *Neutral verdigris*

Ackroyd *et al.* (2000); Barkeshli & Ataie (2002); Bersch (1901) 258–259; Best *et al.* (1995); Cennini (c. 1400/Thompson, 1960) 33; da Vinci (c. 1480/trans. McMahon, 1956) 128–129; Gauthier (1958); Harley (1982) 80–83; Kühn (1993a); Laurie (1914); Lee *et al.* (1997a); Merrifield (1849) ccxvii; Olsson *et al.* (2001); Pey (1998); Pliny (1st cent AD/Rackham, 1952) XXXIV.xxvi–xxviii; Purinton & Newman (1985); Rahn-Koltermann *et al.* (1991); Scott (2002) 270–294; Scott *et al.* (2001a); Scott *et al.* (2001b); Theophrastus (c. 315 BC/Caley & Richards, 1956) 57; Vitruvius (1st cent BC/Grainger, 1934) VII.xiii.1; Woudhuysen-Keller & Woudhuysen (1998); Woudhuysen-Keller (1995)

VERDITER

Blue-Green

Synonym, variant or common name

The term verditer is normally applied to synthetic copper carbonate hydroxide pigments with a chemistry identical to the naturally occurring minerals malachite and azurite (*qq.v.*). These pigments were used to replace the expensive mineral pigments and were typically called 'green' and 'blue' verditer, respectively; however, there is inevitable overlap in the terminology applied to the synthetic and natural varieties (see below). Recent reviews of the pigments have been written by Scott (2002) and Gettens and FitzHugh (1993a,b), and are discussed in further detail under the entries for blue verditer and green verditer.

The pigments were prepared routinely from about the fifteenth century by mixing copper sulfate with, variously, calcium carbonate, lime and sal ammoniac (ammonium chloride) or potash. Although chemically identical to the naturally occurring minerals, the synthetic preparations take on a distinctive spherulitic form that has not been observed in naturally occurring azurite and malachite.

Verditer may also be called Refiner's verditer (*q.v.*). Many of the terms applied to the verditers were also applied to malachite and azurite plus other synthetic copper greens and blues. Weber (1923) lists generic synonyms for blue copper carbonates as azurite, *bergblau*, bice, blue virditer (*sic*), cendre blue, chessylite lime blue, mountain blue, Neuwied blue, blue ashes, copper blue, cenere blue, *azul ceniza* and Bremen blue (*q.v.*; the latter is generally applied to copper hydroxide). The equivalent terms for the green copper carbonates are green verditer, mountain green, green bice and so forth. Harley (1982) additionally lists Sanders blue as probably being a corruption of *Cendres blue/bleu*.

Verditer is not to be confused with 'verdeterre' (that is, *terre vert* or green earth, *q.v.*).

Copper carbonates group; Copper group; Azurite; Green earth; Malachite; *Bice*; *Blue verditer*; *Bremen blue*; *Cendres bleues*; *Chessylite*; *Green verditer*; *Lime blue*; *Mountain green*; *Refiner's verditer*; *Sanders blue*; *Spherulitic malachite*

Gettens & FitzHugh (1993a); Gettens & FitzHugh (1993b); Harley (1982) 49–53; Scott (2002) 114–116; Weber (1923) 15, 87

VERMICULITE

Variable

Generic compound

See: clay minerals group: vermiculite sub-group.

VERMICULUM

Red

Synonym, variant or common name

Vermiculum – literally, 'little worm' – was a Latin term used in the mediaeval period to refer to kermes (*q.v.*; Clarke, 2001), found, for example, in Heraclius (tenth–thirteenth century) in this context. It must be noted, however, that in the first chapter of *Mappae Clavicula*, '*De vermiculo*', the term refers to vermilion (Heraclius). In the Vulgate edition of the Bible (St Jerome, 405 AD; Exodus 38:23) it states '*iuncto sibi socio Hooliab filio Achisamech de tribu Dan qui et ipse artifex lignorum egregius fuit et polymitarius atque plumarius ex hyacintho purpura vermiculo et bysso*'; this is an early and clear example of the use of 'vermiculo' to mean 'red' rather than 'little worm'. In the Wyclif translation of the Vulgate (1382) this is rendered as 'A worcher with nedlis, of iacynct, and purpur, reed clooth [altered from vermycle], and bijs.'

For further discussion of this term as a dyestuff, see: kermes.

Kermes; *Vermilion*

Clarke (2001) 30; Heraclius/Romano (10–13th cent./1996)

VERMILION

Red

Synonym, variant or common name

Vermilion is a widely used historical term for synthetic forms of the mineral cinnabar (mercury(II) sulfide). For a discussion of historical methods of preparation, see: mercury(II) sulfide, cinnabar type.

Pliny, writing in the first century AD, correctly states that the Greeks called (the Latin) *minium* 'cinnabar' (*κινναβαριζ*) to differentiate it from ochre and miltos (*qq.v.*). This was the purest available red, 'vermilion' which is produced from the mercury ore, cinnabar (HgS). The main source of cinnabar in the Mediterranean world was the mines in the Betic Mountains of south-west Spain (now called from the Moorish, Almaden), but it is known from other sources, and according to Theophrastus (c. 315 BC), was first discovered near Ephesus in Turkey. However, although Theophrastus clearly calls this 'artificial' cinnabar, it would seem that the ore was finely disseminated in a sediment and was concentrated through washing and sieving. However, the authors are currently unaware of cinnabar deposits in the region of Ephesus. The Hellenistic Greeks were certainly aware of the Spanish *minium*; Theophrastus refers to the pigment as 'Iberian cinnabar'. Strabo in the first century BC (with undisguised loyalty to his home town) says 'There are exported from Turdentania … large quantities of kermes [*κοκκος*] and miltos [*μιλτος*] which is not inferior to the Sinopean earth' (*Geography*, III.ii.6; Turdentania was in the Betics, the modern Sierra Morena, or Sierra de Almaden, Ciudad Real province, Spain).

Both Vitruvius (first century BC) and Pliny note that pure cinnabar pigment (*minium*) was unsuitable for painting outside as it turns black in the sunlight (and moonlight); however, it could be protected by a coat of oil and wax. It is well known, however, that this discoloration did not happen with *all* cinnabar-based paints and it has been recently shown (McCormack, 2000) that it occurs only in cinnabars containing traces of chlorine or in pigments exposed to the halogens. Moreover, Field (1835) is emphatic that blackening and fading in vermilion are always due to adulteration 'by mixture with lake or carmine … by red or orange lead'.

Minium was perhaps the Romans most valuable pigment and it was used in ambitious works and demonstrated great wealth. Perhaps the most spectacular use is in the Frieze of the Mysteries in *Oecus V* of the Villa of the Mysteries at Pompeii. This prized Spanish minium was very expensive. The price was indeed capped by law at 70 sesterces per pound to stop it rising out of all proportion. All the same this was still ten times more expensive than high quality red ochre from Sinope. The Frieze of the Mysteries demonstrates lavish expenditure on behalf of the patron. For those with tighter purse strings, Pliny says that minium may be adulterated with goats' blood, red lead ('second rate' minium) or crushed berries (he is probably referring here to Kermes red, see below).

According to Harley (1982) 'In English two names, cinnabar and vermilion, have been used interchangeably in the past to describe either the natural or the manufactured product, but, by the seventeenth century, vermilion was used more frequently. Browne [Alexander Browne, *Ars Pictoria*, 1669] speaks of artificial vermilion and native cinnabar, but it does not seem to have been until the second half of the eighteenth century that cinnabar was applied only to the unground, native mineral.' On Chinese vermilion, Field (1835) comments that it is 'A native cinnabar so pure as to require grinding only to become very perfect vermilion … Chinese vermilion is of a cooler or more crimson tone than that generally manufactured from factitious cinnabar in England, Holland and different parts of Europe.'

Carlyle (2001) lists a number of nineteenth century British terms indicating shade and/or source variants of vermilion including Chinese v., carmine v., European v., pale v. deep v. and (Field's) orange v. as well as scarlet v. and extract of v. Typical adulterants of the period are given by Salter (1869) and Standage (1887); these include brickdust and orpiment as well as iron oxide, Persian red and iodine scarlet (*qq.v.*). Toch (1916) describes permanent v. as well as American quicksilver v. and Trieste v., the latter so called because it was found and made in the region.

Mercury(II) sulfide, cinnabar type; Cinnabar; Kermes; Lead(II,IV) oxide; Mercury iodide; Minium; Ochre; Orpiment; Red ochre; *Persian red*; *Sinoper*
Carlyle (2001) 511; Field (1835) 93; Gettens *et al.* (1993b); Harley (1982) 125; McCormack (2000); Pliny (1st cent AD/Rackham, 1952) XXXIII.xxxviii, XXXV.xii; Salter (1869) 153–158; Standage (1887); Strabo (1st cent BC); Theophrastus (c. 315 BC/Caley & Richards, 1956) 58; Toch (1916) 66–67; Vitruvius (1st cent BC/Grainger, 1934) VII.viii.1, VII.ix.1

VERMILIONETTE
Red
Synonym, variant or common name

Heaton (1928) describes the formation of substitutes for vermilion (*q.v.*), known variously as vermilionette, royal red, signal red, Victoria red and so forth, where dyes such as eosin were precipitated onto 'orange lead' (lead(II,IV) oxide) rather than a white base such as aluminium hydroxide. He describes the resulting pigments as 'very brilliant' and with 'considerable opacity', but notes their fugitive character.

Eosin; Lead(II,IV) oxide
Heaton (1928) 196

VERNALIS
Green
Synonym, variant or common name

Vernalis was the name given by the Society of Tempera Painters to a pigment made by heating chalk and viridian (chromium oxide hydrate) with a trade name of *Victoria green* (a mixed green of viridian and zinc yellow; however, probably of variable composition). This was a potter's pigment recommended for use by the Society for Painters in Tempera for use with tempera and fresco (Burton, 1907).

Chalk; *Victoria green*; *Viridian*
Burton (1907)

VERNET GREEN
Green
Synonym, variant or common name

Mayer (1991) associates this term with Bremen green.

Bremen green
Mayer (1991) 46, 61

VERONA BROWN
Brown
Synonym, variant or common name

Specific use of the term Verona brown appears to have been a nineteenth century introduction. Merrifield (1849), for example, states in a discussion of burnt green earth that 'modern writers do not mention this colour, but the use of it has been revived by an eminent English artist, under the name of "Verona Brown" '. Linton (1852) states that 'When calcined, [terre verte] forms another beautiful pigment called Verona Brown.' However, Salter (1869) calls it 'a native ferruginous earth' without indicating other processing. Toch (1916) says that Verona brown was a fancy name for a mixture of burnt umber and burnt or raw sienna. By the time Heaton was writing in 1928 he considered the term to be obsolete or only rarely used.

Green earth; *Green earth*, *burnt*
Heaton (1928) 384; Linton (1852) 55; Merrifield (1849); Salter (1869) 353; Toch (1916)

VERONA EARTH
Green
Synonym, variant or common name

A variety of green earth (*q.v.*). According to Grissom (1986) this was 'The most famous source of the pigment, that near Verona, Italy, was described as early as 1574 by Mercati in the catalogue of the Vatican mineral collection (de Brignoli de Brunnhoff, 1820). The designations terra verde di Verona, terra di Verona, Verona earth and Verona green have long been used to denote pigment from this source. Its excellent reputation encouraged the adoption of the name for green earths from other sources.'

Green earth
Brignoli de Brunnhoff (1820) 356–357; Grissom (1986)

VERONA GREEN

Green
Synonym, variant or common name

See: Verona earth.

VERONA YELLOW

Yellow
Synonym, variant or common name

Heaton (1928) lists Verona yellow as a by-then obsolete or rarely used term synonymous with Turner's yellow (lead chloride oxide; *q.v.*).

Lead chloride oxide; *Turner's yellow*
Heaton (1928) 384

VÉRONÈSE GREEN

Green
Synonym, variant or common name

Carlyle (2001) points out that in France, Véronèse green was probably first applied to a compound of copper and arsenic (the English emerald green). Salter (1869) states that French Véronèse green was often adulterated with arsenic; however, this term appears to have been applied to various pigments including chrome green and viridian (*qq.v.*; Newman, 1997). Alternately, discussing emerald green, Fiedler and Bayard (1997) state that 'In France, emerald green was called vert Paul Véronèse (or *vert Véronèse*) after the sixteenth-century Venetian painter Paolo Veronese; it is not clear why it was named after this artist since his career predates the pigment.' They go on to suggest that it was probably a proprietary colour term since authors such as Guignet (1888) speak of the beautiful colour and special preparation without actually explaining how to prepare it, and Coffignier (1924) describes it as 'an arsenical colour prepared in Germany and England whose method of preparation has not been described apart from the fact that it contains arsenic and copper'.

Other sources also indicate that Véronèse green could be used to mean green earth (*q.v.*; Toch, 1925; Wehlte, 1975; Grissom, 1986) though it may be that there was a confusion in this context between Verona and 'Veronese' (that is, 'from Verona'), that city being the location of a famous source of green earth ('Verona earth, *q.v.*).

Green earth; *Chrome green*; *Emerald green*; *Verona earth*; *Viridian*
Carlyle (2001) 158–159, 228, 493–494; Coffignier (1924); Fiedler & Bayard (1997); Grissom (1986); Guignet (1888); Newman (1997); Salter (1869) 268; Toch (1925); Wehlte (1975)

VERT ANGLAIS

Green
Synonym, variant or common name

Heaton (1928) lists *Vert Anglais* as a then-current term for a pigment composed of emerald green (*q.v.*).

Emerald green
Heaton (1928) 384

VERT ARNAUDON

Green
Synonym, variant or common name

See: Arnaudon's chrome green.

VERT DE CHROME

Green
Synonym, variant or common name

Vert de chrome is synonymous with chromium oxide (*q.v.*). (Newman, 1997).

Chromium oxide
Newman (1997)

VERT DE VESSIE

Green
Synonym, variant or common name

See: verde vessie.

VERT DE ZINC

Green
Synonym, variant or common name

See: zinc green.

VERT DINGLER

Green
Synonym, variant or common name

See: vert Schnitzer.

VERT ÉMERAUD

Green
Synonym, variant or common name

See: emerald green.

VERT SCHNITZER

Green
Synonym, variant or common name

See: Schnitzer's green and Arnaudon's chrome green.

VERTS SOLIDES

Green
Synonym, variant or common name

According to Coffignier (1924), Verts solides was a mixed green made in Germany comprised of hydrated chromium oxide (viridian) with zinc yellow and sometimes barium sulfate (*qq.v.*). This produces a less saturated and more opaque colour which is more stable (Coffignier, 1924). This colour is grouped by Coffingier under the term Victoria green.

Barium sulfate; *Chrome green*; *Victoria green*; *Viridian*; *Zinc yellow*
Coffignier (1924)

VERZINO

Red
Synonym, variant or common name

An Italian term for brazilwood lake.
See: brazilwood.

VESTORIAN BLUE

Blue
Synonym, variant or common name

In his discussion of the blue pigment *caeruleum*, the classical author Pliny (77 AD) describes a number of varieties including *Vestorianum*, or 'Vestorian blue'. These are all interpreted as being Egyptian blue (calcium copper silicate). Vitruvius (first century BC) states that caeruleum came originally from

Alexandria, but that Vestorius had founded a factory in Puteoli (modern Pozzuoli) to manufacture it.

Calcium copper silicate; *Caeruleum*; *Egyptian blue*
Pliny (1st cent AD/Rackham, 1952) XXXIII.lvii.161–163; Vitruvius (1st cent BC/Grainger, 1934) VII.xi.1

VIBERT BROWN
Brown
Synonym, variant or common name

Vibert (1892; cf. Carlyle, 2001) describes this brown pigment as 'a mixture of lithanthrax and oxide of iron on an aluminium basis'. Lithanthrax is used as a scientific name for mineral coal (that is, 'coal' in the modern sense; *q.v.*), in distinction from xylanthrax, which is charcoal (*OED*, 2002).

Iron oxides and hydroxides group; Coal
Carlyle (2001) 480; *OED* (2002) 'Lithanthrax'; Vibert (1892)

VICTORIA GREEN
Green
Synonym, variant or common name

Eibner (1909) has noted that *permanentgrün* and *viktoriagrün* (both German terms) were mixed colours comprised of hydrated chromium oxide (viridian) with zinc yellow and sometimes barium sulfate, Coffignier (1924) adding that in France these were also sold as *verts solides*. Heaton (1928) describes the composition as being the same as that of Brunswick green, which he states is compounded of 'mixtures of Prussian blue, chrome yellow and barytes'. According to Kühn and Curran (1986), Victoria green is a mixture of zinc chrome green (itself a mixture of Prussian blue and zinc yellow) and hydrated chromium oxide. Mayer (1991) on the other hand states that it is composed of '80 parts viridian, 40 parts zinc yellow and 10 parts of barytes, gypsum, lithopone or zinc oxide'.

Barium sulfate; Baryte; Gypsum; Zinc oxide; *Brunswick green*; *Chrome green*; *Chrome yellow*; *Lithopone*; *Permanent green*; *Prussian blue*; *Vernalis*; *Verts solides*; *Viridian*; *Zinc yellow*
Coffignier (1924) 457; Eibner (1909); Heaton (1928) 384; Kühn & Curran (1986); Mayer (1991) 61

VICTORIA RED
Red
Synonym, variant or common name

Victoria red is listed by Heaton (1928) as a then-current term for a pigment composed of chrome red as well as a form of eosin lake known as vermilionette (*qq.v.*). It is also listed by Kühn and Curran (1986) as an older term for basic lead chromate (lead chromate(VI) oxide, *q.v.*) in their review of chrome red and chrome orange (*qq.v.*) pigments.

Eosin; Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*; *Vermilionette*
Heaton (1928) 196, 384; Kühn & Curran (1986)

VIENNA BLUE
Blue
Synonym, variant or common name

According to Rose (1916), citing Tschelnitz writing in the *Farbenchemie Wien* of 1857, cobalt blue made using arsenic was also called Leithner blue and Viennese (or Vienna) blue.

Cobalt aluminium oxide; *Cobalt blue*; *Leithner's blue*
Rose (1916) 288

VIENNA GREEN
Green
Synonym, variant or common name

Vienna green is listed by Fiedler and Bayard (1997) as one of the less common names applied to emerald green (*q.v.*). Mayer (1991) also describes Vienna green as a synonym for mitis green (*q.v.*).

Emerald green; *Mitis green*; *Scheele's green*
Fiedler & Bayard (1997); Mayer (1991) 61

VIENNA LAKE
Red
Synonym, variant or common name

Heaton (1928) lists Vienna lake as an obsolete or rarely used term for a brazilwood lake. It is probably related to Viennese lake, though this latter term is considered to be a cochineal-based lake prepared by extraction of the dye with alum solution followed by precipitation with soda (Schweppe and Roosen-Runge, 1986).

Brazilwood; Cochineal; *Viennese lake*
Heaton (1928) 384; Schweppe & Roosen-Runge (1986)

VIENNA RED
Red
Index designation

In their discussion of chrome red and chrome orange (*qq.v.*) pigments, Vienna red is listed by Kühn and Curran (1986) as an older term for basic lead chromate (lead chromate(VI) oxide, *q.v.*).

Lead chromate(VI) oxide; *Chrome orange*; *Chrome red*
Kühn & Curran (1986)

VIENNA WHITE
White
Synonym, variant or common name

Vienna white appears to have been applied to two distinct pigments – lead white and a calcium carbonate (*qq.v.*) white. Field (1835) lists *Crems*, *Krems* and *Kremnitz white*, closely related terms meaning lead white, as also called 'Vienna white, being brought from Vienna in cakes of cubical form'. Mayer (1991) on the other hand describes Vienna white as 'chalk [i.e. calcium carbonate] made by air-slaking lime, as in the production of bianco sangiovanni'.

Calcium carbonates group; chalk; *Bianco di Sangiovanni*; *Cremnitz white*; *Lead white*
Field (1835) 69; Mayer (1991) 61

VIENNA YELLOW
Yellow
Synonym, variant or common name

Vienna yellow is listed by Kühn and Curran (1986) as a synonym for chrome yellow (*q.v.*).

Lead chromate(VI); *Chrome yellow*
Kühn & Curran (1986)

VIENNESE LAKE
Red
Synonym, variant or common name

Viennese lake is stated by Schweppe and Roosen-Runge (1986) to be a cochineal (*q.v.*) lake prepared by extraction of the dye with alum solution followed by precipitation with soda. Along with similar terms such as Florentine, Parisian and Venetian lake, the name was probably fanciful in derivation; however, a relationship might also be supposed with Vienna lake, which according to Heaton (1928) was then an obsolete or rarely used term for a brazilwood-based (*q.v.*) lake.

Brazilwood; Cochineal; *Florentine lake*; *Parisian lake*; *Venetian lake*; *Vienna lake*
Heaton (1928) 384; Schweppe & Roosen-Runge (1986)

VIKTORIAGRÜN

Green
Synonym, variant or common name

See: victoria green.

VINE BLACK

Black
Synonym, variant or common name

Vine black may refer to a char of woody material from vines (*Vitis* spp.), but has been historically applied to chars and cokes of a wide range of other materials such as yeasts and, as Winter (1983, citing the third edition of Mayer's *The Artists' Handbook of Materials and Techniques*, 1970) puts it, 'various second-rate materials of vegetable, animal and petroleum origins'. Tingry (1804), however, states that this does in fact come from burnt vine twigs.

It is sometimes listed as *Rebenschwartz* (German). See: carbon-based blacks group: chars sub-group.

Carbon-based blacks group; Carbon-based blacks group: Chars sub-group; Carbon-based blacks group: Cokes sub-group; *Charcoal*; *Grape black*; *Wine lees black*
Tingry (1804) 350; Winter (1983)

VIOLET BLUE

Blue-Purple
Synonym, variant or common name

De Massoul (1797) discusses Violet blue with smalt, enamel blue and cobalt blue (*qq.v.*) as deriving from cobalt ore.

Smalt; *Cobalt blue*; *Enamel blue*
Massoul (1797)

VIOLET CARMINE

Purple
Synonym, variant or common name

According to Salter (1869), violet carmine was prepared from a dye derived from the root of *Anchusa tinctoria* (now *Alkanna lehmannii* Tineo). While most other authors of the period concur with this, Seward (1889; cf. Carlyle, 2001) exceptionally lists it as derived from cochineal.
See: alkanet.

Alkanet; Cochineal
Carlyle (2001) 502; Salter (1869) 302–303; Seward (1889) 64

VIOLET MADDER LAKE

Purple
Synonym, variant or common name

Mayer (1991) states this is a synonym for alizarin violet, a pigment produced from synthetic purpurin in the same manner as an alizarin lake.

Purpurin; *Alizarin violet*
Mayer (1991) 61

VIOLET ULTRAMARINE

Purple
Synonym, variant or common name

See: ultramarine violet.

VIRIDE AERIS

Blue-Green
Synonym, variant or common name

'*Viride aeris*' is one of the many terms associated with verdigris (*q.v.*; Kühn, 1970, 1993a).

Copper acetate group; *Verdigris*
Kühn (1970); Kühn (1993a)

VIRIDE GRAECUM

Blue-Green
Synonym, variant or common name

See: verdigris.

VIRIDE HISPANICUM

Blue-Green
Synonym, variant or common name

Theophilus (c. twelfth century) describes two different modes of preparation for verdigris (various copper acetate compounds), *viride salsum* and *viride Hispanicum* (literally 'Spanish green'); the latter is formed when copper is exposed to vinegar or urine. Many writers do not distinguish between the various verdigris preparations and refer synonymously to *viride salsum, viride Hispanicum, viride Graecum* and *viride Rothomagense* (Merrifield, 1849); however, Banik (1989) found the various recipes produced a mixture of copper salts – basic and neutral copper acetates and some malachite and atacamite.
See: *viride salsum*.

Copper acetate group; *Viride salsum*; *Spanish green*; *Verdigris*
Banik (1989); Merrifield (1849) ccxvii; Theophilus (c. 12th cent/ Hawthorne & Smith, 1963) I.36

VIRIDE SALSUM

Blue-Green
Synonym, variant or common name

Theophilus (c. twelfth century) describes two different modes of preparation for *verdigris* (various copper acetate compounds), *viride Hispanicum* and *viride salsum*, literally, 'salt green', the latter being formed when copper covered in honey and salt is exposed to urine or vinegar vapours. Many writers do not distinguish between the various verdigris preparations and refer synonymously to *viride salsum, viride Hispanicum, viride Graecum* and *viride Rothomagense* (Merrifield, 1849). Banik (1989, cf. Scott 2002) found the various recipes produced a mixture of copper salts; in the case of *viride salsum*, some malachite, atacamite, and in the area of the honey, nantokite. Several mediaeval manuscripts give recipes for *album viride* (cf. Oltrogge, 2003), clearly a mixture of verdigris or a green earth with lead white and *viride croceum*, a mixture with saffron or orpiment.

Copper acetate group; Copper halides group; *Salt green*; *Verdigris*
Banik (1989); Merrifield (1849) ccxvii–ccxviii; Oltrogge (2003); Scott (2002); Theophilus (c. 12th cent/ Hawthorne & Smith, 1963) I.36

VIRIDIAN

Green
Synonym, variant or common name

Viridian is a hydrated chromium oxide (chromium(III) oxide dihydrate). Riffault *et al.* (1874) describe this as 'remarkable for its property of preserving brightness and purity under artificial light'. This transparent form of chromium oxide was developed by Pannetier about 1838 who only communicated his secret to Binet who also manufactured it. It was some time later that Guignet reproduced the colour by a 'curious reaction' which he patented in 1859 (Coffignier, 1924). It was first described in England by Salter (1869) and was included in the Winsor & Newton catalogue of that year (Carlyle, 2001). Scott Taylor described it in 1885 as a sesquioxide of chromium. It was considered a beautiful and durable colour which was sold at high cost.

There were, however, a number of manufacturing variants, so, for example, we find Terry writing in England at the end of the nineteenth century listing as many as 12 distinct methods of preparation; these include forms such as that known as Arnaudon's chrome green (*q.v.*) (a chromium phosphate). It is generally prepared, however, by calcining a bichromate compound with boric acid and then hydrolysing this while washing to remove soluable matter (Patton, 1973j).

Viridian, like chromium oxide, is expensive to produce and therefore had limited use. It has, however, been found on numerous French impressionist paintings in the National Gallery, London (Bomford *et al*., 1990), in paintings by van Gogh (Leighton *et al*., 1987) and German neoclassical painters in the Schack Gallerie in Munich (Kühn, 1969).

Other terms listed by Church (1901) are Pannetier's green ('vert Pannetier'), Giugnet's green ('vert de Guignet'*)*, Mittler green, *vert émeraude* and emerald oxide of chromium. Further synonyms include: Casali's green, transparent oxide of chromium, Nürnberg green and emerald chromium. Veronese green, although originally referring to a copper arsenic compound, became synonymous with viridian in England sometime in the second half of the nineteenth century.

Mixtures of viridian have been manufactured; with zinc yellows these include so-called Victoria green*,* permanent green and *verts solides*, and with ultramarine academy blue. Church (1901) states that it was also mixed with barium chromate to alter the hue. It is listed in the *Colour Index* as CI 77289/Pigment Green 18.
See also: chromuim oxide hydrate.

Chromium oxides and hydroxides group; Chromium oxide hydrate; *Casali's green*; *Chrome sesquioxide*; *Emerald oxide of chromium*; *Guignet's green*; *Mittler's green*; *Nürnberg green*; *Pannetier's green*; *Transparent oxide of chromium*; *Veronese green*
Bomford *et al*. (1990); Carlyle (2001) 158–159, 472, 491–493; Church (1901) 194–195; Coffignier (1924) 451–452; *Colour Index* (1971) 77297; Kühn (1969); Leighton *et al*. (1987); Patton (1973j); Riffault *et al*. (1874) 568; Salter (1869) 269; Scott Taylor (1885) 136; Terry (1893) 125–129

VITRUM

Blue
Synonym, variant or common name

See: indigo.

VITRY WHITE

White
Synonym, variant or common name

Riffault *et al*. (1874) describe Vitry white as composed of variable proportions of zinc white and barium sulfate.

Barium sulfate; *Zinc white*
Riffault *et al*. (1874)

VIVIANITE

Blue
Generic compound

Vivianite is a hydrous iron phosphate mineral with composition $Fe_3(PO_4)_2.8H_2O$. Vivianite occurs as soft white crystals with sectile fracture which transform to dark blue or blue-green crystals on contact with air. The mineral occurs as radiating prismatic or fibrous crystals, as concretions or as an earthy deposit, when it is commonly known as blue iron ore. It forms as a secondary mineral in two main environments. The first is in the vicinity of iron, lead, tin and copper deposits: vivianite is most well known from the St Agnes mine (Cornwall, England) where it was discovered by Werner in 1817; it is also known from elsewhere in the British Isles (Whale Chine, Isle of Wight), the ore deposits in Salzburg (Austria), Saxony (Germany), Colorado (USA), Buckland River (Queensland, Australia), Minas Gerais (Brazil) and Chihuahua (Mexico). Vivianite also forms within lacustrine sediments or peat deposits where oxygen and calcium contents are low and where organic material is present (such as Lake Malawi, Malawi (Kalindekafe, 1993); Thessaly, Greece (Stamatakis and Koukouzas, 2001); Lake Baptiste and Narrow Lake, Alberta, Canada (Manning *et al*., 1991, 1999)). Under these conditions, vivianite is often found with pyrite (*q.v.*) lining fossil bones and shells, or in nodules with manganite, goethite and nontronite (*qq.v.*) formed from the dissolution of apatite group minerals (derived from the organic matter, in particular fish debris) and redeposition under reducing conditions.

The colour formation in vivianite is due to the oxidation of Fe^{2+} to Fe^{3+}, leading to intervalency charge transfer between paired ions at the surface and along crystal cleavages (Hanzel *et al*., 1990). The mineral is otherwise generally stable in colour (Watson, 1918), though Howard (1995) indicates that she found discoloration of the vivianite to yellow, causing greenness in a paint film, a phenomenon which might be due either to changes in the balance of Fe^{2+} and Fe^{3+} or else conversion to the related mineral metavivianite (*q.v.*).

Field (1835) described a mineral colour called blue ochre 'of rare occurrence found in Cornwall, and also in North America' which he expressed as being a 'sub-phosphate of iron', the second edition (1841) adding that it is found with iron pyrites; Field is clearly referring here to the mineral vivianite. Harley (1982) states that this colour is mentioned in late eighteenth and early nineteenth English sources.

Recent identifications of vivianite include those by both Nauer (1984) and Eggert (1989) in Roman paint residues from Germany, by Richter (1988) on six objects from southern Germany dating to the period 1150 to 1235 (the author also noting deposits of vivianite in the Bavarian forest), by Funders and Möller (1989) from painting in rooms in Lower Saxony (Germany), by Howard (1995) in English mediaeval wall paintings at Winchester, c. 1180, by Filatov *et al*. (1965) on eleventh to eighteenth century icons and by Koller (1993) on seventeenth to eighteenth century Austrian paintings. Hill (2001) has found rare occurrences of vivianite used as a pigment in Papua New Guinea, where the Wiru people of the Southern Highlands apply it to arrowheads and spirit masks.

Rose (1916) states that *Eisenblau* ('iron blue') and *Blaueisenerde* ('blue iron earth') were terms for vivianite; iron blue more commonly refers to Prussian blue.

Apatite group; Iron group; Iron phosphates group; Goethite; Iron phosphate hydrate; Manganite; Metavivianite; Nontronite; Prussian blue; Pyrite; *Blue ochre*; *Native Prussian blue*
Eggert (1989); Field (1835); Filatov *et al.* (1965); Funders & Möller (1989); Hanzel *et al.* (1990); Harley (1982) 59; Hill (2001); Howard (1995); Kalindekafe (1993); Koller (1993); Manning *et al.* (1991); Manning *et al.* (1999); Nauer (1984); Richter (1988); Rose (1916) 223; Stamatakis & Koukouzas (2001); Watson (1918)

VOLKONSKOITE

Green
Generic compound

Volkonskoite is a hydrated aluminosilicate mineral with composition $Ca(Cr,Mg,Fe)_2(Si,Al)_4O_{10}(OH)_2.4(H_2O)$. It was named after the Russian prince and minister, P.M. Volkonskoi (1776–1852; Dana, 1932). Volkonskoite is a member of the clay minerals group (specifically the smectite sub-group; *qq.v.*) and is defined as being particularly rich in calcium and chrome (Foord *et al.*, 1987; Mackenzie, 1984); it may also contain elements such as Ti, Na, Mn and K as impurities. It occurs as soft fine green scaly or fibrous crystals which have a resinous lustre. It is a relatively rare mineral which forms as a secondary mineral in the voids of sedimentary rocks as a result of the local decomposition of organic matter (as in the Okhansk region, Ural Mountains, Russia), or as a weathering product of serpentinite (such as at Gotse Delchev, Bulgaria) where it is often found with members of the chlorite group (*q.v.*) of minerals.

Currently available as a pigment from Kremer Pigmente, Germany.

Chlorite group; Clay minerals group; Clay minerals group: Smectite sub-group; Sheet silicates group
Dana (1932) 681; Foord *et al.* (1987); Mackenzie (1984)

VOSSEN BLUE

Blue
Synonym, variant or common name

Vossen blue is the trade name used by Degussa, Germany, for their 'iron blue' (that is, hexacyanoferrate(II) compounds) products (Berrie, 1997; Buxbaum, 1998).

Hexacyanoferrate group; *Iron blue*
Berrie (1997); Buxbaum (1998) 131

W

Wad

Black-Brown
Common generic composite

Wad is a generic term usually referring to black or dark brown, impure earthy deposits composed primarily of the oxides and hydroxides of manganese and iron. Wad (alternatively spelled wadd or wadt) is a colloquial term used by miners in the North of England and has therefore also been applied to other black, non-hydrocarbon mineral deposits including graphite (Tyler, 1995). Ford (2001) defines wad as an impure manganese deposit containing about 50% manganese oxides, thus differentiating it from umber which should contain less than 20% manganese oxides. However, the two materials could be said to be gradational in composition. Wad is composed of a mixture of pyrolusite ($MnO_2.nH_2O$), birnessite ($Na_4Mn_{14}O_{27}.9H_2O$), todorokite ($(Mn_2, Ca, Mg)(Mn_3O_7.H_2O)$) and the psilomelane group mineral, romanechite ($BaMn_9O_{16}(OH)_4$). Hydrated iron oxides generally classified as limonite are also present. Additionally, traces of baryte, lead, various clay minerals and quartz may be present. Ure (1847) describes wad as having equal amounts of the oxides of iron and manganese.

Other terms used in reference to this material include bog manganese, black wad, black wadd (Bristow, 1996b), black earth and '*ochra friabilis nigra-susca*' (Mendes Da Costa, 1757). Absolite (alternatively known as asbolan, earthy cobalt and black oxide of cobalt) is a hydrated manganese oxide deposit containing up to 40% cobalt oxide, cobalt sulphide plus trace amounts of copper, iron and nickel oxides. This deposit occurs in associaton with cobalt and manganese ores. Heaton (1928) described the pigment as having a greenish coloration.

Wad is one of the earliest used pigments. Black pigments based on hydrated manganese oxide earths are well known from European Palaeolithic cave art (see: Vouvé *et al*., 1992; Guineau *et al*., 2001) and from contexts in the pre-Hispanic Canary Islands (Sánchez-Moral *et al*., 2002). During the eighteenth century, wad was used as an industrial pigment, particularly for painting ships and houses. Josiah Wedgwood investigated its use as a colourant for ceramic bodies and also noted its occurrence on the palettes of contemporary artists working in the British Midlands (Wedgwood, 1783). Tingry (1830) notes that wad was derived from Derbyshire but also occurred in Devon and Somerset and that it was useful for painting exterior ironwork in a medium of tar oil. Bristow (1996b) reviews briefly the use of 'black wadd' in domestic painting.

Clay minerals group; Manganese oxides and hydroxides group; Baryte; Birnessite; Graphite; Limonite; Pyrolusite; Pyromorphite; Quartz; Romanechite; Todorokite; Umber

Bristow (1996b) 59; Ford (2001); Guineau *et al*. (2001); Heaton (1928) 166; Mendes Da Costa (1757); Sánchez-Moral *et al*. (2002); Tingry (1830) 83; Tyler (1995); Ure (1847); Vouvé *et al*. (1992); Wedgwood (1783)

Wairakite

White
Generic compound

Wairakite is a calcium aluminium silicate mineral of ideal composition $CaAl_2Si_4O_{12}.2H_2O$. Named after the locality where it was first noted (Wairekei, New Zealand; Steiner, 1955), it forms in cavities in rocks and as grains in sandstones and clay deposits. It has also been identified by the authors as a phase in pigments excavated at Pompeii.

Steiner (1955)

Waisdo

Blue
Synonym, variant or common name

See: indigo.

Walnut

Brown
Common generic composite

Two species of walnut are noted as historical sources of dyestuffs, *Juglans nigra* L., the black walnut, and *J. regia* L. (Juglandaceae). Juglone is a naphthoquinone derivative, specifically, 5-hydroxy-1,4-naphthoquinone, found as a natural product of the black walnut, *Juglans nigra* L. Juglone (*q.v.*) is the most widely known and studied compound in the walnut and has been identified in the roots, fruits and leaves of the plant. Analyses of *Juglans regia* L. show that juglone is the active compound in the leaves, along with quercetin, cyanadin, kaempferol, caffeic acid and traces of p-coumaric acid, hyperin (0.2%), quercitrin, kaempferol-3-arabinoside and quercetin-3-arabinoside. Seven naphthoquinones aside from juglone have been identified in the black walnut: 2-methyl-1,4-naphthoquinone; 2,3-dihydro-5-hydroxy-2-methyl-1,4-naphthalenedione (hydroplumbagin); 5-hydroxy-2-methyl-1,4-naphthoquinone (plumbagin); 5-hydroxy-3-methyl-1,4-naphthoquinone; 2,3-dimethyl-5-hydroxy-1,4-naphthoquinone; 2,3-dihydro-5-hydroxy-1,4-naphthalenedione (hydrojuglone); 1,4-naphthoquinone.

According to Thompson (1956), walnut is mentioned in mediaeval manuscripts as a yellow colour used to improve the colour of vermilion.
See: naphthoquinones group.

Naphthoquinones group; Juglone; Kaempferol; Quercetin; Quercitron;
Thompson (1956) 188

WARENCIA

Red
Synonym, variant or common name

Warencia is a term for madder (*q.v.*) found in Heraclius (tenth to thirteenth centuries AD) and in the 1431 manuscript by Jehan de Bergue (Clarke MS 2790; cf. Merrifield, 1849). Also spelled *Warantia*, *Waranz* and *Waranciam* in Latin and is synonymous with garancia, a sixteenth century Italian term for madder (Merrifield)
See: madder.

Madder; *Garancia*
Heraclius/Romano (10–13th cent/1996); Merrifield (1849) 145

WATER BLUE

Blue
Synonym, variant or common name

Mierzinski (1881) lists *wasserblau* (‘water blue’) as a synonym for Paris blue (*q.v.*).

Paris blue
Mierzinski (1881) 354

WEDDELLITE

White
Generic compound

Weddellite is a tetragonal calcium oxalate mineral with composition $Ca(C_2O_4).2H_2O$. It was named by Frondel and Prien in 1942 after it was discovered in material dredged from the Weddell Sea (Antarctica). It forms as white or yellowish prismatic crystals or aggregates and has since been found to occur as a minor mineral in recent peat sequences and other organic-rich sediments (for example, the Philippi Basin, north-east Greece and Florida, USA; Griffin *et al.*, 1984; Kalaitzidis and Christanis, 2002) in association with quartz, calcite, pyrite, siderite and members of the clay, feldspar and apatite (*qq.v.*) groups of minerals, and as a component of calcareous rock surface crusts usually associated with organic activity (such as in Derbyshire, England; Primorskiy Kray, Russia; south-west Texas, USA). Weddellite is a more hydrated, though less stable, form of whewellite (*q.v.*); it is also related to the iron oxalate mineral, humboldtine (*q.v.*). Weddellite has been observed to act as a water absorbing and accumulating substrate for lichens on rock surfaces and to transform back to whewellite when humidity decreases.

In a pigment context, Russ *et al.* (1996, 1999) have identified weddellite with whewellite in a surface crust covering prehistoric pictographs in south-west Texas (USA); they have shown more recently that the origin of the crust is associated with the activity of the desert lichen *A. calcarea*. In more recent occurrences, weddellite has been found in crust layers formed on the surfaces of buildings in the Mediterranean. For example, Alaimo and Montana (1993) identified wedellite along with whewellite and gypsum (*q.v.*) in reddish patinas formed on the calcareous substrates of buildings and artefacts in Palermo (Sicily); they suggested that the formation of these minerals was due to biological activities, past restoration work and pollution. Alessandrini *et al.* (1996) observed weddellite on the façade of a painted building in Bergamo (Italy), while Delmonte and Sabbioni (1983) reported the presence of weddellite on limestone surfaces in Venice (Italy). Bacci *et al.* (1997) examined alteration products such as weddellite and gypsum in the calcareous coating of the brickwork structure of the Parma Baptistery (Italy). Lamprecht *et al.* (1997) have reported how, in association with lichen activity, calcium oxalate layers can form on calcareous artefacts such as the Chinese terracotta soldiers and Egyptian epigraphs; they also showed that the growth of lichen and the formation of the oxalate layers was inhibited by the presence of copper-bearing pigments such as Egyptian blue and Han blue and purple (*qq.v.*). From their laboratory studies, Cariati *et al.* (2000) have suggested that the organic substances used in past conservation treatments and applied to the surfaces of stone artefacts could promote the formation of weddellite and whewellite crusts.

Apatite group; Barium copper silicates group; Calcium group; Clay minerals group; Feldspar group; Calcite; Calcium copper silicate, cuprorivaite type; Gypsum; Humboldtine; Pyrite; Quartz; Siderite; Whewellite; *Egyptian blue*; *Han blue*; *Han purple*
Alaimo & Montana (1993); Alessandrini *et al.* (1996); Bacci *et al.* (1997); Cariati *et al.* (2000); Delmonte & Sabbioni (1983); Frondel & Prien (1942); Griffin *et al.* (1984); Kalaitzidis & Christanis (2002); Lamprecht *et al.* (1997); Russ *et al.* (1996); Russ *et al.* (1999)

WEIT

Blue
Synonym, variant or common name

Weit is a German term for woad.
See: woad and indigo.

WELD

Yellow
Common generic composite

Weld is a dyestuff derived from *Reseda luteola* (‘dyer’s rocket’, ‘dyer’s herb’, ‘fuller’s herb’ or ‘weld’) of which the principal colouring matter is the yellow flavonoid compound luteolin (*q.v.*). It was the most universally used yellow dye in mediaeval Europe prior to the widespread availability of quercitron (*q.v.*), and although it has less colouring power than some other yellow dyes, it is desirable as it produces a very pure colour (Gettens and Stout, 1966) said to be as brilliant as orpiment. The pigment is produced by strewing the whole dried plant in a weak solution of alum and then precipitating this with the addition of calcium sulfate, eggshell or lead white. Thompson states that the colour was most beautiful when somewhat opaque but that when precipitated onto eggshells or lead white it produced a very brilliant colour.

Vitruvius (first century BC) states that those who cannot afford malachite steep blue dye with the herb ‘that is called weld’ (*quae luteum appellatur*) and obtain a brilliant green which is called ‘dyer’s green’ (*infectiva*). The pigment was called *arzica* (probably a corruption of arsenicon, or orpiment; Thompson) in Italian, although Merrifield points out that there was also another meaning for this term (see the entry for *arzica*). Cennini (c. 1400, Clarke MS 590) describes *arzica* as an artificial colour used for miniature painting, while the Bolognese MS (fifteenth century, Clarke MS 160; cf. Merrifield, 1849) gives a fuller description of its preparation: ‘194. To make good and fine arzica Take 1 lb of weld, which the dyers use, cut it very fine, then put it into a glazed or tinned vase, and add it to enough water to cover the herb. Make it boil until the water is half wasted, and if there is not enough water add a sufficient quantity and no more; then take 2 oz. of travertine (*q.v.*) finely ground, or 2 oz. of white lead, and half oz. of roche alum ground very fine, then put all these things together a little at a time to boil in the vase directly, before the water cools, and stir the water continually, remove the vessel from the fire, and when nearly dry, pour off the water. Then take a new brick hollow in the middle, layer the arzica on it, and let it settle perfectly; then put it on a small and well polished board to dry, and it is done.' The Bolognese MS actually uses the term *gualda*, which was a Spanish and Portuguese name for *Reseda luteola*; this in turn was also known to Spanish painters as *ancorca* (*q.v.*), or *encorca* and, when used for estofado painting, was mixed with lemon juice and weak glue size. Thompson lists a fifteenth century MS (Rome, Bibl. Casanatense MS 1793, f. 13v, Clarke MS 3050) where *gualda* is used to produce a yellow pigment by staining eggshell. Ploss (1962) describes a possible etymology for the term weld, although through the Old German words *wau* and *walt*, and *Resida luteola*, was called *Gilbblumen*, 'gelbe blumen' (yellow flowers) in a German colour book of the fifteenth century (Bavarian Staatsbibliothek, Cgm 317, Clarke MS 2180; cf. Ploss).

Other terms associated with weld lakes include Italian pink (*q.v.*) and *Laque de gaude*. The Italian term *Giallo santo* (*q.v.*) refers to a yellow lake colour of indeterminate source which could have been weld.

Apigenin; Luteolin; Quercitron; *Ancorca*; *Arzica*; *Giallo santo*; *Italian pink*; *Laque de gaude*
Cennini (c. 1400/Thompson 1960) 186–189; Gettens & Stout (1966) 174; Merrifield (1849) cliii; Ploss (1962) 128; Vitruvius (1st cent BC/Grainger, 1934) VII.xiv

Wet process vermilion

Red
Generic compound

See: mercury(II) sulfide, cinnabar type and vermilion.

Whewellite

White
Generic compound

Whewellite is a monoclinic calcium oxalate mineral with composition $Ca(C_2O_4).H_2O$ (Deganello and Piro, 1981; Deganello, 1981). It is named after the British mineralogist W. Whewell (1794–1866) and was first discovered in Havre (Montana, USA) by Brooke and Miller in 1852. Whewellite forms with granular habit or as brittle tabular or prismatic crystals with pearly lustre which fracture conchoidally into fine fragments. It is closely related to weddellite (*q.v.*), $Ca(C_2O_4).2H_2O$, a more hydrated but less stable form of calcium oxalate, and to humboldtine (*q.v.*), $Fe(C_2O_4).H_2O$, the Fe(II)-bearing oxalate. Whewellite forms from the interaction of low temperature hydrothermal solutions percolating through carbon-rich rocks such as graphitic shales, coal strata and anthracite deposits (such as in Yorkshire, England; Saxony, Germany; Urbeis, France; Pribram, Czech Republic). It also forms as a crust on the surfaces of calcareous rocks such as limestones, often in association with gypsum and members of the clay minerals (*qq.v.*) group, where its deposition may be promoted by organic activity (such as in south-west Texas, USA); whewellite has been shown to form from the dehydration of weddellite, acting as a water absorbing substrate for lichen on rock surfaces.

In an art context, whewellite has been found in crusts obscuring certain pictographs. Ford (2001) reported the presence of whewellite (and ankerite, *q.v.*) as an alteration crust obscuring the surface of Western Australian rock art. Using laser and permanganate oxidation techniques and ^{14}C accelerator mass spectrometry, Watchman *et al.* (2000) dated the formation of a whewellite crust, observed to have formed on the engraved and painted rock surfaces at Yiwarlarly (Northern Territory, Australia), to have commenced around 3160 BP, thus allowing some dating of the artwork itself. Russ *et al.* (1994, 1996, 1999) and Edwards *et al.* (1998, 1999) reported the presence of whewellite (and weddellite) in a natural rock crust covering prehistoric rock paintings in the Lower Pecos region of south-west Texas (USA); their more recent study showed that the origin of the whewellite-rich crust is associated with the activity of the desert lichen *A. calcarea*.

In a more recent context, whewellite and weddellite have been found with gypsum in reddish patinas on the calcareous substrates of artefacts and buildings in the Mediterranean. Alaimo and Montana (1993) have suggested that the formation of the oxalate layers observed in such patinas from Palermo (Sicily) is due to biological activities, past restoration work and pollution. Lamprecht *et al.* (1997) have also reported how the formation of calcium oxalate layers can occur on calcareous artefacts, such as the Chinese terracotta soldiers and Egyptian epigraphs, in association with lichen activity; they also demonstrated that the presence of copper-bearing pigments (notably Egyptian blue and Han blue and purple, *qq.v.*) inhibited the growth of lichen and the formation of such layers. From their laboratory studies, Cariati *et al.* (2000) have suggested that the formation of whewellite and weddellite on the surfaces of stone artefacts may be promoted by the application of organic substances to the surfaces, in particular materials used in past conservation treatments.

Calcium group; Clay minerals group; Ankerite; Gypsum; Humboldtine; Limestone; Weddellite *Egyptian blue*; *Han blue*; *Han purple*
Alaimo & Montana (1993); Brooke & Miller (1852); Cariati *et al.* (2000); Deganello & Piro (1981); Deganello (1981); Edwards *et al.* (1998); Edwards *et al.* (1999); Ford (2001); Lamprecht *et al.* (1997); Russ *et al.* (1994); Russ *et al.* (1996); Russ *et al.* (1999); Watchman *et al.* (2000)

White bole

White
Synonym, variant or common name

See: kaolin.

White earth

White
Synonym, variant or common name

According to Mayer (1991) white earth is 'a pure white clay whose general composition and physical characteristics are the same as green earth [*q.v.*]. Not the same material as terra alba [*q.v.*]. It is highly absorbent to dyestuffs and therefore finds a limited use as a base for lakes.'

Green earth; *Terra alba*
Mayer (1991) 61–62

White lead

White
Synonym, variant or common name

See: lead white.

White of Morat

White
Synonym, variant or common name

White of Morat or White of Moudon is described by Tingry (1804) as a pure clay and thus a 'true Spanish white' from Switzerland. Morat is near Moudon in the Canton of Vaud. This has probably led to confusion with Meudon white, (*q.v.*) Meudon being in France, near Paris.

Meudon white; *Spanish white*
Tingry (1804) 289

White of Moudon

White
Synonym, variant or common name

See: white of Morat.

White ultramarine

White
Synonym, variant or common name

Experiments by H. Ritter of Lünebourge produced a 'white' ultramarine at 900–950°C which could then be converted into the blue and green compounds (Riffault *et al*., 1874).

Ultramarine blue; *Ultramarine green*
Riffault *et al*. (1874) 327–328

Whiting

White
Synonym, variant or common name

Whiting is a term commonly applied to natural prepared chalk and synthetically prepared calcium carbonate (*qq.v.*). Hall (1973), for example, states that 'The name "whiting" for natural calcium carbonate originally referred to a very finely pulverised form of chalk but the term is now used more broadly to include all finely divided carbonates that are derived from high-calcium or dolomitic limestone [*q.v.*].'

Calcium carbonates group; Calcite; Calcium carbonate, calcite type; Chalk; Limestone
Hall (1973) 109

Wilkinite

White
Synonym, variant or common name

Wilkinite is said to be a trade name for a colloidal bentonite (*q.v.*) typically used in papermaking (*Colour Index*, 1971, CI 77004). Also given as *Wilconite* and *Wilkonite*.

Bentonite
Colour Index (1971) 77004

Wilkinson's blue

Blue
Synonym, variant or common name

Various authors of the later nineteenth and earlier twentieth centuries claim that a London colour-maker by the name of Wilkinson introduced Prussian blue (*q.v.*) to England, the term *Wilkinson's blue* therefore referring to that pigment; Heaton (1928), for example, goes so far as to provide the recipe. However, Harley (1982) points out that this information can only really be traced back to the late nineteenth century, with no earlier sources using the name. It is probably an example of a number of apparent pigment names, notable of the period involved, deriving from a specific recipe accorded to a particular author.

Hexacyanoferrate group; *Prussian blue*
Harley (1982) 72; Heaton (1928) 157

Williamson's blue

Blue
Synonym, variant or common name

See: Prussian blue.

Wine lees black

Black
Synonym, variant or common name

Wine lees black was made from 'the lees of wine from which the tartar has been washed, by burning, in the manner of ivory black' (Field, 1835).
See: carbon-based blacks group: cokes sub-group; yeast; Frankfort black and German black.

Field (1835)

Wisteria yellow

Yellow
Synonym, variant or common name

See: gamboge.

Witherite

White
Generic compound

Witherite is a barium carbonate mineral with composition $BaCO_3$. It was first found in Cumberland (England) by Werner in 1789 and was named after the English mineralogist W. Withering (1741–99; Dana, 1932). Witherite commonly crystallises as white stubby pseudo-hexagonal prisms with striated surfaces and repeated twinning; it may also be found with massive, columnar, reniform, nodular and botryoidal habits. Witherite forms as a gangue mineral in low temperature hydrothermal veins intruded into sedimentary rocks, where it is often found in association with baryte, anglesite and galena (*qq.v.*); it may also form from or alter to baryte (Rutley, 1988). Witherite is found worldwide at locations such as in Northumberland (England), Tyrol (Austria), Saxony (Germany), Arizona (USA), Minas Gerais (Brazil), Tsumeb (Namibia) and Siberia (Russia).

Vanherman, in a discussion of white pigments in 1828, states that there were two types of 'Barytes, or ponderous spar – the sulphate and the carbonate', indicating only the latter to be used on the basis of an erroneous supposition regarding inertness of the sulfate; he indicates a source near Minsterly, Shrewsbury, England. The third edition of Tingry (1830) mentions the use of witherite, or 'Cocks comb spar' from Murton, Cumbria. The use of witherite as a pigment is also described by Heaton (1928), who explains that it is processed in a similar manner to baryte. Barium carbonate is listed in the *Colour Index* (1971) as CI 77099/Pigment White 10.

Barium carbonates group; Barium group; Anglesite; Barium carbonate; Baryte; Galena; Cocks-comb spar; *Light spar*
Colour Index (1971) 77099; Dana (1932) 523; Heaton (1928) 105; Rutley (1988) 298–299; Tingry (1830); Vanherman (1828)

Woad

Blue
Synonym, variant or common name

This term applies both to the plant and the dyestuff derived from the plant *Isatis tinctoria* L. native to the Mediterranean and Western Asia grown in Europe and North America, and *Isatis indigota* Fortune ex Linl. from China. (Other *Isatis* plants exist; however, there is no indication of their use in a pigment context.) It essentially produces indigo (*q.v.*; Schweppe, 1997); however, it was generally considered an inferior source for indigo as the colouring strength is considerably less than that produced from indigo plants (*Indigofera tinctoria*). It was, however, more readily

available in Europe. It is native to the Caucasus and eastern Siberia, but was cultivated in East Asia, India, North Africa and most of Europe as far north as the middle of Sweden and Finland (Schweppe, 1992). The dyestuff produced by woad is analytically indistinguishable from that from indigo. Other terms for woad include *erwaisda*, *gaudus herba*, *glastum*, *guattum*, *uvatum* and *weit.*
See: indigo.

Indigoid group; Indigo
Schweppe (1992) 295; Schweppe (1997)

WOLLASTONITE

White
Generic compound

Wollastonite is a white calcium silicate mineral with ideal composition $CaSiO_3$, although iron, magnesium, aluminium, manganese, sodium or potassium may also be incorporated, colouring the mineral yellow, grey, red or brown. It is a pyroxenoid mineral, with a crystal structure similar to that of the pyroxene group of minerals, which consist of single chains of SiO_4 tetrahedra; however, in a pyroxenoid, the SiO_4 chains are distorted (Mamedov and Belov, 1956). Three polymorphs of wollastonite exist. The most common type is the triclinic wollastonite-Tc form, first described by Henmi *et al.* in 1978 from the Cicova Mountains (Romania) and named after the English mineralogist W.H. Wollaston (1766–1828); it is the form most likely to be referred to in identification of natural samples. The second most common type is the monoclinic wollastonite-2M form, also known as parawollastonite. These two forms are known as the low temperature phases ($\alpha\text{-CaSiO}_3$). Pseudowollastonite ($\beta\text{-CaSiO}_3$) is the third type and is the high temperature form, stable above 1120°C. It is triclinic and rare in nature, although it is known from metamorphic rocks in south-west Iran. Wollastonite-Tc usually occurs as fine-grained white fibrous or columnar masses, sometimes with radiating habit, although larger prismatic or tabular crystals may also be found. It is formed from the high temperature contact metamorphism of impure limestone or calcareous sediments (such as siliceous dolomites, calcareous sandstones) by the reaction of quartz and calcite (*qq.v.*) and with an associated release of CO_2 (for example, at Monte Somma, Vesuvius, Italy; Merida, Spain; Notch Peak, Utah, USA; Reynolds Range, Central Australia). It is often found in association with diopside, forsterite or periclase (*qq.v.*). The 2-M form can occur with the same paragenesis but is much rarer (it is found at Crestmore, California, USA and Sarawak, Malaysia). Wollastonite also occurs in some alkaline igneous rocks (for example, Oldoiyno Lengai, Tanzania; Alno, Sweden).

Patton (1973c) states that wollastonite is the only pure white mineral commercially available that is wholly acicular, with particle lengths that are typically 13–15 times the diameter. That author also indicates that widespread use of wollastonite as a pigment only came in around 1953, when deposits at Willsboro, New York, USA, began to be employed for this purpose, finding application as a functional filler in a wide range of materials including paints. Different grades were supplied that reflected a range of particle sizes. It is still widely used in the coatings industry.

The *Colour Index* (1971) lists calcium silicate (*q.v.*) as CI 77230/Pigment White 28; this is likely to be the synthetic analogue of wollastonite or a hydrated form. Wollastonite may also be called ‘natural calcium silicate’ (or ‘metasilicate’; Patton, 1973c). Other discussions of the role of wollastonite can be found in Engelhardt (1979) and Hare (1993).

A copper-rich wollastonite, sometimes called ‘cupro-wollastonite’, can occur as a phase in the production of Egyptian blue and as an important component in ‘Egyptian green’ (*qq.v.*). Cupro-wollastonite has been shown to be present in samples of Egyptian blue as well as being used on its own as a pigment, when it has sometimes been termed as green frit (El Goresy *et al.*, 1986). However, frit refers to a partly fused material, whereas wollastonite or a cupro-wollastonite is fully crystalline. Bouherour *et al.* (2001) identified cupro-wollastonite mixed with libethenite (*q.v.*) in an early Egyptian pigment sample.

Calcium group; Silicates group; Calcite; Calcium silicate; Cupro-wollastonite; Libethenite; Quartz; *Egyptian blue*; *Egyptian green*; *green frit.*
Bouherour *et al.* (2001); *Colour Index* (1971) 77230; El Goresy *et al.* (1986); Engelhardt (1979); Green (2001); Hare (1993); Henmi *et al.* (1978); Mamedov & Belov (1956); Patton (1973c)

WONGSHY RED

Red
Synonym, variant or common name

Wongshy red is another of Salter’s (1869) speculative pigments; he reports that ‘There was imported a few years ago from Batavia a new colouring principle, under the name of wongshy, and consisting of the seed-capsule of a species of gentian. The aqueous extract, freed from the pectin which it contains, yields with baryta- and lime-water yellow precipitates, from which acids separate the colouring matter of a vermilion hue.’ While suggesting its possible use as a pigment, he admits that it had not been used as such at that time (Salter, 1869).

The plant concerned may be *Gentiana lutea* L. (Gentianaceae), the ‘great yellow gentian’, a source of the xanthone gentisin (Schweppe, 1992).

Salter (1869) 180; Schweppe (1992) 430, 465

WOOD-TAR BLUE

Blue
Synonym, variant or common name

Under the general heading wood-tar blue, Salter (1869) discusses the possible application of compounds derived from wood-tar, comparing their potential to the so-called ‘coal-tar’ colours (*q.v.*). From a compound he calls *picamar* (‘as aniline is a product of coal-tar, so picamar is a product of wood-tar’), Salter describes the production of Picamar blue or Pittacal (from the Greek *pitta*, ‘pitch’ and *calloz*, ‘ornament’); it is produced when ‘a few drops of baryta-water are added to an alcoholic solution of impure picamar … the liquor instantly [assuming] a bright blue tint, which in a few minutes passes into an indigo colour.’

Salter (1869) 233–234

WORINA

Purple
Synonym, variant or common name

The Book of Master Peter of St. Audemar on Making Colours (cf. Merrifield, 1849) states: ‘*Of Folium*. The purple colour called folium [*q.v.*] by the laity, by whom (or rather by the English, in whose country it is prepared, and who call it worina) it is used in dying wool, is not always tempered in the same manner; for some persons distemper it with urine, or with ley made from the ashes of ash trees, and particularly on walls; while others, on parchment, distemper it with cheese-glue.'

Folium; *Turnsole*
Merrifield (1849) 128

WULFENITE

Yellow-Orange
Generic compound

Wulfenite is a lead molybdenate mineral with composition $PbMoO_4$. It was first reported by Haidinger in 1845 and was named after the Austrian mineralogist F.X. von Wulfen (1728–1805). Wulfenite occurs as yellow, yellow-orange or red-orange platy to tabular crystals which are often intergrown, resulting in an encrusting appearance; it is also found with massive or granular form. Wulfenite crystals are brittle with a resinous or vitreous lustre and fracture conchoidally. They form in the oxidising zones of lead deposits and may be found with other lead-rich minerals such as galena, vanadinite, mimetite and cerussite (*qq.v.*; Rutley, 1988). Africano *et al.* (2002) have also recently reported the formation of wulfenite at the Satsuma-Iwojima volcano, Japan, from volcanic gas deposits. Wulfenite is also known as yellow lead ore and is found worldwide in areas such as Cumbria (England), Attica (Greece), Tuscany (Italy), Chihuahua (Mexico), Carinthia (Austria), Broken Hill (Australia) and Tsumeb (Namibia) .

Wulfenite has been identified by Bimson (1980) as a yellow pigment in cosmetics from the Royal Cemetery at Ur. Synthetic lead molybdate (*q.v.*) is used in the manufacture of molybdate red and orange pigments (*qq.v.*; de Keijzer, 1989a).

Lead chromates group; Lead group; Molybdenum group; Cerussite; Galena; Lead molybdate; Mimetite; Vanadinite
Molybdate red; *Molybdate orange*
Africano *et al.* (2002); Bimson (1980); Keijzer (1989a); Rutley (1988) 345–346

WURTZITE

Brown
Generic compound

Wurtzite is a zinc iron sulfide mineral with composition (Zn,Fe)S, and is named after the French chemist C.A. Wurtz (1817–84). It forms as brown tabular or platy hexagonal crystals, six-sided pyramids, radiating acicular crystals or as botryoidal crusts. It occurs close to metal ore deposits and is often found in association with galena, baryte, sphalerite and pyrite (*qq.v.*). Wurtzite, often designated as wurtzite-2H, is the high temperature hexagonal polymorph of sphalerite, stable above 1020°C (although this temperature decreases with increasing iron content). Wurtzite can exist metastably at room temperature but it is readily converted to the cubic sphalerite form upon grinding (Deer *et al.*, 1992). Matraite (*q.v.*) is a closely related mineral, being the rare iron-free form of zinc sulfide. Wurtzite, as well as sphalerite, is found in areas with metal and sulfide deposits such as Alsace (France), Saxony (Germany), Attica (Greece), Cornwall (England), Tuscany (Italy), Broken Hill (New South Wales, Australia), Oruro (Bolivia), Durango (Mexico), Kokanee Range (Canada) and Arizona (USA). *Schalenblende* is an aggregate of botryoidal crusts containing layers of wurtzite, sphalerite and galena, and is sometimes used as an ornamental stone.

Zinc sulfide (*q.v.*) was introduced as a synthetic white pigment in 1852 although it was not widely used due to the grey hue imparted by trace iron; a purer form was introduced in 1927 (Heaton, 1928).

Zinc sulfides group; Baryte; Galena; Matraite; Pyrite; Sphalerite; Zinc sulfide
Deer *et al.* (1992) 600; Heaton (1928) 88

WÜRZBURG GREEN

Green
Synonym, variant or common name

Würzburg green is a less common name for emerald green (*q.v.*), said to be derived from its place of origin in Germany (Fiedler and Bayard, 1997).

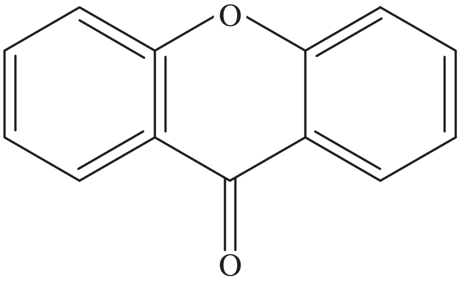
Emerald green
Fiedler & Bayard (1997)

X

XANTHONES GROUP

Red-Orange-Yellow
Group term

The xanthone structure is closely related to the anthrone, anthracene and anthraquinone structures, having three fused rings with the central ring bearing an oxygen atom at one apex (bridging the two outer rings) and a carbonyl group on the other (again, bridging the two outer rings):



The xanthones (and hydroxanthones) include a variety of compounds found in pigments as apparently diverse as Indian yellow, dragon's blood and gamboge. Specific species include Carajurin (from *Bignonia chica* Humb. et Bonpl.); euxanthone and euxanthic acid, including the calcium and magnesium salts (from Indian yellow); dracorubin and dracorhodin (from *Daemonorops* spp.); gentisin (from *Genistein*, *Gentiana lutea* L.); gambogic acid, isogambogic acid, morellic acid, isomorellic acid, morellin, morellinol, isomorellinol, desoxymorellinol, dihydroisomorellin and neogambogic acid (from *Garcinia* spp.).

Anthraquinones group; Dragon's blood; Gamboge; *Indian yellow*

XANTHORRHOEA

Yellow
Common generic composite

Various *Xanthorrhoea* species, also known as 'accroides' or 'grass-tree', yield a useful resin employed for a variety of purposes including as a colourant. According to Brady (1971), accroides is a 'red or yellow resin obtained from the base of Australian grass trees of the Xanthorrhoea family. Red accroides comes primarily from X. australis in southeastern Australia. Yellow accroides, also known as black boy gum, is relatively scarce and comes from the tree X. preissii of Western Australia. The resins are chemically similar to balsams and contain some cinnamic acid. They produce hard, insoluble films. Treatment with sulfuric acid produces a lightfast brown-black dye … Accroides is used for varnishes, metal lacquers, surface finishes for leather and paper, substitute for rosin, sealing waxes and inks.' However, it was also used as a preparation layer for painting wooden artefacts and apparently as a pigment by Aboriginal peoples in Australia, though their principal use of it was as an adhesive.

According to Mills and White (1994), the resin contains the components xanthorrhoein and xanthorrhoeol.

Brady (1971); Mills & White (1994) 146

XANTHORRHOEIN

Yellow
Generic compound

Component found in *Xanthorrhoea* (accroides; *q.v.*) resins (Mills and White, 1994).

Xanthorrhoea
Mills & White (1994) 146

XANTHORRHOEOL

Yellow
Generic compound

Component found in *Xanthorrhoea* (accroides) resins (Mills and White, 1994).

Xanthorrhoea
Mills & White (1994) 146

XIUQUILITL

Blue
Synonym, variant or common name

Also spelled *xiuhquilitl*, several sixteenth century manuscripts have allowed the identification of this term as the Aztec language (Nahuatl) word for indigo (*q.v.*) derived from *Indigofera suffruticosa* Mill. (Wallert, 1995c); the term comes from *xiuhtil* meaning 'turquoise' and *quilit* meaning 'vegetable' (Colombo, 1995). This is the dye basis for Maya blue (*q.v.*).

Indigoid group; Indigo; *Maya blue*
Colombo (1995) 174; Wallert (1995c)

Y

YEAST
Black-White
Generic variety

Yeasts are a group of unicellular fungi. Certain species of the genus *Saccharomyces* are used in the baking and brewing industries and form the basis of material used to produce yeast cokes (*OED*, 2002).

Carbon-based blacks group: Cokes sub-group
OED (2002) 'Tartar'

YEAST BLACK
Black
Synonym, variant or common name

See: wine lees black, yeast and carbon-based blacks group: cokes sub-group.

YELLOW ARSENIC
Yellow
Synonym, variant or common name

See: orpiment.

YELLOW BERRIES
Yellow
Synonym, variant or common name

Various *Rhamnus* species produce a yellow dyestuff, generally extracted from the unripe berries. These latter are typically referred to in the historical literature as yellow berries, buckthorn (*q.v.*), French berries or Avignon berries (*q.v.*). The dye is in turn used to produce various yellow lake pigments, often called pink in earlier documentary sources. The term 'yellow berries' was also applied to the actual pigment produced from these berries, and came to replace the earlier term *pink* (Harley, 1982). For a fuller discussion of the species involved, constituent compounds, substrates and alternative terminology, see the entry for rhamnus.

Flavonoids group; Rhamnus; *Avignon berries*; *Buckthorn*; *Dutch pink*; *English pink*; *French berries*; *French pink*; *Stil de Grain*
Harley (1982) 109

YELLOW BUTTON OF GOLD
Yellow
Synonym, variant or common name

Kühn and Curran (1986), quoting from *Fiche Technique* (1966), cite this as an old name for zinc yellow (*q.v.*).

Zinc yellow
Fiche Technique (1966); Kühn & Curran (1986)

YELLOW CARMINE
Yellow
Synonym, variant or common name

Salter (1869) says of this pigment that it is 'a rich transparent colour, somewhat resembling an ochre compounded with Indian yellow'. According to Scott Taylor (1885), yellow carmine was a term for a quercitron-based lake.

Carlyle (2001) found from an examination of nineteenth century English sources that various yellow lakes were differentiated, which were placed in descending order of intensity: yellow carmine, Dutch pink, English pink and yellow lake; this therefore is the most intense.

Quercitron; *Dutch pink*; *English pink*; *Yellow lake*
Carlyle (2001) 520; Salter (1869) 123–124; Scott Taylor (1885) 29, 50, 52

YELLOW LAKE
Yellow
Synonym, variant or common name

'Yellow lake' might reasonably be defined as any pigment formed by the deposition of a dyestuff onto a base which gives a yellow compound. Historically a wide range of dyestuffs has been used to produce yellow-coloured lakes, notably those from flavonoid sources such as the bark of *Quercus* species – oak – and the berries of various *Rhamnus* species – buckthorn (*qq.v.*); bases such as cuttlefish, aluminium hydroxide, marl, chalk and occasionally lead white and starch were used.

More specifically, the term yellow lake appears in some nineteenth century British sources such as Scott Taylor (1885); this latter author indicates that it was based on quercitron. Carlyle (2001), in her survey of nineteenth century British documentary sources, found yellow lake given among various related terms differing in order of intensity from yellow carmine (strongest), through Dutch and English pinks to yellow lake (weakest), supporting the notion that there was a more specific meaning to the term at that time. Mayer (1991) on the other hand has treated yellow lake as a somewhat unstandardised term for 'a number of transparent pigments', even mentioning cobalt (*q.v.*) and Hansa yellows as substitutes.
See entry for *Rhamnus*.

Flavonoids group; Buckthorn; Quercitron; Rhamnus; *Dutch pink*; *English pink*; *Persian berries*; *Yellow carmine*
Carlyle (2001) 520; Mayer (1991) 62; Scott Taylor (1885) 29, 50, 52

YELLOW MADDER
Yellow
Synonym, variant or common name

According to Scott Taylor (1885), yellow madder was a term for a quercitron-based lake.

See: madder yellow.

Quercitron
Scott Taylor (1885) 29, 50, 52

YELLOW OCHRE

Yellow
Synonym, variant or common name

Yellow ochres are naturally occurring earth pigments forming either as the direct weathering of iron-rich ore deposits or as soils, concentrating iron for underlying bedrocks. Yellow ochres are known from worldwide localities in abundance. Current commercially important deposits are known in the Republic of South Africa and France, but many other small-scale production localities occur and other good pigment deposits have been exhausted (for example, the Shotover ochres of Oxfordshire, UK and the Attic ochre of Greece). The principal colouring matter is primarily the iron oxide hydroxide goethite (α-FeOOH; *q.v.*) although the term has been applied *sensu lato* to earths rich in one of the yellow jarosite-group minerals (see: Jarosite and Natrojarosite) but this use is not to be encouraged. However, deposits are infrequently pure and can typically be associated with a wide range of other minerals including the less common yellow iron oxide hydroxide lepidocrocite (γ-FeOOH), clay and feldspar group minerals, carbonates (calcite and dolomite; *qq.v.*) and many other phases depending on the geological occurrence of the material. Geologically, these deposits, usually fine grained, friable and soft, are referred to as limonites (*q.v.*). Yellow ochres are prepared by washing, levigation and grinding to produce very stable pigment that can be used in all media. They can be burnt to produce brown, red and violet shades through oxidisation to iron(III) oxide. This technology has apparently been available since the Palaeolithic (Pomiès *et al.*, 1999b; Buxbaum, 1998). Church (1901) writes that, in 'recent years', yellow ochre could be adulterated with turmeric (or other organic yellows) and chrome yellow (*q.v.*), the latter being also noted as an extender by Weber (1923). Dossie (1764; cf. Harley, 1982) suggests Dutch pink as an additive.

Yellow ochres are formed in all climates and environments and goethite is in fact the most commonly occurring iron oxide in soils. However, in contrast to the classic Mediterranean-tropical climate red ochre soils, goethite-rich soils are more typical of higher latitude, humid environments, where the soils rarely dry out (Cornell and Schwertmann, 1996). They develop above low acidity rocks especially soft limestones and marls, but also above volcanic rocks. Goethite can also be produced by the bacterial breakdown of iron(III) oxides. Lepidocrocite is much less common in soils than either hematite or goethite and does not occur in calcareous soils, but may be found with goethite in yellow ochre soils that have *not* developed above limestones. Lepidocrocite can transform to goethite in aerobic conditions.

Yellow ochres are among the earliest of pigments used. They have been identified in European Palaeolithic cave art by Cabrera-Garrido (1978) and Pomiès *et al.* (1999a,b), although the pigment appears to have been used far less than red ochres or burnt ochre. Yellow ochre in rock art has also been recognised from more recent aboriginal cultures (see Scott and Hyder, 1993; Wainwright *et al.*, 2002; Watchman *et al.*, 1993). Yellow ochres were widely used in Egyptian art (see Colinart, 2001; David *et al.*, 2001), in some cases they have been found adulterated with orpiment (McCarthy, 2001). Yellow ochres have been found in wall paintings and reliefs excavated from Persepolis (Stodulski *et al.*, 1984) and were important pigments used in Roman wall paintings. During the Republican and Imperial periods, the best known (and most expensive) variety, which had reached legendary status by the time of Vitruvius (first century BC) and Pliny (77 AD) was yellow ochre from the silver mines west of Athens at Laurion (Laurium), 'Attic Slime' as Pliny describes it. Confusingly, although Vitruvius tells us supplies had been exhausted by his time, Pliny quotes us a price of two denarii a pound for this ochre. Vitruvius refers to yellow ochre as *ochra* and *sil*, Pliny as *sil*, and both authors name sources in Italy, Scyros, Gaul, Rome, Lydia and Achaia. Yellow ochres in Roman art have been widely identified by authors such as Béarat (1997) and others.

Yellow ochres are important pigments in Byzantine and mediaeval western art, especially in icons (see Sr. Daniilia *et al.*, 2002) and frescos (Bikiaris *et al.*, 1999). They have widespread use in Renaissance art (see Bomford *et al.*, 1989) and have been detected by Baronti *et al.* (1997) in panel paintings by Signorelli (1450–1532) and in a portrait miniature of Elizabeth I by Derbyshire and Withnall (1999). They have been identified on the diverse palettes of Vermeer (Kühn, 1968b), Turner (Townsend, 1993b), van Goyen and van Ruysdael (Gifford, 1983b) and on Mexican *santeros* by Gettens and Turner (1951).

John Smith (1676) in *The Art of Painting* describes 'Plain-Oker' as 'a certain concret, or stony substance, found among stiff Clays in divers parts of this Kingdom; but those parts that contain most of it, is the Shotover Hills near Oxford, from whence most of the Yellow-Oaker that is sold in England is dug out; 'tis a Colour, that with pains, will grind very fine, it bears an excellent body, and resists the weather well' (cf. Bristow, 1996b). Shotover ochre, also called Oxford stone ochre or Oxford ochre, was considered the best available in the UK at the time and formed as a direct weathering product of the local carbonate-ironstone deposits. Heaton (1928) says that the supplies were almost exhausted by his time.

Important sources of yellow ochre as an artists' pigment are in France. Heaton (1928) describes in some detail the French yellow ochres (also listed by Tingry, 1804, as 'natural yellow ochre'). French ochre was bright yellow and derived from the Périgord, Yonne Valley and the Vaucluse. It was graded according to quality and classified as follows:

J.C. = jaune commun (common yellow)
J.F. = jaune foncé (deep yellow)
J.F.L. = jaune foncé lavé (levigated deep yellow)
J.F.L.S. = jaune foncé lavé sur fin (superfine levigated deep yellow)
J.F.L.S.E. = jaune foncé lavé sur fin extra (extra superfine levigated deep yellow)

Church (1901) notes under yellow ochre various forms such as those he calls 'brown haematite', 'yellow haematite', 'xanthosiderite' or 'lymnite'. These terms are now somewhat obsolete mineralogically and are all synonymous with goethite. Yellow ochre pigments are often named after their source. Church also mentions cyprusite, a yellow ochre from Cyprus, with which he is unfamiliar. Church also lists the synonyms Roman ochre, golden ochre, mineral yellow, brown ochre and Oxford ochre. In many cases the word 'ochre' unmodified is used to refer to yellow rather than red ochres. Tingry (1804) lists the names ochre de rue, a dark yellow colour and calcined ochre de rue, a yellow colour. Harley (1982) also lists a dull yellow variety called spruce oker (as a corruption of Prussian ochre, again named from the deposit locality). Heaton (1928) lists Italian ochre, from Southern Italy and Sicily. This was also called Roman ochre and was a reddish yellow with a warm tone (Harley, 1982).

There is possibly some confusion of terminology here with the siennas (*q.v.*), these frequently being described as a variety of yellow ochre. However, they are described here separately based on their difference in chemistry. Siennas, unlike ochres, contain minor amounts of manganese oxide.

Clay minerals group; Feldspar group; Iron oxides and hydroxides group; Calcite; Dolomite; Goethite; Hematite; Jarosite; Lepidocrocite; Limonite; Natrojarosite; Ochre; Sienna; *Arzica*; *Brown ochre*; *Italian ochre*; *Mineral yellow*; *Ochre de rue*; *Oxford ochre*; *Red ochre*; *Roman ochre*; *Spruce ochre*

Baronti *et al*. (1997); Béarat (1997); Bikiaris *et al* (1999); Bomford *et al.* (1989); Bristow (1996b) 30–33; Buxbaum (1998) 83; Cabrera Garrido (1978); Church (1901) 138; Colinart (2001); Cornell & Schwertmann (1996); Daniila *et al.* (2002); David *et al*. (2001); Derbyshire & Withnall (1999); Dossie (1764); Gettens & Turner (1951); Gifford (1983); Harley (1982) 89–91; Heaton (1928) 165–170; Kühn (1968b); McCarthy (2001); Pliny (1st cent AD/Rackham, 1952) XXXV.xvii.36; Pomiès *et al* (1999a,b); Scott & Hyder (1993); Smith (1676); Stodulski *et al.* (1984); Tingry (1804) 351; Townsend (1993b); Vitruvius (1st cent BC/ Grainger, 1934) VII.vii.1, VII.xi.2; Wainwright *et al.* (2002); Watchman *et al.* (1993); Weber (1923) 92–95

YELLOW OF ANTIMONY

Yellow

Synonym, variant or common name

See: antimony yellow.

YELLOW STIL DE GRAIN

Yellow

Synonym, variant or common name

See: Stil de grain.

YELLOW ULTRAMARINE

Yellow

Synonym, variant or common name

See: ultramarine yellow.

YEO'S YELLOW

Yellow

Synonym, variant or common name

A yellow lake is mentioned in the artist Sir Joshua Reynolds' manuscripts (MSS 1-1916, 2-1916, Charles Fairfax Murray gift 1916, Fitzwilliam Museum, Cambridge) called Yeo's yellow. This pigment is thought to have been specially made by the contemporary Royal Academician Richard Yeo, the composition being otherwise unknown (Kirby Talley, 1986; Dubois, 2002).

Dubois (2002); Kirby Talley (1986)

YOUNG FUSTIC

Yellow

Synonym, variant or common name

Young fustic is a yellow flavonoid dyestuff derived from the plant *Cotinus coggygria* (formerly *Rhus cotinus* L.) where the principal colouring matter is the flavonoid compound fisetin (*q.v.*) as well as fustin. It should not be confused with old fustic, which is a yellow dye derived from *Chlorophora tinctoria* Gard.
See: fustic.

Flavonoids group; Fisetin; *Fustic*; *Old fustic*

Z

ZAFFRE

Blue
Synonym, variant or common name

Zaffre is a precursor used in the preparation of smalt (*q.v.*), consisting essentially of an impure cobalt oxide (Tingry, 1804). It would be mixed with silica and potash and then fused to produce the pigment. It is also called *saffer* and *zaffera*. Merrifield (1849) states that the pigment *smalto di Flandra* ('Flanders smalt') made in Venice was zaffre and 'very close to the pigment we now call smalt'. Fifteenth century references to *smalto* and *smaltino* probably did not refer to smalt (*q.v.*).

Smalt
Merrifield (1849) ccvi–ccvii; Tingry (1804) 300

ZANGAR

Green
Synonym, variant or common name

Zangar is an Indian term equivalent to verdigris; a mixture of orpiment and indigo has been described as 'artificial verdigris', *zangar-i-amali* (Bhowmik, 1970; Lee *et al.*, 1997).

Copper acetate group; Indigo; Orpiment; *Verdigris*
Bhowmik (1970); Lee *et al.* (1997)

ZEDOARY

Yellow
Synonym, variant or common name

Robert Dossie (1764) describes what he calls zedoary wash. This would appear to be from *Curcuma zedoaria* (Christm.) Roscoe (Zingiberaceae), a native plant of north-east India related to turmeric, *C. longa* L., though it is also possible that Dossie did not distinguish between these species and merely turmeric is meant. The preparation was by boiling in water until 'the water appear sufficiently tinged to make a stain on paper of a full yellow colour' (Dossie, 1764).
See: turmeric.

Turmeric
Dossie (1764) I–111

ZEMBRA PUNIC PURPLE

Purple
Synonym, variant or common name

During excavations carried out on the island of Zembra in Tunisia, a purple clay earth was discovered in a stratigraphic layer dating back to the third century BC. Karmous *et al.* have made various studies of what they term Zembra punic purple or purple earth from Zembra and shown it to be a shellfish purple (such as 'Tyrian purple'; *q.v.*) on a clay substrate, analogous to Maya blue (*q.v.*; Karmous *et al.*, 1996, 2000).

Indigoid group; Maya blue; *Tyrian purple*
Karmous *et al.* (1996); Karmous *et al.* (2000)

ZINC BROWN

Brown
Synonym, variant or common name

According to Salter (1869) zinc brown was 'A yellow-brown, so yellow that it might fairly have been classed with the ochrous colours of that denomination, is made by combining zinc with another metal by the aid of heat.' It is likely to be zinc iron brown (*q.v.*) however. Riffault *et al.* (1874) describe blende (zinc sulphide; *qq.v.*) as a brown colour.

Zinc group; *Zinc iron brown*
Riffault *et al.* (1874); Salter (1869) 360–361

ZINC CARBONATE

White
Generic compound

Zinc carbonate is a white material with composition $ZnCO_3$ which occurs in nature as the mineral smithsonite (*q.v.*). It is listed in the *Colour Index* (1971) as CI 77950, where it is described as synthesised by precipitating a zinc salt with sodium bicarbonate and as used in the USA as a white pigment (*Merck Index*, 1996). As mentioned by Kühn (1986), zinc carbonate was used with copper as a starting material in the manufacture of brass in ancient times from which the by-product of white zinc oxide (*q.v.*) was first produced. Zinc carbonate may also form as an alteration product of zinc oxide in a humid environment.

Zinc group; Smithsonite; Zinc oxide
Colour Index (1971) 77950; Kühn (1986); *Merck Index* (1996) 10260

ZINC CARBONATE HYDROXIDE

White
Generic compound

Zinc carbonate hydroxide has the chemical formula $2ZnCO_3.3Zn(OH)_2$. It occurs naturally as the mineral hydrozincite and is listed in the *Colour Index* (1971) as CI 77951. The composition of the commercial product is reported to vary and it may contain zinc oxide (*q.v.*) as an impurity. It is used in the USA as a white pigment, and in the manufacture of porcelains, pottery and rubber (*Merck Index*, 1996).

Zinc group; Zinc oxide
Colour Index (1971) 77951; *Merck Index* (1996) 10260

ZINC CARBONATES GROUP

Variable
Group term

The following primary and secondary zinc carbonates are known as or associated with pigments:

Carbonates: smithsonite ($ZnCO_3$); zinc carbonate ($ZnCO_3$); zinc carbonate hydroxide ($2ZnCO_3.3Zn(OH)_2$, also known as hydrozincite); aurichalcite ($(Cu,Zn)_5(CO_3)_2(OH)_6$); claraite ($(Cu,Zn)_3(CO_3)(OH)_4.4H_2O$); rosasite and its synthetic analogue ($(Cu,Zn)_2(CO_3)(OH)_2$).

ZINC CHROMATE HYDROXIDE

Yellow
Generic compound

Zinc chromate hydroxide, $ZnCrO_4.4Zn(OH)_2$, is one of four types of zinc chromate described as pigments in the literature. It is listed by the *Colour Index* (1971) as CI Pigment Yellow 36:1 (CI 77956) and is synthesised by adding a solution of chromic acid to a slurry of zinc oxide.

Zinc chromate hydroxide is one of two zinc chromates given by Kühn and Curran (1986) as the composition of zinc yellow, the other being zinc potassium chromate hydrate (approximately $K_2O.4ZnCrO_4.3H_2O$) (*qq.v.*). However, Leisy (1941) and Kittel (1960) suggest that examples of earlier pigments are more likely to composition based on the latter as zinc chromate hydroxide was only patented in 1941.
See: zinc chromates group.

Zinc chromates group; Zinc potassium chromate hydrate; *Zinc yellow*
Colour Index (1971) 77956; Kittel (1960); Kühn & Curran (1986); Leisy (1941)

ZINC CHROMATES GROUP

Yellow
Group term

There are four zinc chromate pigments described in the literature – a zinc dichromate hydrate ($ZnCr_2O_7.3H_2O$), a zinc potassium chromate hydrate of approximate composition $K_2O.4ZnCrO_4.3H_2O$ (*Colour Index*, 1971) or $K_2CrO_4.3ZnCrO_4.Zn(OH)_2.2H_2O$ (Lalor, 1973) as well as its sodium analogue, and a zinc chromate hydroxide of ($ZnCrO_4.4Zn(OH)_2$). Three are listed by the *Colour Index* (CI 77955/Pigment Yellow 36, CI 77956/Pigment Yellow 36:1 and CI 77957). Zinc potassium chromate has also commercially been divided into two groups, types I and II, relating to their soluble salt content (Lalor, 1973). A zinc chromate mineral exists, called zincochromite ($ZnCr_2O_4$), but this does not appear to have had pigment usage.

According to Lalor, zinc potassium chromate is prepared by slowly adding a solution of sodium bichromate to a thick slurry of zinc oxide to which potassium chloride has been added, the pH of the slurry then being adjusted with hydrochloric acid; there are several other practical routes also employed. Zinc chromate hydroxide on the other hand is simply prepared by adding a solution of chromic acid to a slurry of zinc oxide.

Carlyle (2001) found that the earliest reference to zinc chromate in the late eighteenth and nineteenth century English sources she examined was Martel (1860). This is consistent with the observations of Kühn and Curran (1986), who state that although 'zinc yellow' was first synthesised about 1800, it found no immediate use and is not mentioned in chemical dictionaries and encyclopaedias before 1850. It would also appear that earlier examples of the pigment are likely to be the zinc potassium chromate, zinc chromate hydroxide only being patented in 1941 (Leisy, 1941; Kittel, 1960). Modern use is primarily as an anti-corrosive coating for metals.

Associated terms include citron yellow, zinc chrome and zinc yellow.

Chromates group; Zinc group; *Citron yellow*; *Zinc chrome*; *Zinc yellow*
Carlyle (2001) 523; *Colour Index* (1971); Kittel (1960); Kühn & Curran (1986); Lalor (1973); Leisy (1941); Martel (1860) 21

ZINC CHROME

Yellow
Synonym, variant or common name

Heaton (1928) lists zinc chrome as a then-current term for a pigment composed of 'chromate and hydrate of zinc'.
See: zinc chromates group.

Zinc chromates group; *Zinc yellow*
Heaton (1928) 385

ZINC COBALT BLUE

Blue
Synonym, variant or common name

According to Salter (1869), zinc cobalt blue was made 'by adding a solution of ordinary phosphate of soda in excess a solution first of sulphate of zinc and then of sulphate of cobalt, and washing and igniting the precipitate. The result is a vitreous blue with a purple cast, of little body, and exceedingly difficult to grind.' Salter compares the pigment to smalt, though indicates that it held no particular advantage for painting apart from use on porcelain.

Calcium group; Zinc group
Salter (1869) 235–236

ZINC DICHROMATE HYDRATE

Yellow
Generic compound

Zinc dichromate hydrate, $ZnCr_2O_7.3H_2O$, is one of four compositions of zinc chromate to be found in the literature. It is listed in the *Colour Index* (CI 77957) as an orange-yellow pigment, synthesised by treating zinc hydroxide with chromic acid. It may be equivalent to the zinc chrome pigment listed by Heaton (1928), although the composition of most zinc chromate pigments (commonly known as zinc yellow) is given as zinc potassium chromate hydrate ($\sim K_2O.4ZnCrO_4.3H_2O$), or zinc chromate hydroxide, $ZnCrO_4.4Zn(OH)_2$ (*qq.v.*; Kühn and Curran, 1986).

Zinc chromates group; Zinc chromate hydroxide; Zinc chrome; Zinc potassium chromate hydrate; Zinc yellow
Colour Index (1971) 77957; Heaton (1928) 385; Kühn & Curran (1986)

ZINC FERRITE

Yellow-Brown
Synonym, variant or common name

See: iron zinc oxide.

ZINC GREEN

Green
Synonym, variant or common name

Typically a synonym for cobalt green (a cobalt zinc oxide; *qq.v.*). However, Terry (1893), after identifying zinc green as cobalt green, also describes a zinc hexacyanoferrate (*q.v.*) compound in the following terms: 'A handsome but not permanent green may be made by combining zinc with iron instead of cobalt, in the form of a double cyanide… finely powdered Prussian blue is stirred into a concentrated solution of chloride of zinc, and put by to allow the decomposition to take place. After some time, the precipitated ferro-zinc cyanide is thoroughly washed, and dried out of reach of the light.' Finally, Mayer (1991) additionally lists zinc green as a mixture of zinc yellow, Prussian blue ('steel or Milori, not the reddish shades') and barytes (baryte; *qq.v.*).

Baryte; Cobalt zinc oxide; Zinc Hexacyanoferrate(II); *Cobalt green*; *Milori blue*; *Prussian blue*; *Steel blue*; *Zinc yellow*
Mayer (1991) 62; Terry (1893) 137

Zinc group
Variable
Group term

Both metallic zinc and zinc compounds and are known in an art context. Bieganska *et al.* (1988) describe the use of flakes of metallic zinc while according to the *Merck Index* (1996), mosaic gold (*q.v.*) can also refer to an alloy of 65.3% copper and 34.7% zinc. There are many zinc compounds that are used as pigments of which zinc oxide, lithopone and zinc chromate are the principal materials. The group includes:

Carbonates: aurichalcite ($((Cu,Zn)_5(CO_3)_2(OH)_6)$; claraite ($((Cu,Zn)_3(CO_3)(OH)_4.4H_2O)$; copper zinc carbonate, rosasite type ($((Cu,Zn)_2(CO_3)(OH)_2)$; rosasite ($((Cu,Zn)_2(CO_3)(OH)_2)$; smithsonite ($ZnCO_3$); zinc carbonate ($ZnCO_3$); zinc carbonate hydroxide ($2ZnCO_3.3Zn(OH)_2$), also known as hydrozincite.
Oxides and Hydroxides: cobalt zinc oxide; franklinite ($ZnFe_2O_4$); iron zinc oxide ($ZnO.Fe_2O_3$); lead antimony zinc oxide; zinc iron brown ($ZnFe_2O_3$); zinc oxide (ZnO); zinc titanate ($ZnTiO_3$; Zn_2TiO_4; $Zn_2Ti_3O_8$); zincite (ZnO).
Chromates: zinc chromate(VI) hydroxide ($ZnCrO_4.4Zn(OH)_2$); zinc dichromate hydrate ($ZnCr_2O_7.3H_2O$); zinc potassium chromate ($\sim K_2O.4ZnCrO_4.3H_2O$; $K_2CrO_4.3ZnCrO_4.Zn(OH)_2$); zinc potassium chromate hydrate ($K_2CrO_4.3ZnCrO_4.Zn(OH)_2$; $K_2CrO_4.3ZnCrO_4.Zn(OH)_2.2H_2O$).
Phosphates: cobalt zinc phosphate; zinc phosphate ($Zn_2P_3O_7$); zinc phosphate hydrate ($Zn_3(PO_4)_2.4H_2O$).
Sulfates: zinc sulfate ($ZnSO_4$).
Sulfides: blende (ZnS); cadmium zinc sulfide ($(Cd,Zn)S$); matraite (ZnS); sphalerite ($(Zn,Fe)S$); wurtzite ($(Zn,Fe)S$); zinc sulfide (ZnS); zinc sulfide hydrate ($ZnS.H_2O$); zinc oxide sulfide.

A zinc hexacyanoferrate(II) is also known.

Zinc chromates group; Zinc oxides and hydroxides group; Zinc sulfides group; Aurichalcite; Cadmium zinc sulfide; Claraite; Cobalt zinc oxide; Copper zinc carbonate, rosasite type; Franklinite; Iron zinc oxide; Iron zinc oxide; Lead antimony zinc oxide; Matraite; Rosasite; Smithsonite; Sphalerite; Wurtzite; Zinc carbonate; Zinc carbonate hydroxide; Zinc dichromate hydrate; Zinc hexacyanoferrate(II); Zinc oxide; Zinc oxide sulfide; Zinc phosphate; Zinc potassium chromate; Zinc potassium chromate hydrate; Zinc sulfate; Zinc sulfide; Zinc sulfide hydrate; Zinc titanate; Zincite; *Blende*; *Mosaic gold*; *Murexide*
Bieganska *et al.* (1988); *Merck Index* (1996)

Zinc hexacyanoferrate(II)
Blue-Green
Generic compound

As an addendum to a discussion of zinc green, Terry (1893) describes the preparation of what is clearly a zinc hexacyanoferrate compound (see the entry for zinc green for this recipe) while Heaton (1928), dealing with the pigment known as Antwerp blue (*q.v.*), further states that zinc hexacyanoferrate(II) ('zinc ferrocyanide') is rarely encountered, but that it is made by precipitating a mixture of zinc and ferrous sulfates with sodium ferrocyanide. The *Colour Index* (1971; CI 77530) provides additional information about manufacture, stating that Antwerp blue is prepared from a solution of zinc sulfate (2 parts) and ferrous sulfate (1–2 parts according to the depth of hue required) with a dilute solution of potassium ferrocyanide. This presumably forms a zinc iron(III) hexacyanoferrate compound.
See: Antwerp blue.

Antwerp blue; *Zinc green*
Colour Index (1971) CI 77530; Heaton (1928) 162; Terry (1893)

Zinc iron brown
Brown
Synonym, variant or common name

According to Buxbaum (1998), variation of the zinc to iron ratio in red-brown iron spinel ($ZnFe_2O_3$) or replacement of some of the iron by aluminium and titanium gives light to medium brown pigments.

Iron group; Titanium group; Zinc group
Buxbaum (1998) 101

Zinc iron yellow
Yellow
Synonym, variant or common name

See: iron zinc oxide.

Zinc lead white
White
Synonym, variant or common name

Heaton (1928) describes this as being 'intermediate between basic lead sulphate and direct zinc oxide', with a composition of roughly equal proportions formed by sublimation of ores containing both metals. It was apparently largely used in America.

According to Faloon (1925), S. Wetherill of the New Jersey Zinc Company developed a process (now termed the 'American' or 'direct' process) between 1854 and 1868 in which zinc oxide (*q.v.*) is produced by the burning of zinc ores with coal. This method produces a less pure form of the oxide than the indirect process and according to Ullman (1932), this was the sole method of production in the USA until 1892, with purer products imported from elsewhere. Leaded zinc oxides can also be produced from the direct process using zinc and lead ores as starting materials, with the products termed 'co-fumed'. The term 'leaded zinc oxide' is used in Germany to refer to products containing >90% ZnO and up to 10% lead oxide ('plumbic zinc oxide' is applied to products containing >75% ZnO), while in the USA, the term referred to products containing up to 70% lead compounds, often lead sulfates, although according to Kühn (1986) this material is no longer manufactured in the US.

Zinc oxide; *Lead white*; *Zinc white*
Faloon (1925); Heaton (1928) 385; Kühn (1986); Ullman (1932)

ZINC ORANGE

Orange
Synonym, variant or common name

Salter (1869) describes how ‘When hydrochloric acid and zinc are made to act on nitro-prusside of sodium, a corresponding zinc compound is formed of a deep orange colour.’

Zinc group
Salter (1869) 261

ZINC OXIDE

White
Generic compound

Zinc(II) oxide, ZnO, has been one of the principal compounds of zinc manufactured as a white pigment. In an art context it is more commonly known as zinc white or Chinese white and is listed in the *Colour Index* (1971) as CI 77947/Pigment White 4. Zinc oxide occurs naturally as the mineral zincite (*q.v.*; Rutley, 1988), although it is commonly red due to the presence of significant amounts of manganese. White zinc oxide, as mentioned by Kühn (1986), has been known since ancient times as a by-product of brass production in which copper and zinc carbonate (*q.v.*) were smelted. However, it was not used widely as a pigment until the end of the eighteenth century, when alternatives were being sought to replace the toxic lead white. It is unclear whether its first production, which began in the 1780s, is attributable to Courtois of Dijon (as suggested by Crell (1783) and Gettens and Stout (1966)), or to Guyton de Morveau. The latter published a study of all known white pigments and alternative materials in 1782, claiming that zinc white was the best replacement for lead white, at which time, according to Harley (1982), zinc oxide was already being manufactured by Courtois. Vandemaele (1965) also mentions an earlier attempt at its manufacture by the German chemist Cramer in 1739. Although production continued during the eighteenth century, Lemoine and du Manoir (1893) state that its popularity diminished, perhaps due to financially inefficient methods of production and reports that it had poor covering power when used in oil. In 1803 J.C. Ibbetson wrote ‘White lead is the only white we have of sufficient body to use in oil. White has been made from zinc, but it has not sufficient substance.’ Interest in the use of zinc oxide as a pigment was revived some years later and by the 1830s it was established as an important watercolour, with Winsor and Newton introducing in 1834 a fine-grained form sold under the name Chinese white; at this time zinc oxide was still not popular in oil as the paints dried poorly and had poor hiding power.

As mentioned by Harley and Kühn, Leclaire developed a method in France during 1835–44 for the industrial production of zinc oxide (known as the ‘French’ or ‘indirect’ process), in which the pure oxide is made from the controlled oxidation of zinc vapours derived from heating metallic zinc at 300°C (see Petit, 1907, for further details). During this time, Leclaire improved zinc white for use in oil painting by combining it with a siccative oil that had been boiled with pyrolusite (*q.v.*). After 1845 there was rapid and widespread use of zinc oxide as a pigment, with its production beginning in other countries. According to Faloon (1925), S. Wetherill of the New Jersey Zinc Company developed a process (now termed the ‘American’ or ‘direct’ process) between 1854 and 1868 in which zinc oxide is produced by the burning of zinc ores with coal. This method produces a less pure form of the oxide than the indirect process and according to Ullman (1932) this was the sole method of production in the USA until 1892, with purer products imported from elsewhere. Leaded zinc oxides can also be produced from the direct process using zinc and lead ores as starting materials, with the products termed ‘co-fumed’. The term ‘leaded zinc oxide’ is used in Germany to refer to products containing >90% ZnO and up to 10% lead oxide (‘plumbic zinc oxide’ is applied to products containing >75% ZnO), while in the USA, the term referred to products containing up to 70% lead compounds, often lead sulfates, although according to Kühn, this material is no longer manufactured in the US. The French and American processes remain the two main methods of manufacture of zinc oxide although a third set of methods exists, involving precipitation (from carbonated zinc sulfate solutions formed from the leaching of smelting by-products with sulfuric acid) or hydrolysis (of zinc ammoniates produced by adding ammonia or sodium hydroxide to zinc-bearing materials); the products obtained from these methods are known as ‘precipitated zinc white’.

Variations in particle morphology in zinc oxides have been identified and are divided into two main types. The acicular-type crystals, which occur as individual, twinned or tetrahedral combinations, are found in zinc oxides derived from the slow burning of zinc vapour, as mentioned by Kühn, usually from the French process. The nodular-type particles are the most common and have a more rounded appearance, being produced from faster burning syntheses. The manufacturing methods yield different grades of pigment based on particle size which are sold under different brands of Seal. The Red Seal has the coarsest grain size and the lowest purity, as has the Gold Seal; the Green Seal grades have a slightly finer grain size and a purity of >99% ZnO; White Seal is the finest grade (0.5–0.7 mm grains) and the whitest, with the same purity as Green Seal although it has a poor hiding power. A further type known as Gray Seal is reported to contain metallic zinc. The differences in grain size also means that the oil requirements vary. Varieties which require little oil (usually those with larger particle size) are often known as ‘zinc white double’ or ‘zinc oxide double’.

Early terms for zinc oxide, introduced to describe the material’s appearance during brass production, include *lana philosphica*, *pómpholyx*, *spodós and spodium*. Later terms introduced in the sixteenth century include *nix alba*, *nihilum album (nihili*, *nil album)* and *tutia* or *tucia* (from the Persian *dûd*) after its fine white flake – or smoke-like – appearance, with *spiritus volatilis cadmiae* introduced by the alchemist Libavius around 1614. As reported by Schneider (1972), *flores zinci* (flowers of zinc) was used during the period 1670–1750, with *zincum oxydatum* subsequently preferred with *Zinkweiss*, *blanc de zinc*, *bianco di zinco* and *blanco de cinc*; more recent synonyms coined mainly during the nineteenth century are snow white (*blanc de neige*, *Schneeweiss*), *blanc de trémie*, *blanc léger* (mentioned by Saint-Victor in 1835), Hubbocks white, Chinese white, constant white, zinc white No. 1 and stone grey (which contained lead).

The use of zinc white as a pigment has been reviewed by Kühn, and is shown to date from the end of the eighteenth century, with the pigment more frequently encountered in paintings with increasing numbers after 1850. It is reportedly commonly found mixed with lead white or baryte (*q.v.*), or as a lightening agent in coloured pigments added by the manufacturers. Zinc white, along with titanium dioxide white (*q.v.*) and lead white were the three main white pigments used commercially in the mid- to late twentieth century. In these applications zinc white was often mixed with titanium dioxide and lead white paints as a minor component to improve the paint properties particularly in outdoor applications, as mentioned by Kittel (1960). Müller

(1962) has reported that the strong ultra-violet absorbency of zinc protects the lead and titanium pigments from the photochemical changes. However, zinc oxide has been reported to affect the fading behaviour of organic pigments, with Eibner (1911) declaring that 'Zinc white indeed accelerates light-fading of artists' paints.' Studies by the Doerner Institute demonstrated that Prussian blue (*q.v.*) mixed with zinc white suffered little fading compared to mixtures with other white pigments. However, Kühn also states that drying processes, particle morphology, impurities and lattice defects are also now known to play an important role on the photochemical properties of zinc white; the review by Wulf (1974) also discusses the rapid fading of mixtures of Prussian blue and zinc white.

Although zinc white is stable in light, studies have shown that it tends to saponify the fatty acid component of certain oils, with the degree of soap formation being dependent upon the particle size of the pigment, with the finest particles resulting in more rapid soap formation (Payne, 1961; Bell, 1970; Morley-Smith, 1958). Kittel has shown that this formation process can be beneficial in some vehicles as it causes hardening of the layer and that for this reason zinc white has long been used as an additive in titanium dioxide white and barium sulfate (*q.v.*) paints to improve weather resistance. As noted by Kühn, Rubin *et al.* (1953) and Hoffman and Savacz (1969) have shown that irradiation of zinc oxides by near ultra-violet light can promote the formation of hydrogen peroxide, a process which can cause dehydration of other pigments and subsequent embrittlement. In a humid environment, zinc white can convert to zinc carbonate, or in the presence of moisture and sulfur dioxide, to zinc sulfate. As also reported by Kühn, zinc oxide may alter to form zinc sulfide in the presence of hydrogen sulfide, particularly in pigments dispersed in aqueous media. However, the conversion product is also white so little change in the pigment is observed visually, unless the pigment contains lead in which case darkening will occur.

More recently, zinc oxide has been mixed with cobalt oxide and bismuth oxide to form new green and yellow pigments, respectively, as reported by Sulcova and Trojan (1998, 1999).

Zinc group; Zinc sulfides group; Barium sulfate; Baryte; Pyrolusite; Zinc carbonate; *Chinese white*; *Lead white*; *Lithopone*; *Prussian blue*; *Titanium dioxide white*; *Zinc white*
Bell (1970); *Colour Index* (1971) 77947; Crell (1783); Eibner (1911); Faloon (1925); Gettens & Stout (1966); Harley (1982) 178; Hoffman & Savacz (1969); Ibbetson (1803); Kittel (1960); Kühn (1986); Leclaire (1849); Lemoine & du Manoir (1893); Morley-Smith (1958); Müller (1962) 70; Payne (1961) v.2, 763; Petit (1907) 67–79; Rubin *et al.* (1953); Rutley (1988) 259–260; Saint-Victor (1835) 38; Schneider (1972) 26, 148; Sulcova & Trojan (1998); Sulcova & Trojan (1999); Ullman (1932) v.10, 708; Vandemaele (1965); Winsor & Newton (1930) 15; Wulf (1974) 98

ZINC OXIDE SULFIDE

White
Generic compound

See: zinc sulfides group and Griffith's white.

ZINC OXIDES AND HYDROXIDES GROUP

White
Group term

The group consists of both naturally occurring minerals and synthetic materials used as pigments, of which zinc oxide (ZnO) is of major importance. The group includes: cobalt zinc oxide; franklinite ($ZnFe_2O_4$); iron zinc oxide ($ZnO.Fe_2O_3$); lead antimony zinc oxide (a lead antimony oxide-lead antimonate pigment formed with zinc); zinc iron brown ($ZnFe_2O_3$); zinc oxide (ZnO); zinc titanate ($ZnTiO_3$; Zn_2TiO_4; $Zn_2Ti_3O_8$); zincite (ZnO; *qq.v.*). Zinc titanate (Zn_2SiO_4) is also mixed with magnesium titanate (Mg_2TiO_4) to produce a blue-green suite of spinel pigments (*q.v.*). A cobalt nickel zinc titanium oxide, $(Co,Ni,Zn)_2TiO_4$, is listed in the *Colour Index* as CI 77377/Pigment Green 50.
See: zinc oxide. Zinc oxide sulfide is discussed in the zinc sulfides group.

Zinc group; Cobalt zinc oxide; Franklinite; Iron zinc oxide; Lead antimony zinc oxide; Zinc iron brown; Zinc oxide; Zinc titanate; Zincite; *Spinel pigments*
Colour Index (1971) 77377

ZINC PHOSPHATE

White
Generic compound

Zinc phosphate, also known as zinc pyrophosphate, is a white compound with composition $Zn_2P_3O_7$ that occurs naturally as the mineral hopeite, although this is rare (*Merck Index*, 1996). Zinc phosphate may be produced by heating a soluble zinc salt with ammonium phosphate. It is listed in the *Colour Index* (1971) as CI 77965, where it is reported to be used in the US as a white pigment. A related hydrous compound zinc phosphate hydrate, $Zn_3(PO_4)_2.4H_2O$, also exists, which is listed in the *Colour Index* as CI 77964.

Zinc group
Colour Index (1971) 77964, 77965; *Merck Index* (1996) 10284

ZINC POTASSIUM CHROMATE HYDRATE

Yellow
Generic compound

Two formulations for zinc potassium chromate hydrate are given in the pigment literature. According to the *Colour Index* (1971), the composition is approximated by the formula $K_2O.4ZnCrO_4.3H_2O$, which describes a series of compounds of variable ZnO:CrO_4 ratio and water of crystallisation content; they are designated as CI Pigment Yellow 36 (CI 77955) and also form a component of Pigment Green 16. However, Lalor (1973) gives the composition as $K_2CrO_4.3ZnCrO_4.Zn(OH)_2.2H_2O$ (and also a sodium analogue), prepared by slowly adding a solution of sodium bichromate to a thick slurry of zinc oxide containing potassium chloride, the pH of the slurry then being adjusted with hydrochloric acid; other synthesis routes are also accessible. Lalor also states that commercially produced zinc potassium chromate has been divided into two types (known as I and II) on the basis of their soluble salt content.

Kühn and Curran (1986) list $K_2O.4ZnCrO_4.3H_2O$ as one of the two zinc chromates which are referred to as the pigment zinc yellow, the other being zinc chromate hydroxide (*qq.v.*), $ZnCrO_4.4Zn(OH)_2$. The *Colour Index* states that most commercial zinc yellow products have a composition given as $4ZnO.K_2O.4CrO_3.3H_2O$. According to Leisy (1941) and Kittel (1960), older zinc yellow pigment samples are more likely to be zinc potassium chromate, as zinc chromate hydroxide was only patented in 1941.
See: zinc chromates group.

Zinc chromates group; Zinc chromate hydroxide; *Zinc yellow*
Colour Index (1971) 77955; Kittel (1960); Kühn & Curran (1986); Lalor (1973); Leisy (1941)

ZINC SULFATE

White

Generic compound

Zinc sulfate, $ZnSO_4$, was also known as white vitriol or zinc vitriol. According to Zerr and Rübencamp (1906) it was only used for certain resinate lakes, and as a component of the patented compound known as *Sulfopone* (*q.v.*), a patented product similar to *lithopone* (*q.v.*).

According to Kühn (1986), zinc sulfate can form when zinc oxide (*q.v.*) is exposed to an environment containing sulfur dioxide and a high moisture content.

Zinc group; Lithopone; Sulfopone; Zinc oxide

Kühn (1986); Zerr & Rübencamp (1906/1908) 124, 327

ZINC SULFIDE

White

Generic compound

See: zinc sulfides group.

ZINC SULFIDE HYDRATE

White

Generic compound

See: zinc sulfides group.

ZINC SULFIDES GROUP

White

Group term

Zinc sulfide, ZnS, also known as zinc blende, occurs naturally as the mineral matraite; closely related zinc sulfide minerals are wurtzite and sphalerite (*qq.v.*) which contain essential iron (with composition [Zn,Fe]S). Zinc sulfide compounds may also be made synthetically and include cadmium zinc sulfide ([Cd,Zn]S; *q.v.*), zinc sulfide, zinc sulfide hydrate ($ZnS.H_2O$) and zinc oxide sulfide.

Heaton (1928) reports that when synthetic zinc sulfide was prepared by precipitation it gave a 'white substance of great opacity'. Supposedly introduced as a pigment in 1852, it was not widely used because of a grey cast caused by traces of iron sulfide group (*q.v.*) compounds. A purer product was marketed from 1927 under the trade name *Sachtolith*; this also contained 3% zinc oxide (*q.v.*). According to the *Merck Index* (1996), synthetic zinc sulfide often contains 15–20% water of hydration; it is therefore heated in the absence of air to 725°C to convert it to wurtzite, the hexagonal form of ZnS preferred by the paint industry.

Kühn (1986) has also described how zinc sulfide may form as an alteration product of zinc oxide when exposed to hydrogen sulfide; this is more apparent in zinc oxides used in aqueous media. In this transformation, little visual change in the pigment is observed as the product is also white; however, leaded zinc oxides will darken due to the formation of lead sulfide.

Zinc sulfide hydrate, $ZnS.H_2O$, is listed in the *Colour Index* (1971) as CI 77975/Pigment Black 17/Pigment White 7. It is synthesised by passing hydrogen sulfide into an aqueous solution of a zinc salt to obtain a brilliant white pigment. It also forms as an intermediate product in the synthesis of zinc sulfide where it is heated in the absence of air to convert it to ZnS.

The *Colour Index* (CI 77975) describes Griffith's zinc white as zinc oxide sulfide ('zinc oxysulfide'). It was produced by precipitating a zinc solution with barium sulfide and calcining the precipitate (recipe according to Bersch, 1901). However, other sources simply indicate – as the recipe seems to imply – that Griffith's zinc white was a variety of lithopone (*q.v.*).

The co-precipitation of zinc sulfide with barium sulfate (*q.v.*) gives the widely used pigment known as *lithopone*. As reported by Huckle *et al.* (1966; cf. Fiedler and Bayard, 1986), zinc sulfide is also used in the manufacture of cadmium sulfide group (*q.v.*) pigments to decrease the red hue, with a maximum of approximately 25 mol% ZnS used; a cadmium zinc sulfide (*q.v.*) compound is also known. Buxbaum (1998) has noted that although zinc sulfide pigments are still of economic importance, they have continually lost volume to titanium dioxide white (*q.v.*) pigments since the 1950s.

Zinc group; Cadmium sulfides and selenides group; Iron sulfide group; Barium sulfate; Cadmium zinc sulfide; Matraite; Sphalerite; Wurtzite; Zinc oxide; *Blende*; *Griffith's white*; *Lithopone*; *Sachtolith*; *Titanium dioxide white*; *Zinc lead white*; *Zinc white*

Bersch (1901); Buxbaum (1998) 70–77; *Colour Index* (1971) 77975; Fiedler & Bayard (1986); Heaton (1928); Huckle *et al.* (1966); Kühn (1986); *Merck Index* (1996)

ZINC TITANATE

White

Generic compound

Three zinc titanates are known to exist – the metatitanate $ZnTiO_3$, the orthotitanate Zn_2TiO_4 and $Zn_2Ti_3O_8$ (Kim *et al.*, 2001). The formation of the Zn_2TiO_4 and $Zn_2Ti_3O_8$ compounds is limited by the presence of anatase, whereas $ZnTiO_3$ is only formed in the presence of rutile (*qq.v.*). Buxbaum (1998) describes the formation of blue to green compounds via the incorporation of cobalt, nickel and lithium into Zn_2TiO_4 (and Mg_2 TiO_4). Zinc metatitanate, $ZnTiO_3$, is stated to have been used as a white pigment by the *Colour Index* (1971; CI 77980); it may also be called titanium white (*q.v.*; Laver, 1997).

Titanium group; Zinc group

Anatase; Rutile; *Titanium white*

Buxbaum (1998) 100–101; *Colour Index* (1971) 77980; Kim *et al.* (2001); Laver (1997)

ZINC WHITE

White

Synonym, variant or common name

Although normally taken to infer zinc oxide, there were in fact a number of other related zinc compounds used as white pigments (Kühn, 1986). This was recognised early on; for example, Salter (1869) states that the composition of zinc white 'Is either the anhydrous oxide, the hydrate oxide, or hydrated basic carbonate of zinc.' To these we may add zinc phosphate, zinc sulfate, the zinc sulfides and zinc titanate.

Zinc white is discussed more specifically in the entry for zinc oxide and other relevant entries.

Zinc oxide

Kühn (1986); Salter (1869) 76

ZINC YELLOW

Yellow

Synonym, variant or common name

There are two formulations of zinc chromate which are termed zinc yellow – a zinc potassium chromate hydrate, with approximate composition $K_2O.4ZnCrO_4.3H_2O$, and zinc chromate hydroxide, $ZnCrO_4.4Zn(OH)_2$ (*qq.v.*). They are listed by the *Colour Index* (1971) as CI Pigment Yellow 36 (CI 77955) and CI Pigment Yellow 36:1 (CI 77956), respectively. According to Kittel (1960) and Leisy (1941), older forms of zinc yellow are more likely to have the zinc potassium chromate hydrate composition, as zinc chromate hydroxide was only patented in 1941. Kühn and Curran (1986) further state that the older pigments may have zinc potassium chromate hydrate compositions which vary widely as different $ZnO:Cr_2O_3$ ratios could be produced (Kittel, 1960). Although zinc chromate hydroxide appears to be a twentieth century formulation, the *Colour Index* states that most modern zinc yellows are of the $K_2O.4ZnCrO_4.3H_2O$ composition.

Kühn and Curran, citing Guignet (1888), state that zinc chromate was first synthesised around 1800 in a systematic study of chromates; this is presumably the study published by Vauquelin in 1809. Kühn and Curran further state that interest in zinc chromate as a pigment appears to have come later as the art literature and technical dictionaries published prior to 1850 do not mention it. It is also debatable as to who is responsible for the development of zinc chromate as a pigment. According to Remington (1944), the Scottish chemist Murdock discovered the pigment in 1847 and produced three shades (marigold, lemon and pale primrose). However, Mellor (1931) and Brown (1944) attribute the discovery to earlier workers such as Thomson in 1825 and Lampidus in 1829, with Leclaire strongly associated with its introduction as a pigment (Kühn and Curran). According to Gettens and Stout (1966), who give the composition as $ZnCrO_4$, 'The pigment has a bright, clean, lemon shade, much like strontium chromate' (*q.v.*).

According to Kühn and Curran, synonyms for zinc yellow were *Zinkgelb*, *jaune de zinc*, *giallo di zinco*, *Amarillo de zinc*, *aenki*, ultramarine yellow (*q.v.*), yellow button of gold, *jaune de chrôme malterve* and permanent yellow (*q.v.*). Salter (1869) also identifies citron yellow (*q.v.*) as an alternative term, with buttercup yellow given by Riffault *et al.* (1874). Heaton (1928) lists zinc chrome as a then-current term for a pigment composed of 'chromate and hydrate of zinc'.

Zinc yellow has been identified by Kühn (1969) in paintings dated after 1855, while Richter and Härlin (1974b) have identified it in a collection of pigments belonging to Böcklin (1827–1901); Moreau-Vauthier (1923) has also listed artists whose palettes contained zinc yellow (cf. Kühn and Curran). Zinc yellow has been used more commonly as mixed with other pigments, particularly blues to form green pigments, such as chrome green and Victoria green (*qq.v.*); it is also listed in the *Colour Index* as a component of Pigment Green 16. As reported in sources such as Gettens and Stout, zinc yellow has a tendency to darken on exposure to light due to the formation of chromium oxide (*q.v.*). This causes the pigment to develop a grey-green colour, and mixtures containing zinc yellow could also suffer the same affect. Modern uses are primarily for anti-corrosive coatings on metals.

Zinc chromates group; Chromium oxide; Strontium chromate; Zinc chromate hydroxide; Zinc potassium chromate hydrate; *Chrome green*; *Citron Yellow*; *Permanent green*; *Permanent yellow*; *Ultramarine yellow*; *Victoria green*
Brown (1944); *Colour Index* (1971) 77955, 77956; Gettens & Stout (1966) 178; Guignet (1888) 98; Heaton (1928); Kittel (1960); Kühn & Curran (1986); Kühn (1969); Leisy (1941); Mellor (1931); Moreau-Vauthier (1923); Remington (1944) 116; Richter & Härlin (1974b); Riffault *et al.* (1874) 387; Salter (1869) 95; Vauquelin (1809)

ZINCITE

Red-Orange-Yellow
Generic compound

Zincite is a zinc oxide mineral with ideal chemical composition ZnO, although up to 10% manganese is usually present, giving the mineral its red to yellow coloration (pure ZnO is white); a small amount of iron is often also incorporated (Rutley, 1988). It is named after its bulk composition and was first reported by Haidinger in 1845 (Dana, 1944). Zincite commonly occurs with massive or granular habit, or as disseminated grains, with larger crystals rarely found. It forms as a weathering product of zinc deposits of metamorphic and hydrothermal origin, and is commonly found with franklinite, willemite and calcite; it weathers to form smithsonite (*qq.v.*). It is found in abundance at its type localities of the Sterling Hill and Franklin mines at New Jersey (USA) where it is an important zinc ore (Rutley, 1988). It is rare elsewhere, with more minor occurrences reported at Tuscany (Italy), Saxony (Germany), Attica (Greece), Dalarna (Sweden) and Tsumeb (Namibia).

Synthetic zinc oxide (*q.v.*) has been used extensively as white pigment. Hardy *et al.* (1998, 2002) have reported that zincite itself is a major component in some traditional eye cosmetics used in the Middle East; galena, hematite, calcite, aragonite and amorphous carbon (*qq.v.*) were also found as major components in some of the products.

Carbon-based black groups; Aragonite; Calcite; Franklinite; Galena; Hematite; Smithsonite; Zinc oxide
Dana (1944) 504; Hardy *et al.* (1998); Hardy *et al.* (2002); Rutley (1988) 259–260

ZINNOBER GREEN

Green
Synonym, variant or common name

Zinnober green ('*Zinnobergrün*') is stated in the German literature to be an olive-coloured shade of chrome green (*q.v.*; Mierzinski, 1881). It is generally used as the main term for *chrome green* (mixed chrome greens) in German literature.
See: green cinnabar.

Chrome green; *Green cinnabar*
Mierzinski (1881) 185

ZINOX

White
Synonym, variant or common name

Toch (1916), writing in the US, describes *Zinox* as 'a hydrated oxid [*sic*] of zinc not manufactured in this country, but made and used almost entirely in France. It is not yet sold dry, but generally sold either in the form of a ready mixed enamel or in a semi-paste form.' More recently, 'Zinox' has been used as a trade name for grades of zinc oxide (*q.v.*) produced by American Chemet Corporation.

Zinc oxide
Toch (1916) 45

ZIRCON

White
Generic compound

Zircon occurs in nature as a mineral of composition $ZrSiO_4$. Although large natural crystals of zircon have been known and prized as gems for millennia, commercial zircon is produced by physical separation from vast deposits of beach sands located in Queensland, Australia and Florida, USA. Although colourless when pure, it is often coloured when found in nature due to impurities, crystal defects and through heterogeneities of radioactive origin. Exploitation of zirconium dioxide and zircon as ceramic opacifiers has been described since the early twentieth century. Due to problems with obtaining appropriately sized particles, commercial products suitable for other pigmentary applications do not appear to have been forthcoming, despite the fact that the optical properties of these compounds would suit them to such a role (Blumenthal and Jacobs, 1973).

The presence of zircon in coloured grounds of the seventeenth to eighteenth century French School has been noted by Duval (1992), a natural impurity in earth pigments.

Silicates group; Zirconium group; Zirconium silicate
Blumenthal & Jacobs (1973); Duval (1992)

ZIRCON WHITE

White
Synonym, variant or common name

See: zirconium oxide and zircon.

ZIRCONIUM GROUP

Variable
Group term

Zircon combines with oxygen and silicon to form a limited number of compounds that are known in a pigment context. Synthetic zirconium oxide (*q.v.*) is the form most commonly encountered as a pigment; the other compounds are usually found as associated materials.

Oxides and hydroxides: Arkelite ($ZrO_{1.87}$; $ZrO_{2.12}$); Baddeleyite (ZrO_2); Zirconium oxide (ZrO_2).
Silicates: Zircon ($ZrSiO_4$).

Arkelite; Baddeleyite; Zircon; Zirconium oxide

ZIRCONIUM OXIDE

White
Generic compound

There are several crystal-structural modifications of zirconium oxide (ZrO_2), analogues of the minerals arkelite and baddeleyite; the latter of these is the form normally encountered as a pigment. Blumenthal and Jacobs (1973) indicate that there were two production methods. The first involves heating zircon (*q.v.*) and carbon at temperatures in excess of 2000°C to form zirconium carbide; this would then be burnt in air to form zirconium oxide. In the second process, zirconium salts were precipitated with an alkali sulfate; this apparently gives 'very pure polysulfatopolyzirconic acids', calcination of which yields the pure oxide.

The stable form of the oxide is reportedly monoclinic – that is, having the same structure as baddeleyite – at room temperature; this can be converted to a tetragonal structure above 1200°C, which, under suitable conditions (the presence of stabilising impurities), can be preserved on cooling.

The *Colour Index* lists zirconium oxide as CI 77990/Pigment White 12 and is also known as zircon white. Principal modern uses appear to be in ceramic glazes.
See: arkelite; baddeleyite.

Zirconium group; Arkelite; Baddeleyite; Zircon; *Zircon white*
Blumenthal & Jacobs (1973); *Colour Index* (1971) 77990

ZIRCONIUM SILICATE

White
Generic compound

See: zircon.

ZUNI BLUE

Blue
Synonym, variant or common name

According to Carrillo (1998), writing about the New Mexico artists known as santeros ('saint makers'), 'The only documented use of a specific mineral used by santeros is that of Zuni blue. In 1792 it was noted that a blue of Zuni origin was used in the construction of the Zuni altar. Father Juan Agustín de Morfí commented that: "the Indians furnished to my companion … as much Prussian blue as he needed without more cost or labor than gathering it *up* from a mineral water which they discovered." In 1812, Don Pedro Bautista *Pino* also commented about the blue pigment source in his Exposicion Sucinta y Sencilla de la Provincia del Nuevo Mexico. The blue, made from ground azurite, was used by Bernardo Miera y Pacheco.'

Azurite; *Prussian blue*
Carrillo (1998)

ZWICKAU GREEN

Green
Synonym, variant or common name

Listed as a term for emerald green (*q.v.*) by Fiedler and Bayard (1997). This was presumably a form manufactured at Zwickau in Saxony, Germany, which has long been a centre of industrial production.

Emerald green
Fiedler & Bayard (1997)

ZWICKAU YELLOW

Yellow
Synonym, variant or common name

Zwickauergelb, 'Zwickau yellow', is given as a synonym for chrome yellow (*q.v.*) by Tschelnitz (1857; cf. Kühn and Curran, 1986). This was presumably a form manufactured at Zwickau in Saxony, Germany, which has long been a centre of industrial production.

Chrome yellow
Kühn & Curran (1986); Tschelnitz (1857)

PIGMENT CLASSIFICATION: A SYSTEMATIC LISTING OF COMPOUNDS FOUND AS PIGMENTS

The following classification index developed out of the desire to compile a comprehensive list of historical pigments. However, it was clear from the outset that such an exercise would be no simple task, for the following notable reasons:

1. Such lists as the authors were aware of were mostly partial and often tended to run into problems of nomenclature (see below).
2. Criteria for inclusion of specific compounds needed to be defined, such as:
    (a) How often does a compound need to be used (or cited as used) to merit inclusion?
    (b) What historical and geographical limits should be placed on the entries?
    (c) What contexts of use should be considered (for example, easel painting and rock art are relatively straightforward, but what about ceramics or body painting)?
    (d) What is the status of compounds encountered only as deterioration products?
3. Complexities of nomenclature exist, such as how to handle common names that might cover a number of different chemical substances.

This index is essentially a systematic listing of compounds used as pigments and therefore does not include common names, synonyms or variant terms, though this latter information was necessarily correlated during preparation of the list and forms the basis of the main text of this volume. The index is instead a list of pigment 'building blocks' – compounds that form the basis of materials used, either individually or severally. There are certain consequences of this, not least that it becomes necessary to define common 'compound' pigments, which are frequently encountered combinations of the building blocks. This issue will be discussed at greater length below.

The naming of the pigments presents a number of difficulties, largely stemming from the fact that there is currently no widely accepted method for the systematic construction of names that are capable of reflecting the diversity of material in a both chemically accurate and pragmatically useful manner. In practice it was evident that, from an analytical perspective, one could reasonably define the individual compounds that form the basis of pigments as the fundamental units. This allows one, for example, when seeking to identify a particle by an analytical technique such as polarised light microscopy to initially specify the optical properties of a single compound rather than dealing with groups of compounds or natural or artificial mixtures. One can then potentially build a hierarchical relationship to deal with mixtures. These fundamental unit compounds, however, are referred to here as 'generic' pigments, much in the same sense that pharmaceutical compounds are called 'generic' – by basic chemical composition rather than, say, a trade name. Therefore the term 'generic' is defined here as meaning a pigment or pigment component, which, by virtue of its chemical composition, crystal structure and/or mode of formation is a material capable of being distinguished from another.

Further, the use of previously established naming systems for particular types of generic such as synthetic inorganic compounds, minerals and so forth, was felt to be desirable and therefore incorporated into the overall system. The following naming systems have been employed:

1. Compounds derived from naturally occurring mineral sources are called by their currently accepted mineral name based on the International Mineralogical Association (IMA); where there was a terminological divergence, mineral names and compositions as given by *Hey's Mineral Index* (Clark, A.M. (ed.) *Hey's Mineral Index*, third edn, Chapman & Hall, London, 1993) were used. Mineral names might also be used in the context of corrosion products where the occurrence is not intentional (for instance, natural patination or alteration products of pigments in certain contexts), but not where such mechanisms are part of the artificial process of synthesis of a pigment (such as the production of lead white by the 'stack' process). The authors feel that the use of mineral names in all other contexts should be either qualified or discouraged, even where analytical methods commonly used give data expressed as minerals (notably X-ray diffraction studies).
2. Inorganic compounds produced synthetically should be called by their chemical name based on current International Union of Pure and Applied Chemistry ('IUPAC') conventions, under the so-called 'Red Book' (IUPAC *Nomenclature of Inorganic Chemistry. Recommendations 1990*, G.J. Leigh (ed.) Blackwell Scientific Publications, Oxford, 1990). In practice IUPAC rules offer a range of possible constructions and therefore certain practices were adopted within these rules. For example, forms such as 'aluminate' or 'stannate' have not been used, these being substituted by constructions such as '*xxx* aluminium oxide' and '*xxx* tin oxide'; the compounds concerned are then classed as oxides of the first-named element. However, as the list currently stands it is not wholly consistent; for example, 'chromate' has been used,

given as a sub-class of the chromium oxides. The use of IUPAC forms also leads us to use 'sulfur' rather than 'sulphur', and so forth.

3. Organic compounds should ideally be again named according to current IUPAC conventions (in this case by the so-called 'Green Book'). Unfortunately many of these – particularly names formed with substitutional systems – are unfeasibly long for general use. Since there are often already widely used terms established in the field which are sufficiently specific (for example, 'alizarin'), it would seem reasonable to use these unless there is a good basis to do otherwise. Consequently, in cases where a well-recognised name of convenience exists for a complex compound and no ambiguity accrues by its use, this has been substituted for reasons of brevity and memorability. Fuller formulae are generally given in the main text entry in this volume.
4. For organo-metallic compounds of precisely known composition, again IUPAC conventions would be preferable, though once again the principle of simplification without ambiguity has been adopted where possible. In certain important cases, however, where the composition is indefinite or the relationship too complex to be described simply, or the composition perhaps too poorly understood (for example, with the so-called 'copper resinate' and 'copper oleate'), certain *ad hoc* naming methods are used and the classes moved to the 'composites' index. In the specific cases just cited the compounds are referred to as 'copper-resin complex' and 'copper-oil complex', with consequent provision for specifying the relevant resin or oil (such as, 'copper-mastic resin complex', 'copper-linseed oil complex') where known. This was an area where it was felt more research is particularly needed.

Standard names used in all the entries have been checked against a number of sources to ensure that they represent as accurately as possible current practice. According to the conventions laid out in the section on naming pigments at the end of this volume, terminology follows that given in a series of reference works. Hence all mineral names follow that given in the latest edition of *Hey's Mineral Index* as described above, inorganic names have been formed following current IUPAC rules and checked against entries in the *Dictionary of Inorganic Chemistry* (MacIntyre, 1992). Plant names have been confirmed against the authoritative *The Plant Book* (Mabberley, 1998) unless there was reason to believe this source was inaccurate or incomplete. Other standard texts have been used for specific areas such as coals and clays, scale insects and shellfish purples. Organic terminology, as explained above, presents certain peculiar problems; the authors have generally elected to use the common terms applied where the meaning is precise, though such terms have been verified from various sources such as the widely used *Merck Index* (1996), as well as sources such as Schweppe's *Handbuch der Naturfarbstoffe: Vorkommen, Verwendung, Nachweis* (1992).

Three further sub-categorisations are used to define the pigment more precisely, constructed as pendant qualifiers to the above stems. Although this leads to a certain syntactic inelegance, the meaning is, however, more exact. First, a significant precision and convenience of mineral names is that they specify in a single name both the chemical composition and the crystal structure of that substance. Consequently, to extend the specificity of inorganic terminology along similar lines, mineral names are applied here where crystal structure is an important aspect. Examples might be the copper carbonate hydroxide pigments known as 'blue verditer' and 'green verditer'; these take the analogous forms to the minerals azurite and malachite, so the compounds are here referenced as 'Copper carbonate hydroxide, azurite type' and 'Copper carbonate hydroxide, malachite type'. Where the pigment may be specified unambiguously without the mineral-crystal qualifier, it is generally omitted. This strictly deviates from IUPAC guidelines due to the fact that IUPAC provides only for crystal system clarification (for example, 'orthorhombic type') or for inclusion of the complete space group, thus causing problems where several crystalline forms actually belong to the same crystal system. It was also felt that this latter method of space groups was too complicated, losing an immediate relationship to minerals that we wanted to emphasise. Consequently it was decided that use of the mineral names was actually more helpful.

Second, there are variants due to the manufacturing process which give rise to morphological differences. Typical examples include aqueous preparation as opposed to a process involving sublimation – so-called 'wet' and 'dry' process mercury sulfide ('vermilion') pigments. Consequently, where there are morphological variants, these are referred to either by appending the morphological form (for example, zinc oxide, acicular type), or the generally recognised formation route ('mercury(II) sulfide, cinnabar type, wet process'). As above, where the use of a qualifier is unnecessary to achieve a precise specification, it is omitted.

Third, some additional separation is used, such as where the source of the raw material potentially influences the final product. Simple examples would be different materials taken as starting points for chars ('peachstone char', 'cork char', and so on) or the geological deposit of a mineral. Quite apart from the case of the so-called 'earth' pigments, it is envisaged that this system might be extended in the future to cover distinctions between minerals by virtue of isotopic or trace-elemental composition. An example here might be sulfur isotopes in lazurite used to distinguish between examples from Afghanistan, Lake Baikal in Siberia, and the Chilean Andes.

It was also felt that the organisation of the list should provide some systematic arrangement that linked or associated compounds. Colour is an obviously tempting approach – all blue pigments together, and so on – but this was rejected early on for the simple reason that it does not work particularly well. Instead assignment is by chemical similarity: at the most fundamental it would seem reasonable to try to associate compounds compositionally and structurally – particularly where this might reflect, say, an underlying chromophoric relationship – so in practice this has developed as a general guideline to group assignment. The listing is therefore organised by the principal element or structural base unit (for example, most lead-based compounds under 'lead' and compounds based on anthraquinones, such as alizarin and purpurin, under 'Quinones group: Anthraquinones sub-group'). Cases where the compound could come within more than one group (for example, a copper-chromium compound) are assigned according to where there seems to be a clear association (such as chromates under chromium rather than divided among the individual elements). Simpler inorganic and organometallic compounds and minerals were divided up into convenient sub-groups as:

Element
Carbonates
  Carbonates with Group 1 and/or 2 elements

Cyanides and other -CN compounds (excluding hexacyanoferrates)
Halides
Nitrates (and nitrites)
Oxides and hydroxides
  Tertiary and higher oxides with:
    Group 1/2/3–11, 1st series/3–11, 2nd and 3rd series/ 12/13/14/15/16 elements
Phosphates
Sulfates (and sulfites)
Sulfides (and selenides)
  Tertiary sulfides and selenides
Organo-metallic compounds

It will be clear from the discussion so far that the aim here has been to classify according to individual compounds on which a pigment is based. With naturally occurring dyestuffs classification is less straightforward since they typically contain large numbers of compounds. At the same time they are used as functional composites, processed from plant or animal source but generally used without separation (at most involving an enhancement of certain components such as with 'rose madder'). Moreover, they appear as a single unit microscopically, unlike, say, earth pigments. There are probably two choices: first, classify these composites according to some principal structural group: anthraquinones to contain both single molecular species such as 'alizarin' and 'madder' (dyestuffs derived from *Rubia* and other species of plant). Second, include only the molecular species in the listing and develop a secondary list of composite sources. After experimenting with both approaches, the latter was chosen, for consistency rather than convenience – in practice it makes referring to a number of pigments, such as gamboge, 'dragon's blood' and humic earth as well as dyestuffs, much more complex. (Note: 'lake' pigments are treated quite separately as composite pigments defined by both colouring matter and substrate.)

For azo and synthetic polycyclic pigments it was the sheer number of compounds which presented difficulties since issues of basic structural naming have been resolved in sources such as the *Colour Index*, where they are arranged according to the diazotised components they contain or the underlying polycyclic skeleton. To allow some simplification of structure here these pigments have first been divided into groups following those used by Herbst and Hunger (1997) (though an alternative grouping is given, for example by Berrie and Lomax, 1997). Beyond this it would be possible to use the fuller compositional name but it is in fact more convenient to use the *Colour Index* number, though the system that underlies it where the reacting components are given is more informative (for instance, in CI 11710 where 4-chloro-2-nitroaniline → o-chloroacetoacetanilide). The polycyclic pigments group defined by Herbst and Hunger is, however, a catch-all arrangement, defined by the absence of an azo group in the structure. It was partially retained here, though some historically important groups were moved out into their own categories. Examples are indigoid compounds and the porphyrins and phthalocyanines group.

The index is bound to be incomplete and therefore, in common with all similar exercises, the numbering should be used such as to give scope for insertion of additional species. Therefore, if the numeric value against a compound is to be used as a device for uniquely specifying it, then the individual numbers should be multiplied by a factor of 10. For example, barium manganese oxide has values 4, 6 and 1; the reference number would be 40.60.10. 'Wet' process vermilion ('mercury(II) sulfide, cinnabar type, wet process') becomes 170.80.10.10.20.

COMMON FUNCTIONAL COMPOSITES

Composite pigments are those where, by natural association or by deliberate synthesis, two or more compounds normally occur together; these might be termed 'associational' and 'depositional'. In associational composites, two or more distinct generic compounds are either artificially mixed or occur in natural association, for example most minerals used as pigments and, most importantly, 'earth' pigments (those naturally occurring materials commonly known as ochres, umbers and siennas). With depositional composites, one component is deposited on the surface of another, for example all 'lake' pigments, 'Maya blue', 'bone black' and 'chrome green'.

Common functional composite ('FCs') is a term applied here to broadly defined composites of generics that warrant systematic arrangement by virtue of their common usage. Examples might be 'ochre', 'madder' and 'gamboge', terms widely used in the field yet with sufficiently specific meaning to permit organisation. Within this definition we also include:

- *Particle-particle composites*, which are intimate mixtures of generics of marked physical size. An example might be earth pigments.
- *Molecular-molecular composites*, which are intimate mixtures of molecular species. An example would be a dyestuff derived from a plant source.
- *Particle-molecular composites*, which are those cases where molecularly divided species are attached physically or chemically to a particulate substrate. Common examples would be 'lake' pigments and 'Maya blue'.

Colloids have not been considered as part of this simplified system as the orientation is toward pigments in the solid ('dried') state rather than the fluid system of preparation and application where the concept of colloids is more immediately relevant. However, the state of molecular aggregation in paint films may be of interest in the future as being indicative of these processes.

FCs are characteristically distinct in being used as discrete materials rather than being a group as defined above (section A), where the group and sub-group structure represents a systematic ordering of related compounds that may not necessarily occur together.

The systematic organisation of these functional composites ('FCs') presents complex problems and a deliberate simplification process has been adopted here. As a partial solution, a series of groups have been formed that are not comprehensive, but which allow us to articulate certain specific relationships which were needed for other discussions. These cover carbon-based materials fromcarbon-based blacks through hydrocarbons, dyes derived from natural sources and earth pigments.

Natural dyestuffs have been structured according to source, with divisions according to plant, lichen, scale insect and shellfish. To derive a list of dye compounds, species identified in the literature were collated and the colouring principles determined from scientific sources (primarily Schweppe, 1992 and Harborne and Baxter, 1999). These were used for the development of the primary compounds listing (that is, not all known dyestuffs have been included, only those where there is evidence for the particular source having been used in a pigment context).

Carbon-based blacks have been treated as a composite group because the chemistry is far more complex than simply that of carbon (for example, they may contain a highly variable hydrocarbon phase). They are also conveniently linked into hydrocarbons and other complex organic materials such as tannins. The carbon-based blacks are differentiated here from one another primarily by source material and production method, these profoundly affecting composition and morphology. However, they have been arranged here according to the naming structure given by Winter (1983) with sub-groupings based on whether they are chars, cokes, flame carbons and so forth.

Earth pigments are listed here according to the arrangement discussed in the main text under 'Earth pigments group'. However, the so-called 'Humic' earths are classified within the 'Hydrocarbons group'.

α	β	γ	δ	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
1	1	1		Aluminium	*Aluminium*	Aluminium		Al	7429-90-5	Edwards (1927); Gettens & Stout (1966); Smith (1983a,b)	
1	2			Aluminium	*Carbonates*						
1	3			Aluminium	*Cyanides*						
1	4			Aluminium	*Halides*						
1	5			Aluminium	*Nitrates*						
1	6	1	1	Aluminium	*Oxides & hydroxides*	Aluminium oxide, amorphous type		Al_2O_3(am)		Heaton (1928) as aluminium oxide then chem. lit.	
1	6	2	1	Aluminium	*Oxides & hydroxides*	Aluminium oxide, corundum type		α-Al_2O_3	1344-28-1	Heaton (1928) as aluminium oxide then chem. lit.	
1	6	2	2	Aluminium	*Oxides & hydroxides*	Corundum		α-Al_2O_3	1302-74-5	Heaton (1928) as aluminium oxide then chem. lit.	
1	6	2	2	Aluminium	*Oxides & hydroxides*	Aluminium hydroxide, boehmite type		γ-Al(O)OH		Synthetic analogue	
1	6	2	2	Aluminium	*Oxides & hydroxides*	Boehmite		γ-Al(O)OH	1318-23-6	Helwig (1995) in 'red earth' (Forbes 6.02.78)	
1	6	2	2	Aluminium	*Oxides & hydroxides*	Aluminium hydroxide, diaspore type		α-Al(O)OH		Related compound	
1	6	2	2	Aluminium	*Oxides & hydroxides*	Diaspore		α-Al(O)OH	14457-84-2	Related mineral	
1	6	3	1	Aluminium	*Oxides & hydroxides*	Aluminium hydroxide, bayerite type		α-$Al(OH)_3$	21645-51-2	Winchell (1927)	
1	6	3	2	Aluminium	*Oxides & hydroxides*	Bayerite		α-$Al(OH)_3$	20257-20-9	Mineral analogue	
1	6	4	1	Aluminium	*Oxides & hydroxides*	Aluminium hydroxide, doyleite type		$Al(OH)_3$		Related synthetic analogue	
1	6	4	2	Aluminium	*Oxides & hydroxides*	Doyleite		$Al(OH)_3$		Related mineral	
1	6	5	1	Aluminium	*Oxides & hydroxides*	Aluminium hydroxide, gibbsite type		γ-$Al(OH)_3$		Synthetic analogue	
1	6	5	2	Aluminium	*Oxides & hydroxides*	Gibbsite		γ-$Al(OH)_3$	14762-49-3	Helwig (1995) in 'red earth' (Forbes 6.02.78)	
1	6	6	1	Aluminium	*Oxides & hydroxides*	Aluminium hydroxide, nordstrandtite type		$Al(OH)_3$		Related synthetic analogue	
1	6	6	2	Aluminium	*Oxides & hydroxides*	Nordstrandtite		$Al(OH)_3$	13840-05-6	Mineral analogue	
1	7	1	1	Aluminium	*Phosphates*	Aluminium phosphate, angelite type		$Al(PO)_4$	7784-30-7	Church (1901) as aluminium phosphate, then chem. lit., e.g. Becher	
1	7	1	2	Aluminium	*Phosphates*	Angelite		$Al(PO)_4$		Mineral analogue	
1	7	2	1	Aluminium	*Phosphates*	Aluminium phosphate		$AlH_3(PO_4)_2$	13967-89-0	Church (1901) as aluminium phosphate, then chem. lit.	
1	7	3	1	Aluminium	*Phosphates*	Aluminium phosphate		$Al(H_2PO_4)_3$	13530-50-2	Church (1901) as aluminium phosphate, then chem. lit.	
1	8			Aluminium	*Sulfides*						
1	9	1	1	Aluminium	*Sulfates*	Aluminium sulfate		$Al_2(SO_4)_3$	17927-65-0	*Colour Index* (1971)	
1	9	2	1	Aluminium	*Sulfates*	Potassium aluminium sulfate hydroxide, alunite type		$KAl_3(SO_4)_2(OH)_6$		Synthetic analogue	
1	9	2	2	Aluminium	*Sulfates*	Alunite		$KAl_3(SO_4)_2(OH)_6$		Newman *et al.* (1980)	Newman *et al.* give: $(K,Na)Al_3(SO_4)_2(OH)_6$
1	10	1	1	Aluminium	*Organo-aluminium compounds*	Aluminium stearate		$[CH_3(CH_2)_{16}COO]_3Al$		Gettens & Stout (1966)	

(*continued*)

A: Generic compounds (*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
2	1	1	1		Antimony	*Antimony*	Antimony		Sb	7440-36-0	*Colour Index* (1971)	
2	2				Antimony	*Carbonates*						
2	3				Antimony	*Cyanides*						
2	4	1	1		Antimony	*Halides*	Antimony(III) chloride		$SbCl_3$	10025-91-9	*Colour Index* (1971)	
2	4	2	1		Antimony	*Halides*	Antimony chloride oxide		$SbOCl$	7791-08-4	*Colour Index* (1971), then chem. lit.	
2	4	3	1		Antimony	*Halides*	Antimony chloride oxide		$Sb_4Cl_2O_5$	12182-69-3	*Colour Index* (1971), then chem. lit.	
2	4	4	1		Antimony	*Halides*	Antimony chloride oxide		$Sb_8Cl_2O_{11}$	12323-75-0	*Colour Index* (1971), then chem. lit.	
2	4	4	2		Antimony	*Halides*	Onoratoite		$Sb_8Cl_2O_{11}$	12381-11-2	*Colour Index* (1971), then chem. lit.	
2	5				Antimony	*Nitrates*						
2	6	1	1		Antimony	*Oxides & hydroxides*	Antimony(III) oxide, senarmontite type		Sb_2O_3		*Colour Index* (1971) as antimony oxide, then chem. lit.	
2	6	1	2		Antimony	*Oxides & hydroxides*	Senarmontite		Sb_2O_3	12412-52-1	Mineral analogue	
2	6	2	1		Antimony	*Oxides & hydroxides*	Antimony(III) oxide, valentinite type		Sb_2O_3	1309-64-4	*Colour Index* (1971) as a ntimony oxide, then chem. lit.	
2	6	2	2		Antimony	*Oxides & hydroxides*	Valentinite		Sb_2O_3	1317-98-2	Mineral analogue	
2	6	3			Antimony	*Oxides & hydroxides*	Antimony(IV) oxide		SbO_2 (or Sb_2O_4)		Gloger & Hurley (1973)	
2	6	4			Antimony	*Oxides & hydroxides*	Antimony(V) oxide		Sb_2O_5		Gloger & Hurley (1973)	'… has no industrial importance as a pigment'
2	7				Antimony	*Phosphates*						
2	8	1			Antimony	*Sulfides*	Antimony(III) sulfide, amorphous type		Sb_2S_3(am)			'Antimony vermilion'
2	8	2	1		Antimony	*Sulfides*	Antimony(III) sulfide, stibnite type		Sb_2S_3	1345-04-6	*Colour Index* (1971)	
2	8	2	2		Antimony	*Sulfides*	Stibnite		Sb_2S_3	1317-86-8	Ferretti *et al.* (1991)	
2	8	3			Antimony	*Sulfides*	Antimony(V) sulfide		Sb_2S_5	1315-04-4	*Colour Index* (1971)	'Antimony vermilion'. According to Cotton *et al.* (1999), Mossbauer spectroscopy shows only Sb(III) to be present
2	8	4			Antimony	*Sulfides*	Antimony oxide sulfide		$2Sb_2S_3.Sb_2O_3$(am) ?	12412-48-5	Heaton (1928) and chem. lit.	
					Antimony	*Sulfides*	Kermesite		Sb_2S_2O	12196-78-0	Related mineral	
2	9				Antimony	*Sulfates*						
2	10				Antimony	*Organo-antimony compounds*						
3	1				Arsenic	*Arsenic*						
3	2				Arsenic	*Carbonates*						
3	3				Arsenic	*Cyanides*						
3	4				Arsenic	*Halides*						
3	5				Arsenic	*Nitrates*						
3	6	1	1		Arsenic	*Oxides & hydroxides*	Arsenic oxide, arsenolite type		As_2O_3	12505-67-8	FitzHugh (1997)	
3	6	1	2		Arsenic	*Oxides & hydroxides*	Arsenolite		As_2O_3	1303-24-8	Mineral analogue	
3	6	2			Arsenic	*Oxides & hydroxides*	Claudetite I		As_4O_6	13473-03-5	Related mineral	
3	6	3			Arsenic	*Oxides & hydroxides*	Claudetite II		As_4O_6	13473-03-5	Related mineral	
3	7				Arsenic	*Phosphates*						
3	8	1	1		Arsenic	*Sulfides*	Arsenic sulfide, amorphous type		As_2S_3(am)	1303-33-9		

3	8	2	1		Arsenic	*Sulfides*	Arsenic sulfide, alacranite type		As_8S_9		Synthetic analogue	
3	8	2	2		Arsenic	*Sulfides*	Alacranite		As_8S_9		FitzHugh (1997)	
3	8	3	1		Arsenic	*Sulfides*	Arsenic sulfide, dimorphite type, α-form		As_4S_3	12512-13-9	Noll (1981) & FitzHugh (1997), then min. lit.	Said to be dimorphic (α-, β-forms)
3	8	3	2		Arsenic	*Sulfides*	Dimorphite, α-form		As_4S_3	1303-41-9	Noll (1981) & FitzHugh (1997), then min. lit.	Said to be dimorphic (α-, β-forms)
3	8	4	1		Arsenic	*Sulfides*	Arsenic sulfide, dimorphite type, β-form		As_4S_3	12512-13-9	Noll (1981) & FitzHugh (1997), then min. lit.	Said to be dimorphic (α-, β-forms)
3	8	4	2		Arsenic	*Sulfides*	Dimorphite, β-form		As_4S_3	1303-41-9	Noll (1981) & FitzHugh (1997), then min. lit.	Said to be dimorphic (α-, β-forms)
3	8	5	1		Arsenic	*Sulfides*	Arsenic sulfide, duranusite type		As_4S			
3	8	5	2		Arsenic	*Sulfides*	Duranusite		As_4S		Noll (1981); FitzHugh (1997)	
3	8	6	1	1	Arsenic	*Sulfides*	Arsenic sulfide, orpiment type	'Dry' process	As_2S_3	1303-33-9	Widely recognised	
3	8	6	1	2	Arsenic	*Sulfides*	Arsenic sulfide, orpiment type	'Wet' process	As_2S_3	1303-33-9	Widely recognised	
3	8	6	2		Arsenic	*Sulfides*	Orpiment		As_2S_3		Widely recognised	
3	8	7			Arsenic	*Sulfides*	Arsenic sulfide, pararealgar type		AsS			
3	8	7			Arsenic	*Sulfides*	Pararealgar		AsS		Green (1995); Corbeil & Helwig (1995)	
3	8	8	1		Arsenic	*Sulfides*	Arsenic sulfide, realgar type		As_2S_2	12279-90-2	Synthetic analogue	
3	8	8	2		Arsenic	*Sulfides*	Realgar		As_2S_2	12044-30-3	Widely recognised	
3	8	9	1		Arsenic	*Sulfides*	Arsenic sulfide, uzonite type		As_4S_5	25114-28-7	FitzHugh (1997), then chem. lit.	
3	8	9	2		Arsenic	*Sulfides*	Uzonite		As_4S_5		FitzHugh (1997)	
3	9				Arsenic	*Sulfates*						
3	10				Arsenic	*Organo-arsenic compounds*						
4	1				Barium	*Barium*						
4	2	1	1		Barium	*Carbonates*	Barium carbonate		$BaCO_3$	513-77-9	*Colour Index* (1971); Heaton (1928)	
4	2	1	2		Barium	*Carbonates*	Witherite		$BaCO_3$	14941-39-0	*Colour Index* (1971); Heaton (1928)	
4	3				Barium	*Cyanides*						
4	4				Barium	*Halides*						
4	5				Barium	*Nitrates*						
4	6	1			Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Barium manganese oxide		$BaMnO_4$		Widely recognised	
4	6	2			Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Barium manganese oxide		Ba_3MnO_5		Chem. lit	Unknown validity
4	6	3			Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Barium manganate(VI) sulfate		$x BaSO_4 . y BaMnO_4$		Widely recognised	
4	6	4	1		Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Barium manganese oxide, hollandite type		$Ba_{0.8–1.5}[Mn(IV), Mn(III)]_8O_{16}$ $\{or\ BaMn_8O_{16}\}$		Guineau *et al.* (2000)	Post (1999) classifies this as a manganese oxide
4	6	4	2		Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Hollandite		$Ba_{0.8–1.5}[Mn(IV), Mn(III)]_8O_{16}$ $\{or\ BaMn_8O_{16}\}$		Guineau *et al.* (2000)	Post (1999) classifies this as a manganese oxide
4	6	5	1		Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Barium manganese oxide, romanechite type		$Ba_{0.66}Mn(IV)_{3.68}Mn(III)_{1.32}O_{10}.1.34H_2O$ $\{or\ BaMn_9O_{16}(OH)_4\}$		Guineau *et al.* (2000)	Post (1999) classifies this as a manganese oxide
4	6	5	2		Barium	*Oxides & hydroxides with Group 3–11 elements (Mn)*	Romanechite		$Ba_{0.66}Mn(IV)_{3.68}Mn(III)_{1.32}O_{10}.1.34H_2O$ $\{or\ BaMn_9O_{16}(OH)_4\}$		Guineau *et al.* (2000)	Post (1999) classifies this as a manganese oxide

(*continued*)

α	β	γ	δ	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
4	7			Barium	*Phosphates*						
4	8			Barium	*Sulfides*						
4	9	1	1	Barium	*Sulfates*	Barium sulfate		$BaSO_4$	7727-43-7	Widely recognised	
4	9	1	2	Barium	*Sulfates*	Baryte		$BaSO_4$	13462-86-7	Widely recognised	
4	10			Barium	*Organo-barium compounds*						
5	1	1		Bismuth	*Bismuth*	Bismuth		Bi			‘Wismutmalerei’
5	2			Bismuth	*Carbonates*						
5	3			Bismuth	*Cyanides*						
5	4	1		Bismuth	*Halides*	Bismuth chloride oxide		BiClO	7787-59-9	*Colour Index* (1971)	
5	5	1		Bismuth	*Nitrates*	Bismuth nitrate		$Bi(NO_3)_3$	10361-46-3	*Merck Index* (1996)	
5	5	2		Bismuth	*Nitrates*	Bismuth nitrate oxide		$BiO(NO_3)$		*Colour Index* (1971)	
5	5	3		Bismuth	*Nitrates*	Bismuth hydroxide nitrate oxide		$Bi_2O_2(OH)(NO_3)$	1304-85-4	*Colour Index* (1971)	
5	6			Bismuth	*Oxides*						
5	7			Bismuth	*Phosphates*						
5	8	1	1	Bismuth	*Sulfides*	Bismuth sulfide		Bi_2S_3			
5	8	1	2	Bismuth	*Sulfides*	Bismuthinite		Bi_2S_3		Seccaroni (1999); Spring (2000)	
5	9			Bismuth	*Sulfates*						
5	10			Bismuth	*Organo-bismuth compounds*						
6	1			Cadmium	*Cadmium*						
6	2	1		Cadmium	*Carbonates*	Cadmium carbonate		$CdCO_3$	513-78-0	Salter (1869) 78; Fiedler & Bayard (1986) 78	
6	2	1		Cadmium	*Carbonates*	Otavite		$CdCO_3$		Related mineral	
6	3			Cadmium	*Cyanides*						
6	4			Cadmium	*Halides*						
6	5			Cadmium	*Nitrates*						
6	6	1		Cadmium	*Oxides & hydroxides*	Cadmium oxide		CdO		Fiedler & Bayard (1986)	
6	6	2		Cadmium	*Oxides & hydroxides*	Cadmium oxide hydrate				Salter (1869) 78	
6	7	1		Cadmium	*Phosphates*	Cadmium phosphate				Fiedler & Bayard (1986)	
6	8	1		Cadmium	*Sulfides & selenides*	Cadmium sulfide, amorphous type		CdS(am)		Fiedler & Bayard (1986)	
6	8	2	1	Cadmium	*Sulfides & selenides*	Cadmium sulfide, greenockite type		CdS	1306-23-6	Fiedler & Bayard (1986)	α-form
6	8	2	2	Cadmium	*Sulfides & selenides*	Greenockite		CdS		Mineral analogue	
6	8	3	1	Cadmium	*Sulfides & selenides*	Cadmium sulfide, hawleyite type		CdS	1306-23-6	Fiedler & Bayard (1986)	β-form
6	8	3	2	Cadmium	*Sulfides & selenides*	Hawleyite		CdS		Mineral analogue	
6	8	4		Cadmium	*Sulfides & selenides*	Cadmium selenide		CdSe	1306-24-7	Fiedler & Bayard (1986)	
6	8	5		Cadmium	*Tertiary sulfides & selenides*	Cadmium selenium sulfide		Cd(S,Se)		Fiedler & Bayard (1986)	
6	8	6		Cadmium	*Tertiary sulfides & selenides*	Cadmium mercury sulfide		(Cd,Hg)S		*Colour Index* (1971)	
6	8	7		Cadmium	*Tertiary sulfides & selenides*	Cadmium zinc sulfide		(Cd,Zn)S		*Colour Index* (1971)	
6	9			Cadmium	*Sulfates*						
6	10	1		Cadmium	*Organo-cadmium compounds*	Cadmium oxalate		CdC_2O_4	814-88-0	Fiedler & Bayard (1986) 78	

7	1				Calcium	*Calcium*						
7	2	1	1		Calcium	*Carbonates*	Calcium carbonate, aragonite type		$CaCO_3$	471-34-1	Synthetic analogue	
7	2	1	2		Calcium	*Carbonates*	Aragonite (as mineral)		$CaCO_3$	14791-73-2	Béarat (1997)	
7	2	1	3		Calcium	*Carbonates*	Aragonite (from biogenic sources)	From shell	$CaCO_3$			
7	2	2	1	1	Calcium	*Carbonates*	Calcium carbonate, calcite type	By conversion of calcium oxide	$CaCO_3$			
7	2	2	1	2	Calcium	*Carbonates*	Calcium carbonate, calcite type	By precipitation	$CaCO_3$		Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	2		Calcium	*Carbonates*	Calcite (as mineral)		$CaCO_3$	13397-26-7	Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	3	1	Calcium	*Carbonates*	Calcite (from biogenic sources)	Coral	$CaCO_3$		Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	3	2	Calcium	*Carbonates*	Calcite (from biogenic sources)	From *Sepia officinalis* (‘cuttlefish’)	$CaCO_3$		Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	3	3	Calcium	*Carbonates*	Calcite (from biogenic sources)	Egg shell	$CaCO_3$		Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	3	4	Calcium	*Carbonates*	Calcite (from biogenic sources)	Oyster shell	$CaCO_3$		Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	4	1	Calcium	*Carbonates*	Calcite (mineralised forms)	Chalk	$CaCO_3$	471-34-1	Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	4	2	Calcium	*Carbonates*	Calcite (mineralised forms)	Limestone	$CaCO_3$	471-34-1	Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	4	3	Calcium	*Carbonates*	Calcite (mineralised forms)	Travertine	$CaCO_3$	471-34-1	Widely recognised; rev.: Gettens *et al.* (1993)	
7	2	2	4	4	Calcium	*Carbonates*	Calcite (mineralised forms)	Marble	$CaCO_3$			
7	2	3	1		Calcium	*Carbonates*	Calcium carbonate, vaterite type		$CaCO_3$			
7	2	3	2		Calcium	*Carbonates*	Vaterite		$CaCO_3$			
7	2	4			Calcium	*Carbonates with Group 1 & 2 elements*	Ankerite		$Ca(Mg_{0.67}Fe_{0.33})(CO_3)_2$		Ford *et al.* (1994)	Another source gives $Ca(Mg_{0.75}Fe_{0.25})(CO_3)_2$
7	2	5	1		Calcium	*Carbonates with Group 1 & 2 elements*	Calcium magnesium carbonate, dolomite type		$CaMg(CO_3)_2$	7000-29-5	Synthetic analogue	
7	2	5	2		Calcium	*Carbonates with Group 1 & 2 elements*	Dolomite		$CaMg(CO_3)_2$	16389-88-1	Ford *et al.* (1994)	
7	2	5	2		Calcium	*Carbonates with Group 1 & 2 elements*	Dolomite, ferroan		$Ca(Mg,Fe^{2+})(CO_3)_2$		Segal & Porat (1997)	Considered to be a solid solution series between dolomite and ankerite
7	2	6	1		Calcium	*Carbonates with Group 1 & 2 elements*	Calcium magnesium carbonate, huntite type		$CaMg_3(CO_3)_4$	22450-53-9	Synthetic analogue	
7	2	6	2		Calcium	*Carbonates with Group 1 & 2 elements*	Huntite		$CaMg_3(CO_3)_4$	19569-21-2	Riederer (1974); Barbieri *et al.* (1975), Clarke (1976)	
7	3				Calcium	*Cyanides*						
7	4	1			Calcium	*Halides*	Fluorite		CaF_2		Agricola (1955); Richter *et al.* (2001)	e.g. in form known as ‘antozonite’
7	5				Calcium	*Nitrates*						
7	6	1	1		Calcium	*Oxides & Hydroxides*	Calcium hydroxide		$Ca(OH)_2$	1305-62-0	Synthetic analogue	
7	6	1	2		Calcium	*Oxides & Hydroxides*	Portlandite		$Ca(OH)_2$		FitzHugh (1997)	
7	6	2	1		Calcium	*Oxides & Hydroxides*	Calcium oxide		CaO	1305-78-8		
7	6	2	2		Calcium	*Oxides & Hydroxides*	Lime		CaO	1305-78-8		

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
7	6	3			Calcium	*Tertiary oxides*	Calcium aluminium oxide		[---]		Heaton (1928)	
7	7	1			Calcium	*Phosphates*	Calcium phosphate		$Ca(HPO_4)$	7757-93-9	Zerr & Rübencamp (1908) 241; *Colour Index* (1971) 77298 then chem. lit.	
7	7	2			Calcium	*Phosphates*	Calcium phosphate		$Ca(H_2PO_4)_2$	7758-23-8	[As above]	
7	7	3			Calcium	*Phosphates*	Calcium phosphate		$Ca_3(H_2PO_4)_2$		[As above]	
7	7	4			Calcium	*Phosphates*	Calcium phosphate		$Ca_4(HPO_4)(PO_4)_2$	13767-12-9	[As above]	
					Calcium	*Phosphates*	Apatite		$Ca_5(PO_4)_3(OH,F,Cl)$			
7	7	5			Calcium	*Phosphates*	Carbonate-hydroxylapatite[1]		$Ca_5(PO_4,CO_3)_3(OH)$			
7	7	6			Calcium	*Phosphates*	Chloroapatite		$Ca_5(PO_4)_3Cl$	1306-04-3		
7	7	8			Calcium	*Phosphates*	Fluor-apatite		$Ca_5(PO_4)_3F$	1306-05-4		
7	7	9	1		Calcium	*Phosphates*	Hydroxylapatite (as mineral)		$Ca_5(PO_4)_3(OH)$	1306-06-5	Mineral analogue	
7	7	9	2		Calcium	*Phosphates*	Hydroxylapatite (from biogenic (bone) source)	From mammalian bone	$Ca_5(PO_4)_3(OH)$		Widely recognised	
7	8				Calcium	*Sulfides*						
7	9	1	1		Calcium	*Sulfates*	Calcium sulfate, anhydrite type		$CaSO_4$	7778-18-9	Widely recognised	
7	9	1	2		Calcium	*Sulfates*	Anhydrite		$CaSO_4$	14798-04-0	Mineral analogue	
7	9	2	1		Calcium	*Sulfates*	Calcium sulfate, bassanite type[2]		$CaSO_4$.fiH_2O	26499-65-0	Widely recognised	
7	9	2	2		Calcium	*Sulfates*	Bassanite		$CaSO_4$.fiH_2O	17033-35-1	Capitán-Vallvey *et al.* (1994)	
7	9	3	1		Calcium	*Sulfates*	Calcium sulfate, gypsum type		$CaSO_4.2H_2O$	10101-41-4	Widely recognised	
7	9	3	2		Calcium	*Sulfates*	Gypsum		$CaSO_4.2H_2O$	13397-24-5	Mineral analogue	
7	10	1	1		Calcium	*Organo-calcium compounds*	Calcium acetate		$(CH_3COO)_2Ca$	62-54-4	Eikema Hommes (2002)	
7	10	2	1		Calcium	*Organo-calcium compounds*	Calcium oxalate, weddellite type		$CaC_2O_4.(2 + x)H_2O$	563-72-4	Synthetic analogue	
7	10	2	2		Calcium	*Organo-calcium compounds*	Weddellite		$CaC_2O_4.(2 + x)H_2O$	7236-42-2	Alessandrini *et al.* (1994); Russ *et al.* (1999)	
7	10	3	1		Calcium	*Organo-calcium compounds*	Calcium oxalate, whewellite type		$CaC_2O_4.H_2O$		Synthetic analogue	
7	10	3	2		Calcium	*Organo-calcium compounds*	Whewellite		$CaC_2O_4.H_2O$	14488-96-1	Russ *et al.* (1999)	
	1				Cerium and Samarium	*Cerium*						
	2				Cerium and Samarium	*Carbonates*						
	3				Cerium and Samarium	*Cyanides*						
	4				Cerium and Samarium	*Halides*						
	5				Cerium and Samarium	*Nitrates*						
	6				Cerium and Samarium	*Oxides and hydroxides*						
	7				Cerium and Samarium	*Phosphates*						
	8	1			Cerium and Samarium	*Sulfides*	Cerium sulfide					
	8	2			Cerium and Samarium	*Sulfides*	Cerium fluoride sulfide					

	8	3		Cerium and Samarium	*Sulfides*	Cerium Samarium sulfide				
	9			Cerium and Samarium	*Sulfates*					
	10			Cerium and Samarium	*Organo-cerium compounds*					
8	1			Chromium	*Chromium*					
8	2			Chromium	*Carbonates*					
8	3			Chromium	*Cyanides*					
8	4	1		Chromium	*Halides*	Chromium(III) chloride	$CrCl_3$	10025-73-7	Wohler (cf. *Colour Index* (1971) 77295), then chem. lit.	
8	4	2		Chromium	*Halides*	Chromium(III) chloride hexahydrate	$Cl_3CrH_{12}O_6$, probably as $[Cr(OH_2)_6]Cl_3$	10060-12-5 or 13820-88-7	Wohler (cf. *Colour Index* (1971) 77295), then chem. lit.	
8	5			Chromium	*Nitrates*					
8	6	1	1	Chromium	*Oxides & hydroxides*	Chromium oxide	Cr_2O_3	1308-38-9	Widely recognised (rev.: Newman (1997))	CI 77288/Pigment Green 17
8	6	1	2	Chromium	*Oxides & hydroxides*	Eskolaite	Cr_2O_3		Mineral analogue	
8	6	2		Chromium	*Oxides & hydroxides*	Chromium oxide hydrate	$Cr_2O_3.xH_2O$, where $x \sim 2$	12001-99-9	Widely recognised (rev.: Newman (1997))	
8	6	3		Chromium	*Oxides & hydroxides*	Chromium oxide hydrate	$Cr(OH)_3.3H_2O$ or $Cr_2O_3.9H_2O$	1308-14-1	Chem. lit.	Dihydrate?
8	6	4		Chromium	*Oxides & hydroxides*	Chromium oxide hydroxide	$Cr_2O(OH)_4$		*Colour Index* (1971) 77289 (unconfirmed)	
8	6	5		Chromium	*Oxides & hydroxides*	Chromium oxide hydroxide	$Cr_4O_3(OH)_4$		*Colour Index* (1971) 77289 (unconfirmed)	
8	6	6		Chromium	*Oxides & hydroxides*	Chromium oxide hydroxide	$Cr_4O(OH)_{10}$		*Colour Index* (1971) 77289 (unconfirmed)	
8	6	7		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromium aluminium oxide	[---]		*Colour Index* (1971) 77288 (unconfirmed)	
8	6	8		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromium aluminium cobalt oxide	[---]		Kühn (1969); Pamer (1978)	
8	6	9		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromium aluminium tin oxide	[---]			
8	6	10		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromium borate	[---]		*Colour Index* (1971) 77292; Newman (1997) 279	
8	6	11		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromium(III) iron(III) oxide	$(Fe,Cr)_2O_3$		*Colour Index* (1971) 77500	
8	6	12		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromium(III) iron(II) oxide	Cr_2FeO_4	12068-77-8	*Colour Index* (1971) 77500 then chem. lit.	
8	6	13		Chromium	*Tertiary & quaternary oxides (Al + Co, Sn; Cu, Fe)*	Chromoferrite	Cr_2FeO_4	1308-31-2	*Colour Index* (1971) 77500 then chem. lit. (mineral analogue)	
8	6	14		Chromium	*Chromates with group 1/2 elements*	Barium chromate(IV)	CrO_4Ba	10294-40-3	*Colour Index* (1971) 77103	
8	6	15		Chromium	*Chromates with group 1/2 elements*	Barium potassium chromate	$K_2Ba(CrO_4)_2$		*Colour Index* (1971) 77106	
8	6	16		Chromium	*Chromates with group 1/2 elements*	Calcium chromite	$Ca(CrO_4)_2$			

(*continued*)

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[1] Also known as dahllite (formula sometimes given as $Ca_{10}(PO_4)_6(CO_3).H_2O$).

[2] Also known as the 'hemihydrate' form, bassanite being used here for consistency. However, also see text for a discussion of variations of hydration state.

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
8	6	17			Chromium	*Chromates with group 1/2 elements*	Calcium chromate(IV)		CrO_4Ca	13765-19-0		
8	6	18			Chromium	*Chromates with group 1/2 elements*	Calcium chromate(IV) dihydrate		$CrO_4Ca.2H_2O$	10060-08-9	Salter (1869) as 'Gelbin's yellow' and *Colour Index* (1971) 77223	
8	6	19			Chromium	*Chromates with group 1/2 elements*	Calcium chromate(IV) hydroxide dihydrate		$Ca_2(OH)_2CrO_4.2H_2O$		Salter (1869) as 'Gelbin's yellow' and *Colour Index* (1971) 77223	
8	6	20			Chromium	*Chromates with group 1/2 elements*	Strontium chromate(IV)		CrO_4Sr	7789-06-2	*Colour Index* (1971) 77839	
8	6	21			Chromium	*Chromates with group 3–11 elements*	Copper chromate(VI)		$CuCrO_4$		Martel (1859) and others, then chem. lit.	
8	6	22			Chromium	*Chromates with group 3–11 elements*	Copper chromate hydroxide		$CuCrO_4.Cu(OH)_2$		Martel (1859) and others, then chem. lit.	
8	6	23			Chromium	*Chromates with group 3–11 elements*	Copper chromate hydroxide		$CuCrO_4.2Cu(OH)_2$		Martel (1859) and others, then chem. lit.	
8	6	24			Chromium	*Chromates with group 3–11 elements*	Copper chromate hydroxide		$2CuCrO_4.3Cu(OH)_2$		Martel (1859) and others, then chem. lit.	
8	6	25			Chromium	*Chromates with group 3–11 elements*	Copper chromate(III)		$CuCr_2O_4$	12018-10-9	Martel (1859) and others, then chem. lit.	
8	6	26			Chromium	*Chromates with group 3–11 elements*	Copper chromate oxide hydrate		[---]		Martel (1859) and others, then chem. lit.	
8	6	27			Chromium	*Chromates with group 3–11 elements*	Cobalt chromate		$CoCr_2O_4$		Jännicke (1893) 70	
8	6	28			Chromium	*Chromates with group 3–11 elements*	Iron dichromate		$Fe_2(Cr_2O_7)_3$	10294-53-8	*Colour Index* (1971) 77505	
8	6	29			Chromium	*Chromates with group 3–11 elements*	Iron chromate hydroxide		$Fe(OH)CrO_4$		*Colour Index* (1971) 77505	
8	6	30			Chromium	*Chromates with group 3–11 elements*	Manganese chromate hydrate		CI: '$2MnO.CrO_3.2H_2O$'		*Colour Index* (1971)	
8	6	31			Chromium	*Chromates with group 3–11 elements*	Silver chromate		Ag_2CrO_4	7784-01-2	Salter (1869) 176 and others	
8	6	32			Chromium	*Chromates with group 3–11 elements*	Thallium chromate		[---]		Salter (1869) 177	
8	6	33			Chromium	*Chromates with group 3–11 elements*	Titanium chromate				Seccarroni (pers. comm.)	
8	6	34			Chromium	*Chromates with group 12 elements*	Cadmium chromate		$CdCrO_4$	14312-00-6	Salter (1869); Bersch (1901); *Colour Index* (1971); Fiedler & Bayard (1986)	
8	6	35			Chromium	*Chromates with group 12 elements*	Cadmium chromate hydroxide		$CdCrO_4.Cd(OH)_2$		*Colour Index* (1971) 77188; Fiedler & Bayard (1986)	
8	6	36			Chromium	*Chromates with group 12 elements*	Mercury chromate		$HgCrO_4$ (?)	13444-75-2	Field (1835); Riffault *et al.* (1871)	
8	6	37			Chromium	*Chromates with group 12 elements*	Zinc dichromate hydrate		$ZnCr_2O_7.3H_2O$		*Colour Index* (1971) 77957	
8	6	38			Chromium	*Chromates with group 12 elements*	Zinc chromate(VI) hydroxide		$ZnCrO_4.4Zn(OH)_2$		*Colour Index* (1971) 77956; Lalor (1973)	
8	6	39			Chromium	*Chromates with group 12 elements*	Zinc sodium chromate		$Na_2O.4ZnCrO_4.3H_2O$		Kirk-Othmer (1998)	
8	6	40			Chromium	*Chromates with group 12 elements*	Zinc potassium chromate		A: $\sim K_2O.4ZnCrO_4.3H_2O$ or B: $K_2CrO_4.3ZnCrO_4.Zn(OH)_2.2H_2O$		A: *Colour Index* (1971) 77955; B: Lalor (1973)	

8	6	41	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI)	CrO_4Pb	7758-97-6	Widely recognised (e.g., Dunn, 1973)
8	6	42	Chromium	*Chromates with group 14–15 elements*	Crocoite	CrO_4Pb	14654-05-8	Mineral analogue
8	6	43	Chromium	*Chromates with group 14–15 elements*	Lead dichromate	$PbCr_2O_7$	13453-93-5	*Colour Index* (1971) 77607
8	6	44	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI) hydroxide	$PbCrO_4.Pb(OH)_2$	12017-86-6	
8	6	45	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI) oxide	$PbCrO_4.PbO$	18454-12-1	Dunn (1973)
8	6	46	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI) oxide	$PbCrO_4.4PbO$		Dunn (1973)
8	6	47	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI) oxide hydrate	$2PbCrO_4.5PbO.H_2O$		Dunn (1973)
8	6	48	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI) sulfate, monoclinic type	[---]		
8	6	49	Chromium	*Chromates with group 14–15 elements*	Lead chromate(VI) sulfate, orthorhombic type	[---]		
8	6	50	Chromium	*Chromates with group 14–15 elements*	Antimony chromate			Seccarroni (pers. comm.)
8	6	51	Chromium	*Chromates with group 14–15 elements*	Bismuth chromate(VI)	[---]		Salter (1869)
8	6	52	Chromium	*Chromates with group 14–15 elements*	Bismuth chromate(VI) oxide	$Bi_2(CrO_4)_2O$		*Colour Index* (1971) 77166
8	6	53	Chromium	*Chromates with group 14–15 elements*	Tin(IV) chromate	$Sn(CrO_4)_2$	38455-77-5	Related to ‘tin chromate, basic’
8	6	54	Chromium	*Chromates with group 14–15 elements*	‘Tin chromate, basic’	[---]		Riffault *et al.* (1874); Salter (1869)?
8	7	1	Chromium	*Phosphates*	Chromium phosphate hydrate	$CrPO_4.xH_2O$		*Colour Index* (1971) 77298; Newman (1997)
8	7	2	Chromium	*Phosphates*	‘Chromium phosphate, basic hydrated’	[---]		Church (1901); Coffignier (1924)
8	8		Chromium	*Sulfides*				
8	9	1	Chromium	*Sulfates*	Chromium sulfate	$Cr_2(SO_4)_3$	10101-53-8	*Colour Index* (1971) 77305
8	9	2	Chromium	*Sulfates*	Chromium sulfate hydrate	$Cr_2(SO_4)_3.15H_2O$		*Colour Index* (1971) 77305
8	9	3	Chromium	*Sulfates*	Chromium sulfate hydrate	$Cr_2(SO_4)_3.18H_2O$		*Colour Index* (1971) 77305
8	10		Chromium	*Organo-chromium compounds*				
9	1		Cobalt	*Cobalt*				
9	2	1	Cobalt	*Carbonates*	Cobalt carbonate	$CoCO_3$	513-79-1	*Colour Index* (1971) 77353
9	3		Cobalt	*Cyanides*				
9	4		Cobalt	*Halides*				
9	5	1	Cobalt	*Nitrates*	Cobalt(II) nitrate (hexahydrate)	$Co(NO_3)_2.6H_2O$	10026-22-9	Salter (1869)
9	5	2	Cobalt	*Nitrates*	Tripotassium hexanitrocobalt(III)	$K_3Co(NO_2)_6.nH_2O$		Cornman (1986); Gates (1995)
9	5	3	Cobalt	*Nitrates*	Dipotassium monosodium hexanitrocobalt(III)	$K_2NaCo(NO_2)_6.nH_2O$		Cornman (1986); Gates (1995)
9	6	1	Cobalt	*Oxides & hydroxides*	Cobalt(II) oxide	CoO	1307-96-9	Heaton (1928), then chem. lit.
9	6	2	Cobalt	*Oxides & hydroxides*	Cobalt(III) oxide	Co_2O_3	1308-04-9	Heaton (1928), then chem. lit.
9	6	3	Cobalt	*Oxides with group 2 elements (Mg)*	Cobalt magnesium oxide	[---]		Salter (1869); Riffault *et al.* (1874); Church (1901)
9	6	4	Cobalt	*Oxides with group 3–11 elements (Cr, Fe)*	Cobalt iron oxide	[---]		Field (1835)?
9	6	5	Cobalt	*Oxides with group 12 elements (Zn)*	Cobalt zinc oxide	[---]		Field (1835)?

(continued)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
9	6	6			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Cobalt aluminium oxide ('cobalt aluminate')		$CoAl_2O_4$	1345-16-0	Widely recognised	
9	6	7			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Cobalt boron oxide ('cobalt borate')		[---]		Carlyle (2001)	
9	6	8			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Cobalt tin oxide ('cobalt stannate')		$CoSnO_3$	1345-19-3	Widely recognised	
9	6	9			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Cobalt arsenic oxide ('cobalt arsenate')		[---]			
9	6	10			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Cobalt arsenic oxide hydrate ('cobalt arsenate hydrate')		[---]			
9	6	11			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Erythrite		$Co_3(AsO_4)_2.8H_2O$		Related mineral	
9	6	12			Cobalt	*Oxides with group 13–15 elements (B, Al, Sn, As)*	Cobalt ammonium arsenic oxide		[---]			
9	7	1			Cobalt	*Phosphates*	Cobalt phosphate		$Co_3(PO_4)_2$	13455-36-2	*Colour Index* (1971) 77360	
9	7	2			Cobalt	*Phosphates*	Cobalt phosphate tetrahydrate		$Co_3(PO_4)_3.4H_2O$	36550-56-8	*Colour Index* (1971) 77360	
9	7	3			Cobalt	*Phosphates*	Cobalt phosphate octahydrate		$Co_3(PO_4)_2.8H_2O$	10294-50-5	*Colour Index* (1971) 77360	
9	7	4			Cobalt	*Phosphates*	Cobalt aluminium phosphate		[---]		Church (1901)?	
9	7	5			Cobalt	*Phosphates*	Cobalt ammonium phosphate hydrate		$CoNH_4PO_4.H_2O$		*Colour Index* (1971) 77362	
9	7	6			Cobalt	*Phosphates*	Cobalt magnesium phosphate		[---]		Heaton (1928)	
9	7	7			Cobalt	*Phosphates*	Cobalt zinc phosphate		[---]		Bersch (1901); *Colour Index* (1971) 77339	
9	8				Cobalt	*Sulfides*						
9	9				Cobalt	*Sulfates*						
9	10	1			Cobalt	*Organo-cobalt compounds*	Cobalt(II) acetate		$Co(OAc)_2$	71-48-7	Bouvier (1827) 46	As reported composition of Thénard's blue (probably erroneous)
10	1	1			Copper	*Copper*						
10	1	2			Copper	*Copper*	Copper-nickel alloys ('cupro-nickel')		[Cu,Ni]		Bieganska *et al.* (1988) as metal flake pigment	
10	1	3			Copper	*Copper*	Copper-zinc alloys ('brass')		[Cu,Zn]		Duncan *et al.* (1990)	
10	2	1	1		Copper	*Carbonates*	Copper carbonate hydroxide, azurite type		$2CuCO_3.Cu(OH)_2$		Widely recognised; rev.: Gettens & FitzHugh (1993)	
10	2	1	2		Copper	*Carbonates*	Azurite		$2CuCO_3.Cu(OH)_2$		Widely recognised; rev.: Gettens & FitzHugh (1993)	
10	2	2	1		Copper	*Carbonates*	Copper carbonate hydroxide, malachite type		$2CuCO_3.Cu(OH)_2$		Widely recognised; rev.: Gettens & FitzHugh (1993)	
10	2	2	2		Copper	*Carbonates*	Malachite		$2CuCO_3.Cu(OH)_2$	12069-69-1	Widely recognised; rev.: Gettens & FitzHugh (1993)	
10	2	3			Copper	*Carbonates*	Georgeite		$CuCO_3.Cu(OH)_2$		Related mineral [unstable]	
10	2	4			Copper	*Secondary substituted carbonates (Na, Zn)*	Aurichalcite		$(Cu,Zn)_5(CO_3)_2(OH)_6$		Related mineral	
10	2	5			Copper	*Secondary substituted carbonates (Na, Zn)*	Claraite		$(Cu,Zn)_3(CO_3)(OH)_4.4H_2O$		Related mineral	
10	2	6	1		Copper	*Secondary substituted carbonates (Na, Zn)*	Copper sodium carbonate, chalconatronite type		$Na_2Cu(CO_3)_2.3H_2O$		Scott (2001)	

10	2	6	2	Copper	*Secondary substituted carbonates (Na, Zn)*	Chalconatronite	$Na_2Cu(CO_3)_2.3H_2O$		Banik (1989); Magaloni (1996)	
10	2	7	1	Copper	*Secondary substituted carbonates (Na, Zn)*	Copper zinc carbonate, rosasite type	$(Cu,Zn)_2CO_3(OH)_2$		Synthetic analogue. Dunkerton & Roy (1996)	
10	2	7	2	Copper	*Secondary substituted carbonates (Na, Zn)*	Rosasite	$(Cu,Zn)_2CO_3(OH)_2$		Dunkerton & Roy (1996)	
10	3	1		Copper	*Halides*	Nantokite	$CuCl$	7758-89-6	Related mineral	
10	3	2	1	Copper	*Halides*	Copper chloride hydroxide, atacamite type	$Cu_2Cl(OH)_3$		Delbourgo (1980) and others	
10	3	2	2	Copper	*Halides*	Atacamite	$Cu_2Cl(OH)_3$		Mineral analogue	
10	3	3	1	Copper	*Halides*	Copper chloride hydroxide, bottalackite type	$Cu_2Cl(OH)_3$		Wainwright *et al.* (1993) and others	
10	3	3	2	Copper	*Halides*	Bottalackite	$Cu_2Cl(OH)_3$		Mineral analogue	
10	3	4	1	Copper	*Halides*	Copper chloride hydroxide, clinoatacamite type	$Cu_2Cl(OH)_3$		Scott (2001)	
10	3	4	2	Copper	*Halides*	Clinoatacamite	$Cu_2Cl(OH)_3$		Mineral analogue	
10	3	5	1	Copper	*Halides*	Copper chloride hydroxide, paratacamite type	$Cu_2Cl(OH)_3$		Delbourgo (1980) and others	
10	3	5	2	Copper	*Halides*	Paratacamite	$Cu_2Cl(OH)_3$		Mineral analogue	
10	3	6		Copper	*Halides*	Calumetite	$Cu(OH,Cl)_2.2H_2O$		Van′T Hul-Ehrnreich & Hallebeek (1972); Naumova & Pisareva (1994); Most & Hückel (1996)	
10	3	6		Copper	*Halides*	Anthonyite	$Cu(OH,Cl)_2.2H_2O$		Related mineral	
10	3	7		Copper	*Halides*	Copper chloride hydroxide hydrate	$Cu_7Cl_4(OH)_{10}.H_2O$		Wainwright *et al.* (1997)	Tentative identification
10	3	8	1	Copper	*Halides*	Copper potassium chloride	$K_2CuCl_4.2H_2O$ (?)		Riederer (1982)	
10	3	8	2	Copper	*Halides*	Mitscherlichite	$K_2CuCl_4.2H_2O$		Riederer (1982) then min. lit.	
10	3	10		Copper	*Halides*	Calcium copper chloride	[---]		Bersch (1901) 248 as *Kuhlmann's green*	
10	3	11		Copper	*Halides*	Boleite	$KAg_9Cu_{24}Pb_{26}.Cl_{62}(OH)_{48}$		[Related mineral to Cumengite]	
10	3	12		Copper	*Halides*	Cumengite	$Pb_{21}Cu_{20}Cl_{42}(OH)_{40}$		Prasartset (1990)	
10	4	1		Copper	*Cyanides (excluding hexacyanoferrate(II))*	Copper(I) cyanide	$CuCN$	544-92-3	[References to 'copper cyanide' may be to the hexacyanoferrate]	
10	4	2		Copper	*Cyanides (excluding hexacyanoferrate(II))*	Copper(II) cyanide	$Cu(CN)_2$	14763-77-0	[References to 'copper cyanide' may be to the hexacyanoferrate]	
10	5	1		Copper	*Nitrates & nitrites*	Copper nitrate	$Cu(NO_3)_2$	3251-23-8	Eikema Hommes (2002) and chem. lit.?	
10	5	2		Copper	*Nitrates & nitrites*	Copper nitrate hexahydrate	$Cu(NO_3)_2.6H_2O$		Eikema Hommes (2002) and chem. lit.?	
10	5	3	1	Copper	*Nitrates & nitrites*	Copper nitrite hydroxide	$Cu_2(NO_3)(OH)_3$	10031-43-3	Synthetic analogue to gerhardite	
10	5	3	2	Copper	*Nitrates & nitrites*	Gerhardite	$Cu_2(NO_3)(OH)_3$		Van′T Hul-Ehrnreich & Hallebeek (1972); Banik (1989)	
10	6	1	1	Copper	*Oxides & hydroxides*	Copper(I) oxide	Cu_2O	1317-39-1	Related synthetic analogue	
10	6	1	2	Copper	*Oxides & hydroxides*	Cuprite	Cu_2O	1308-76-5	As associated mineral or alteration product in azurite and malachite	
10	6	2	1	Copper	*Oxides & hydroxides*	Copper(II) oxide	CuO	1317-38-0	Related synthetic analogue	
10	6	2	2	Copper	*Oxides & hydroxides*	Tenorite	CuO		As alteration product of azurite (Gutscher *et al.* (1989))	
10	6	3	1	Copper	*Oxides & hydroxides*	Copper hydroxide	$Cu(OH)_2$	20427-59-2	Related synthetic analogue [unstable as pigment?]	
10	6	3	2	Copper	*Oxides & hydroxides*	Spertiniite	$Cu(OH)_2$		Related mineral [unstable as pigment?]	
10	6	4		Copper	*Oxides with group 3–11 elements (Cr, Fe)*	Copper chromium oxide	$CuCr_2O_4$		Buxbaum (1998) 101	
10	6	5		Copper	*Oxides with group 3–11 elements (Cr, Fe)*	Copper chromium manganese oxide	$Cu(Cr,Mn)_2O_4$	68186-91-4	*Colour Index* (1971) 77428	

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
10	6	6			Copper	*Oxides with group 3–11 elements (Cr, Fe)*	Copper chromium iron oxide		$Cu(Cr,Fe)_2O_4$	55353-02-1	*Colour Index* (1971) 77429	
10	6	7			Copper	*Tertiary oxides*	Copper borate		$Cu(BO_3)_2$		Salter (1869) 285–286; *Colour Index* (1971) 77415	
10	6	8			Copper	*Tertiary oxides*	Copper borate hydrate		[---]		Related compound	
10	6	9			Copper	*Tertiary oxides*	Copper(II) tin oxide		$CuSnO_3.nH_2O$		Elsner (1860); Salter (1869); Riffault *et al.* (1874); *Colour Index* (1971) 77441	
10	6	10			Copper	*Arsenic-containing compounds*	Copper diarsenite		$2CuO.As_2O_3.2H_2O$		Schweizer & Mühlethaler (1968); Fiedler & Bayard (1997)	
10	6	11			Copper	*Arsenic-containing compounds*	Copper orthoarsenite		$3CuO.As_2O_3.2H_2O$	10103-61-4	Schweizer & Mühlethaler (1968); Fiedler & Bayard (1997)	
10	6	12			Copper	*Arsenic-containing compounds*	Copper metaarsenite		$CuO.As_2O_3$		Schweizer & Mühlethaler (1968); Fiedler & Bayard (1997)	
10	6	13			Copper	*Arsenic-containing compounds*	Trippkeite		$CuAs_2O_4$		Schweizer & Mühlethaler (1968); Fiedler & Bayard (1997)	
10	6	14			Copper	*Arsenic-containing compounds*	Tyrolite		$Ca_2Cu_9(AsO_4)_4(OH)_{10}.10H_2O$		Stodulski *et al.* (1984)	
10	6	15			Copper	*Arsenic-containing compounds*	Copper formate arsenite		$Cu_4(OFo)_2(AsO_2)_6$?		Pey (1987)	
10	6	16			Copper	*Arsenic-containing compounds*	Copper acetate arsenite		$Cu_4(OAc)_2(AsO_2)_6$	12002-03-8	Widely recognised; rev.: Fiedler & Bayard (1997)	
10	7	1	2		Copper	*Phosphates*	Libethenite		$Cu_2(PO_4)(OH)$		Bouherour *et al.* (2001)	
10	7	2	1		Copper	*Phosphates*	Copper phosphate hydroxide, pseudomalachite type		$Cu_5(PO_4)_2(OH)_4$	62683-60-7	Synthetic analogue	
10	7	2	2		Copper	*Phosphates*	Pseudomalachite		$Cu_5(PO_4)_2(OH)_4$	61159-32-8	Naumova *et al.* (1990)	
10	7	3			Copper	*Phosphates*	Sampleite		$NaCaCu_5(PO_4)_4Cl.5H_2O$		Related mineral	
10	8	1			Copper	*Sulfides*	Copper(I) sulfide		Cu_2S	22205-45-4	Duang *et al.* (1987), then chem. lit. (Chakrabarti & Laughlin (1983)); also perhaps Bersh (1901) as 'oil blue'	NB: copper-sulfur system is very complex!
10	8	2	1		Copper	*Sulfides*	Copper(II) sulfide, covellite type		CuS	1317-40-4	Duang *et al.* (1987), then chem. lit. (Chakrabarti & Laughlin (1983)); also perhaps Bersh (1901) as 'oil blue'	
10	8	2	2		Copper	*Sulfides*	Covellite		CuS	1317-40-4	Duang *et al.* (1987), then chem. lit. (Chakrabarti & Laughlin (1983)); also perhaps Bersh (1901) as 'oil blue'	
10	9	1	1		Copper	*Sulfates*	Copper sulfate hydroxide, antlerite type		$Cu_3SO_4(OH)_4$		Van'T Hul-Ehrnreich & Hallebeek (1972); Purinton & Newman (1985)	
10	9	1	2		Copper	*Sulfates*	Antlerite		$Cu_3SO_4(OH)_4$		Van'T Hul-Ehrnreich & Hallebeek (1972); Purinton & Newman (1985)	
10	9	2	1		Copper	*Sulfates*	Copper sulfate hydroxide, brochantite type		$Cu_4SO_4(OH)_6$		Martin & Eveno (1992)	
10	9	2	2		Copper	*Sulfates*	Brochantite		$Cu_4SO_4(OH)_6$		Martin & Eveno (1992)	
10	9	3			Copper	*Sulfates*	Bonattite		$CuSO_4.3H_2O$		Related mineral (apparently unknown as pigment)	
10	9	4			Copper	*Sulfates*	Chalcanthite		$CuSO_4.5H_2O$	7758-99-8	Related mineral (apparently unknown as pigment)	
10	9	5			Copper	*Sulfates*	Langite		$Cu_4(SO_4)(OH)_6.2H_2O$		Banik (1989); Naumova *et al.* (1990)	
10	9	6			Copper	*Sulfates*	Posnjakite		$Cu_4SO_4(OH)_6.H_2O$		Naumova *et al.* (1990); Martin *et al.* (1995)	

10	9	7	Copper	*Sulfates*	Copper hydroxide sulfate hydrate	$CuSO_4.3Cu(OH)_2.\frac{1}{2}H_2O$		
10	9	8	Copper	*Sulfates*	Copper calcium sulfate	$3CuSO_4.2CaSO_4$		*Pigmente* (1960) 236–242 as ‘Mineral blau’
10	10	1	Copper	*Organo-copper compounds: Formates*	Copper(I) formate (Compound A)	$Cu(HCOO)$		Scott (2001)
10	10	2	Copper	*Organo-copper compounds: Formates*	Copper(II) formate (Compound B)	$Cu(HCOO)_2$		Scott (2001)
10	10	3	Copper	*Organo-copper compounds: Formates*	Copper(II) formate hydrate (Compound C)	$Cu(HCOO)_2.2H_2O$		Scott (2001)
10	10	4	Copper	*Organo-copper compounds: Formates*	Copper(II) formate hydroxide (Compound D)	$Cu(HCOO)OH$		Scott (2001)
10	10	5	Copper	*Organo-copper compounds: Formates*	Copper(II) formate hydroxide hydrate (Compound E)	$2Cu(HCOO)_2.Cu(OH)_2.2H_2O$		Scott (2001)
10	10	6	Copper	*Organo-copper compounds: Formates*	Copper(II) formate hydroxide (Compound F)	$Cu(HCOO)_2.Cu(OH)_2$		Scott (2001)
10	10	7	Copper	*Organo-copper compounds: Formates*	Copper(II) formate hydroxide (Compound G)	$Cu(HCOO)_2.2Cu(OH)_2$		Scott (2001)
10	10	8	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate hydroxide hydrate (Compound A)	$[Cu(CH_3COO)_2]_2.Cu(OH)_2.5H_2O$		Gauthier (1958); Schweizer & Mühlethaler. (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	9	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate hydroxide hydrate (Compound B)	$Cu(CH_3COO)_2.Cu(OH)_2.5H_2O$		Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	10	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate hydroxide (Compound C)	$Cu(CH_3COO)_2.[Cu(OH)_2]_2$		Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	11	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate hydroxide hydrate (Compound D)	$Cu(CH_3COO)_2.[Cu(OH)_2]_3.2H_2O$		Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	12	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate (Compound E)	$Cu(CH_3COO)_2$	142-71-2	Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	13	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate hydrate (Compound F)	$Cu(CH_3COO)_2.H_2O$		Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	14	Copper	*Organo-copper compounds: Acetates*	Copper(I) acetate (Compound G)	$Cu(CH_3COO)$	4180-12-5	Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	15	Copper	*Organo-copper compounds: Acetates*	Copper(II) acetate hydroxide hydrate (Compound H)	$Cu(CH_3COO)_2.[Cu(OH)_2]_4.3H_2O$		Gauthier (1958); Schweizer & Mühlethaler (1968); Rahn-Koltermann *et al.* (1991); Kühn (1993); Scott (2001)
10	10	16	Copper	*Organo-copper compounds: Acetates*	Copper(II) potassium acetate	$2K(CH_3COO).Cu(CH_3COO)_2$		Orna (1996)/Scott (2001)
10	10	17	Copper	*Organo-copper compounds: Acetates*	Ammonium copper acetate acetic acid	‘$C_{14}H_{50}CuN_4O_{20}$’		Orna (1996)/Scott (2001)
10	10	18	Copper	*Organo-copper compounds: Citrates*	Copper(II) citrate	$Cu_4[HOC(CH_2COO)_2.(COO)]_2$		Turner (1998) from Alcherius/Lebegue (Merrifield (1849)); Scott (2001) from Paduan MS (Merrifield (1849))
10	10	19	Copper	*Organo-copper compounds: Tartrates*	Copper(II) tartrate hydrate	[---]		Turner (1998) from Alcherius/Lebegue (Merrifield (1849)); *Practical Treatise* (1795); de Massoul (1797)

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
10	10	20			Copper	*Organo-copper compounds: Oxalates*	Copper(II) oxalate		CuC_2O_4	5893-66-3	Wainwright *et al.* (1997)	Tentative identification; probably alteration product
10	10	21	1		Copper	*Organo-copper compounds with fatty acids*	Copper azelate[3]					
10	10	21	2		Copper	*Organo-copper compounds with fatty acids*	Copper laurate					
10	10	21	3		Copper	*Organo-copper compounds with fatty acids*	Copper myristate					
10	10	21	4		Copper	*Organo-copper compounds with fatty acids*	Copper palmitate					
10	10	21	5		Copper	*Organo-copper compounds with fatty acids*	Copper palmitoleate					
10	10	21	6		Copper	*Organo-copper compounds with fatty acids*	Copper stearate					
10	10	21	7		Copper	*Organo-copper compounds with fatty acids*	Copper oleate					
10	10	21	8		Copper	*Organo-copper compounds with fatty acids*	Copper linoleate					
10	10	21	9		Copper	*Organo-copper compounds with fatty acids*	Copper linolenate					
10	10	21	10		Copper	*Organo-copper compounds with fatty acids*	Copper salts of linseed oil (extract of seeds of *Linum usitatissimum*)[4]				Widely recognised; e.g. Birelli (1601) 369–370	
10	10	21	11		Copper	*Organo-copper compounds with fatty acids*	Copper salts of poppy oil (extract of seeds of *Papaver somniferum*)					
10	10	21	12		Copper	*Organo-copper compounds with fatty acids*	Copper salts of walnut oil (extract of fruit of *Juglans regia*)					
10	10	21	13		Copper	*Organo-copper compounds with fatty acids*	Copper salts of beeswax				Daniels (pers. comm., 2001)	Use in dynastic Egyptian context
10	10	22			Copper	*Organo-copper compounds with proteins*	[Copper proteinates]					
10	10	23			Copper	*Organo-copper compounds with resin acids*	[Copper resinates]					
11	1	1			Gold	*Gold*	Gold		Au	7440-57-5	Widely recognised	
11	1	2			Gold	*Gold*	Gold colloid ('Purple of Cassius')		Au adsorbed on to SnO_2 in a vitreous matrix		Cassius (1685); Osborn (1845); Salter (1869)	
11	2				Gold	*Carbonates*						
11	3				Gold	*Cyanides*						
11	4				Gold	*Halides*						
11	5				Gold	*Nitrates*						
11	6				Gold	*Oxides & hydroxides*						
11	7				Gold	*Phosphates*						

11	8	1		Gold	*Sulfides*	Gold silver sulfide	Au-Ag-S		Frantz & Schorsch (1990); Hatchfield & Newman (1991) 'Egyptian red gold'
11	9			Gold	*Sulfates*				
11	10			Gold	*Organo-gold compounds*				
12	1			Indium	*Element*				
12	2			Indium	*Carbonates*				
12	3			Indium	*Cyanides*				
12	4			Indium	*Halides*				
12	5			Indium	*Nitrates*				
12	6	1		Indium	*Oxides & hydroxides*	Indium oxide	In_2O_3	1312-43-2	Salter (1869) under 'Indium yellow'
12	7			Indium	*Phosphates*				
12	8	1		Indium	*Sulfides*	Indium sulfide	In_2S_3	12030-24-9	Salter (1869) as 'Indium yellow'
12	9			Indium	*Sulfates*				
12	10			Indium	*Organo-indium compounds*				
13	1	1		Iron	*Iron*	Iron-chromium alloys ('stainless steel')	[Fe,Cr]		Bieganska *et al.* (1988) as metal flake pigment
13	2	1	1	Iron	*Carbonates*	Iron carbonate, siderite type	$FeCO_3$		Synthetic analogue
13	2	1	2	Iron	*Carbonates*	Siderite	$FeCO_3$		Chippindale (pers. comm.)
13	3			Iron	*Cyanides*				
13	4			Iron	*Halides*				
13	5			Iron	*Nitrates*				
13	6	1	1	Iron	*Oxides & hydroxides*[5]	Iron oxide hydroxide, akaganeite type	β-FeOOH		Cornell & Schwertmann (1996)
13	6	1	2	Iron	*Oxides & hydroxides*	Akaganeite	β-FeOOH	12134-57-5	Cornell & Schwertmann (1996)
13	6	2	1	Iron	*Oxides & hydroxides*	Iron oxide hydroxide, feroxyhyte type	δ'-FeOOH		Cornell & Schwertmann (1996)
13	6	2	2	Iron	*Oxides & hydroxides*	Feroxyhyte	δ'-FeOOH	60497-39-4	Cornell & Schwertmann (1996)
13	6	3	1	Iron	*Oxides & hydroxides*	Iron hydroxide, goethite type	α-FeOOH		Cornell & Schwertmann (1996)
13	6	3	2	Iron	*Oxides & hydroxides*	Goethite	α-FeOOH	1310-14-1	Cornell & Schwertmann (1996)
13	6	4	1	Iron	*Oxides & hydroxides*	Iron hydroxide, lepidocrocite type	γ-FeOOH		Cornell & Schwertmann (1996)
13	6	4	2	Iron	*Oxides & hydroxides*	Lepidocrocite	γ-FeOOH	12022-37-6	Cornell & Schwertmann (1996)
13	6	5	1	Iron	*Oxides & hydroxides*	Iron oxide hydrate, ferrihydrite type	$Fe_5HO_8.4H_2O$		Cornell & Schwertmann (1996)
13	6	5	2	Iron	*Oxides & hydroxides*	Ferrihydrite	$Fe_5HO_8.4H_2O$		Cornell & Schwertmann (1996)
13	6	6	1	Iron	*Oxides & hydroxides*	Iron oxide, hematite type	γ-Fe_2O_3		Cornell & Schwertmann (1996)
13	6	6	2	Iron	*Oxides & hydroxides*	Hematite	γ-Fe_2O_3	1317-60-8	Cornell & Schwertmann (1996)
13	6	7	1	Iron	*Oxides & hydroxides*	Iron oxide, maghemite type	γ-Fe_2O_3		Cornell & Schwertmann (1996)
13	6	7	2	Iron	*Oxides & hydroxides*	Maghemite	γ-Fe_2O_3		Cornell & Schwertmann (1996)
13	6	8	1	Iron	*Oxides & hydroxides*	Iron oxide, magnetite type	Fe_3O_4	1317-61-9	Cornell & Schwertmann (1996)
13	6	8	2	Iron	*Oxides & hydroxides*	Magnetite	Fe_3O_4	1309-38-2	Cornell & Schwertmann (1996)
13	6	9	1	Iron	*Tertiary oxides & hydroxides*	Iron aluminium oxide, hercynite type	$FeAl_2O_4$		Synthetic analogue

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[3] The following 'pure' copper salts of fatty and other organo-acids are primarily for reference purposes; presumably the actual chemistry is somewhat more complex and subject to alteration *in vivo*.

[4] Copper salts of oils such as linseed, poppy and walnut should contain a range of fatty acids in accordance with the distribution found in the originating oil.

[5] There are a number of other iron oxides and hydroxides of lesser significance listed by Cornell & Schwertmann: $Fe(OH)_2$, FeO (wüstite), a β-Fe_2O_3, a ε-Fe_2O_3, a high- pressure FeOOH, a ferrimagnetic δ-FeOOH and a crystalline $Fe(OH)_3$ (bernalite). There is also a group of Fe^{III}-oxy-hydroxy salts that are closely related to the oxides, including the oxy-hydroxy sulfate schwertmannite and an oxy-hydroxy nitrate. Some of these may also occur in a pigment context.

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
13	6	9	2		Iron	*Tertiary oxides & hydroxides*	Hercynite		$FeAl_2O_4$		Stos-Fertner *et al.* (1979)	
13	6	10	1		Iron	*Tertiary oxides & hydroxides*	Iron manganese oxide, jacobsite type		$MnFe_2O_4$	12063-10-4	Schweizer & Rinuy (1982)	
13	6	10	2		Iron	*Tertiary oxides & hydroxides*	Jacobsite		$MnFe_2O_4$		Mineral analogue	
13	6	11			Iron	*Tertiary oxides & hydroxides*	Iron titanate		$FeTiO_3$	12022-71-8	Heaton (1928), Buxbaum (1998)	
13	6	12			Iron	*Tertiary oxides & hydroxides*	Ilmenite		$FeTiO_3$	12168-52-4	Heaton (1928), Buxbaum (1998)	
13	6	13			Iron	*Tertiary oxides & hydroxides*	Titanomagnetite		Fe_3O_4-Fe_2TiO_4		Jaksch *et al.* (1983)	As phase in Egyptian blue
13	6	14			Iron	*Tertiary oxides & hydroxides*	Iron zinc oxide		$ZnFe_2O_4$	12063-19-3	*Colour Index* (1971) PY 119	
13	7	1	1		Iron	*Phosphates*	Iron phosphate hydrate, vivianite type		[---]		Synthetic analogue	
13	7	1	2		Iron	*Phosphates*	Vivianite		$Fe_3(PO_4)_2.8H_2O$	14567-67-0	Field (1835) and others; Filatov *et al.* (1965) and others	
13	8	1			Iron	*Sulfides*	Pyrite		FeS_2	1309-36-0	Funders & Möller (1989)	
13	8	2			Iron	*Sulfides*	Marcasite		FeS_2	1317-66-4	Related mineral	
13	9	1	1		Iron	*Sulfates*	Iron sulfate hydrate		$FeSO_4.7H_2O$	7782-63-0	Hsu Wei-yeh *et al.* (1983) (?)	
13	9	1	2		Iron	*Sulfates*	Melanterite		$FeSO_4.7H_2O$		Chippindale (pers. comm.)	
13	9	2			Iron	*Sulfates*	Hydronium-jarosite		$Fe_3(SO_4)_2(OH)_5.2H_2O$		Wallert (1995); Walsh *et al.* (2004)	Also known as 'carphosiderite'
13	9	3			Iron	*Sulfates*	Jarosite		$KFe_3(SO_4)_2(OH)_6$	12449-90-0	Reindell & Riederer (1978); El Goresy *et al.* (1986); Wallert (1995); Colinart (1998); Walsh *et al*. (2004)	
13	9	4			Iron	*Sulfates*	Natrojarosite		$NaFe_3(SO_4)_2(OH)_6$	12449-96-6	Related mineral	
13	10	1	1		Iron	*Organo-iron compounds*	Iron(II) oxalate		$Fe(C_2O_4)$	516-03-0	Salter (1869) as 'Iron yellow (oxalate of protoxide of iron)'?	
13	10	1	2		Iron	*Organo-iron compounds*	Humboldtine		$Fe^{2+}C_2O_4.2H_2O$	6047-25-2	Mineral form by association	
14	1	1			Lead	*Lead*	Lead		Pb	7439-92-1	Dunn (1975)	
14	2	1	1		Lead	*Carbonates*	Lead carbonate		$PbCO_3$	598-63-0	Widely recognised	
14	2	1	2		Lead	*Carbonates*	Cerussite		$PbCO_3$	14476-15-4	Mineral form by association	
14	2	2			Lead	*Carbonates*	Lead carbonate hydroxide		$PbCO_3.Pb(OH)_2$		Zhou *et al.* (1997)	
14	2	3			Lead	*Carbonates*	Lead carbonate hydroxide hydrate		$PbCO_3.Pb(OH)_2.H_2O$		Zhou *et al.* (1997)	
14	2	4	1	1	Lead	*Carbonates*	Lead carbonate hydroxide	From the 'Stack' process	$2PbCO_3.Pb(OH)_2$	1319-46-6	Widely recognised	
14	2	4	1	2	Lead	*Carbonates*	Lead carbonate hydroxide	*et seq*. From other processes (to be defined)	$2PbCO_3.Pb(OH)_2$	1319-46-6	Widely recognised	
14	2	4	2		Lead	*Carbonates*	Hydrocerussite		$2PbCO_3.Pb(OH)_2$	1319-47-7	Mineral form by association	
14	2	5			Lead	*Carbonates*	Lead carbonate hydroxide hydrate		$2PbCO_3.Pb(OH)_2.H_2O$		Zhou *et al.* (1997)	
14	2	6			Lead	*Carbonates*	Lead carbonate hydroxide		$3PbCO_3.2Pb(OH)_2$		Keisch (1972); Katz & Lefker (1957); Mauch & Brunold (1957)	
14	2	7			Lead	*Carbonates*	Lead carbonate hydroxide hydrate		$3PbCO_3.2Pb(OH)_2.H_2O$		Zhou *et al.* (1997)	

14	2	8			Lead	*Carbonates*	Lead carbonate hydroxide oxide		$4PbCO_3.2Pb(OH)_2.PbO$		Keisch (1972); Thompson & Stewart (1940); Stewart (1950)	
14	2	9	1		Lead	*Carbonates*	Lead carbonate hydroxide oxide, plumbonacrite type		$6PbCO_3.3Pb(OH)_2.PbO$		Tétreault *et al.* (1998)	
14	2	9	2		Lead	*Carbonates*	Plumbonacrite		$6PbCO_3.3Pb(OH)_2.PbO$		Mineral analogue	
14	3	1			Lead	*Cyanides*	Lead cyanide		$Pb(CN)_2$	592-05-2	*Colour Index* (1971) 77610	
14	4	1	1		Lead	*Halides*	Lead chloride, cotunnite type		$PbCl_2$		Naruse (1996)	
14	4	1	2		Lead	*Halides*	Cotunnite		$PbCl_2$		Naruse (1996)	
14	4	2	1		Lead	*Halides*	Lead chloride carbonate		[---]		Hsu Wei-yeh *et al.* (1983)	
14	4	2	1		Lead	*Halides*	Lead chloride hydroxide, blixite type		$Pb_2Cl(O,OH)_{2-x}$, $x = \sim 0.3$		Winter (1981)	
14	4	2	2		Lead	*Halides*	Blixite		$Pb_2Cl(O,OH)_{2-x}$, $x = \sim 0.3$		Winter (1981)	
14	4	3	1		Lead	*Halides*	Lead chloride hydroxide, fiedlerite type		$Pb_3Cl_4(OH)_2$		Noble & Wadum (1998)	
14	4	3	2		Lead	*Halides*	Fiedlerite		$Pb_3Cl_4(OH)_2$		Noble & Wadum (1998)	
14	4	4	1		Lead	*Halides*	Lead chloride hydroxide, laurionite type		$PbCl(OH)$	15887-88-4	Winter (1981) Disc. Patterson, 1844, as 'Patterson's white' (cf. *Colour Index* (1971) 77593)	
14	4	4	2		Lead	*Halides*	Laurionite		$PbCl(OH)$		Winter (1981); Naruse (1996); Zhou Guoxin *et al.* (1997)	
14	4	5			Lead	*Halides*	Paralaurionite		$PbCl(OH)$		Related mineral form	
14	4	6			Lead	*Halides*	Lead chloride oxide		$PbCl_{2.5-7}PbO$	12182-67-1	Disc. Turner, 1781; then, e.g. Bersch (1901), *Colour Index* (1971) 77592	'Turner's' or 'Patent' yellow
14	4	7			Lead	*Halides*	Lead bismuth chloride oxide		$(Pb,Bi)_2Cl_{2.5-7}O$(?)		Merimée (1830) 108–109	
14	4	8	1		Lead	*Halides*	Lead chloride oxide, mendipite type		$Pb_3Cl_2O_2$	12205-70-8	Mineral form by association	
14	4	8	2		Lead	*Halides*	Mendipite		$Pb_3Cl_2O_2$		Mineral form by association	
14	4	9			Lead	*Halides*	Lead chlorosulfite (Lead chloride sulfite??)				'Caledonian white'? (Mayer (1991))	
14	4	10			Lead	*Halides*	Lead iodide		PbI_2	10101-63-0	*Colour Index* (1971) 77613	
14	5				Lead	*Nitrates*						
14	6	1	1		Lead	*Oxides & hydroxides*	Lead(II) oxide, litharge type		PbO	1317-36-8	Burgio *et al.* (1998); Duang *et al.* (1987); Le Fur (1990); Mairinger & Schreiner (1986); Preusser *et al.* (1981); Wang *et al.* (1993a,b); Yamasaki (1957); Yamasaki (1972)	
14	6	1	2		Lead	*Oxides & hydroxides*	Litharge		PbO	1317-36-8	[As above]	
14	6	2	1		Lead	*Oxides & hydroxides*	Lead(II) oxide, massicot type		PbO	1317-36-8	Filatov *et al.* (1965); Le Fur (1990); Mairinger & Schreiner (1986); Nord & Tronner (1998); Preusser *et al.* (1981); Riederer (1977b)	
14	6	2	2		Lead	*Oxides & hydroxides*	Massicot		PbO	1317-36-8	[As above]	
14	6	3	1		Lead	*Oxides & hydroxides*	Lead(IV) oxide		PbO_2	1309-60-0	Wang *et al.* (1993b)	
14	6	3	2		Lead	*Oxides & hydroxides*	Plattnerite		PbO_2		Wainwright *et al.* (1997)	Probably as alteration product of lead(II,IV) oxide/minium
14	6	4	1	1	Lead	*Oxides & hydroxides*	Lead(II,IV) oxide	By thermal conversion of another lead oxide	$2PbO.PbO_2$	1314-41-6	Widely recognised; rev.: FitzHugh (1986)	CI Pigment Red 105
14	6	4	1	2	Lead	*Oxides & hydroxides*	Lead(II,IV) oxide	'Fumed'	$2PbO.PbO_2$		Widely recognised; rev.: FitzHugh (1986)	

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
14	6	4	2		Lead	*Oxides & hydroxides*	Minium		$2PbO.PbO_2$	1314-41-6	Forbes and Petrie, cf. FitzHugh (1986)	
14	6	5			Lead	*Oxides & hydroxides*	Lead hydroxide		$Pb_3O_2(OH)_2$			
14	6	6			Lead	*Oxides & hydroxides*	Lead oxide		[CI also lists a Pb_2O_3 – ($PbO.PbO_2$?)]	1314-27-8	*Colour Index* (1971)	
14	6	7			Lead	*Tertiary, quaternary & higher oxides*	Lead aluminium oxide		$PbO.Al_2O_3$	1345-29-5	*Colour Index* (1971) 77585	
14	6	8	1		Lead	*Tertiary, quaternary & higher oxides*	Lead antimony oxide, bindheimite type		$Pb_2Sb_2O_7$ (or $Pb_ySb_{2-x}O_7$, where $0 = x = 1$ and $2 = y = 3$)	15578-55-9	Widely recognised, review Wainwright *et al*. (1993)	
14	6	8	2		Lead	*Tertiary, quaternary & higher oxides*	Bindheimite		$Pb_2Sb_2O_7$		Related mineral form	
14	6	9			Lead	*Tertiary, quaternary & higher oxides*	Lead antimony oxide, rosiaite type		$PbSb_2O_6$		Wainwright *et al.* (1986)	Hexagonal crystal system
14	6	10			Lead	*Tertiary, quaternary & higher oxides*	Rosiaite		$PbSb_2O_6$		Related mineral form	Trigonal crystal system
14	6	11			Lead	*Tertiary, quaternary & higher oxides*	Lead antimony tin oxide		$Pb_2SbSnO_{6.5}$		Cascales *et al*. (1986); Roy & Berry (1998)	
14	6	12			Lead	*Tertiary, quaternary & higher oxides*	Lead antimony zinc oxide		$Pb(Sb_x, Zn_{1-x})O_3$?		Riffault *et al*. (1874)	
14	6	13	1		Lead	*Tertiary, quaternary & higher oxides*	Lead arsenate, schultenite type		$PbHAsO_4$	7784-40-9	Related compound	
14	6	13	2		Lead	*Tertiary, quaternary & higher oxides*	Schultenite		$PbHAsO_4$	14758-11-3	Related mineral	
14	6	14			Lead	*Tertiary, quaternary & higher oxides*	Lead diarsenate (V)		$PbAs_2O_6$	8464-43-2	Related compound	
14	6	15			Lead	*Tertiary, quaternary & higher oxides*	Lead arsenate		$Pb_3As_4O_2$	3687-31-8	Salter (1869) 116 as 'Arsenic yellow', then chem. lit.	
14	6	16			Lead	*Tertiary, quaternary & higher oxides*	Lead pyroarsenate		Pb_2AsO_7	13510-94-6	Salter (1869) 116 as 'Arsenic yellow', then chem. lit.	
14	6	17	2		Lead	*Tertiary, quaternary & higher oxides*	Mimetite		$Pb_5(AsO_4)_3Cl$		Rouveret & Walter (1998)	
14	6	18			Lead	*Tertiary, quaternary & higher oxides*	Lead iron arsenate (?)		'Pb, Fe (Sb, Zn) arsenate'		Meggiolaro *et al.* (1997)	Tentative identification on Corinthian wall paintings of the mid-first century AD
14	6	19			Lead	*Tertiary, quaternary & higher oxides*	Lead tin oxide		Pb_2SnO_4		Widely recognised, review Kühn (1968/1993)	
14	6	20			Lead	*Tertiary, quaternary & higher oxides*	Lead silicon tin oxide		$Pb(Si_x, Sn_{1-x})O_3$		Widely recognised, review Kühn (1968/1993)	
14	6	21			Lead	*Tertiary, quaternary & higher oxides*	Lead antimony bismuth oxide		[---]		*Colour Index* (1971) 77589	
14	6	22			Lead	*Tertiary, quaternary & higher oxides*	Lead antimony bismuth zinc oxide		[---]		*Colour Index* (1971) 77589	
14	7	1			Lead	*Phosphates*	Lead phosphate		$Pb_9(PO_4)_6$		Winter (1981)	
14	7	2			Lead	*Phosphates*	Lead phosphate hydroxide		$Pb_5(PO_4)_3OH$	12207-55-5	Related compound [Apatite group, Naruse (1996)]	

14	7	2		Lead	*Phosphates*	Hydroxypyromorphite	$Pb_5(PO_4)_3OH$		Béarat (1995)	
14	7	2		Lead	*Phosphates*	Pyromorphite	$Pb_5(PO_4)_3Cl$		Béarat (1995) [Apatite group, Naruse (1996)]	
14	7	3		Lead	*Phosphates*	Lead phosphate fluoride	$Pb_5(PO_4)_3F$		Related compound [Apatite group, Naruse (1996)]	
14	7	4		Lead	*Phosphates*	Lead oxide phosphite hydrate	$2PbO.PbHPO_3.0.5H_2O$		Dunn (1973a) 81	
14	8	1		Lead	*Sulfides*	Galena	PbS	1314-87-0	Field (1835); Dunn (1973a)	
14	9	1	1	Lead	*Sulfates & sulfites*	Lead sulfate	$PbSO_4$	7446-14-2	Dunn (1973a)	
14	9	1	2	Lead	*Sulfates & sulfites*	Anglesite	$PbSO_4$	14594-79-7	Piqué (1997)	
14	9	2	1	Lead	*Sulfates & sulfites*	Lead oxide sulfate	$PbSO_4.PbO$		Dunn (1973a)	
14	9	2	2	Lead	*Sulfates & sulfites*	Lanarkite	$Pb_2(SO_4)O$		Related mineral	
14	9	3		Lead	*Sulfates & sulfites*	Lead oxide sulfate	$PbSO_4.2PbO$		Dunn (1973a)	
14	9	4		Lead	*Sulfates & sulfites*	Lead oxide sulfate	$PbSO_4.3PbO$		Dunn (1973a)	
14	9	5		Lead	*Sulfates & sulfites*	Lead oxide sulfate hydrate	$PbSO_4.3PbO.H_2O$		Dunn (1973a)	
14	9	6		Lead	*Sulfates & sulfites*	Lead oxide sulfate	$PbSO_4.4PbO$	12065-90-6	Dunn (1973a)	
14	9	7		Lead	*Sulfates & sulfites*	Lead sulfite hydroxide	$3PbSO_3.Pb(OH)_2$		Brochwicz *et al.* (1993) as 'sulfite white'	
14	9	8		Lead	*Sulfates & sulfites*	Lead sulfate hydroxide	$2PbSO_4.Pb(OH)_2$		Brochwicz *et al.* (1993) as 'Mulhauser's white'	
14	9	9	1	Lead	*Sulfates & sulfites*	Lead sulfate carbonate hydroxide, leadhillite type	$PbSO_4.2PbCO_3.Pb(OH)_2$		Synthetic analogue	
14	9	9	2	Lead	*Sulfates & sulfites*	Leadhillite	$PbSO_4.2PbCO_3.Pb(OH)_2$		Zhou *et al.* (1997)	
14	9	10	1	Lead	*Sulfates & sulfites*	Lead sulfate carbonate hydroxide, susannite type	$Pb_4(CO_3)_2(SO_4)(OH)_2$		[Authors]	
14	9	10	2	Lead	*Sulfates & sulfites*	Susannite	$Pb_4(CO_3)_2(SO_4)(OH)_2$		Mineral analogue	
14	10	1		Lead	*Organo-lead compounds*	Lead(II) acetate trihydrate	$Pb(CH_3COO)_2.3H_2O$	6080-56-4	Tétreault *et al.* (1998) [Unstable intermediate product]	
14	10	2		Lead	*Organo-lead compounds*	Lead acetate oxide hydrate	$Pb(CH_3CO_2)_2.2PbO.H_2O$		Tétreault *et al.* (1998) [Unstable intermediate product]	
14	10	3		Lead	*Organo-lead compounds*	Lead acetate oxide hydrate	$Pb_3(CH_3CO_2)_6.PbO.H_2O$		Tétreault *et al.* (1998) [Unstable intermediate product]	
14	10	4		Lead	*Organo-lead compounds*	Lead citrate	$Pb(C_6H_5O_7)_2.3H_2O$	512-26-5	Toch (1916) 82	Formed when treating lead chromate pigments with organic acids to create paler shades
14	10	5		Lead	*Organo-lead compounds*	Lead tartrate	$PbC_4H_4O_6.H_2O$		Toch (1916) 82	Formed when treating lead chromate pigments with organic acids to create paler shades
15	1			Magnesium	*Magnesium*					
15	2	1	1	Magnesium	*Carbonates*	Magnesium carbonate	$MgCO_3$	546-93-0	Synthetic analogue	
15	2	1	2	Magnesium	*Carbonates*	Magnesite	$MgCO_3$	13717-00-5	Terry (1893); Heaton (1928), Newton & Sharp (1987)	
15	2	2		Magnesium	*Carbonates*	Magnesium carbonate hydroxide hydrate	$5MgCO_3.Mg(OH)_2.3H_2O$		Related compound	
15	2	3		Magnesium	*Carbonates*	Hydromagnesite	$Mg_5(CO_3)_4(OH)_2.4H_2O$		Garavelli *et al.* (1990)	

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
15	2	4			Magnesium	*Carbonates*	Magnesium carbonate hydroxide hydrate		$5MgCO_3.2Mg(OH)_2.7H_2O$		Related compound	
15	2	5			Magnesium	*Carbonates*	Magnesium carbonate hydroxide		$4MgCO_3.Mg(OH)_2$		Related compound	
15	2	6			Magnesium	*Carbonates*	Magnesium carbonate hydroxide hydrate		$3MgCO_3.Mg(OH)_2.4H_2O$		Related compound	
15	3				Magnesium	*Cyanides*						
15	4	1			Magnesium	*Halides*	Magnesium chloride hydroxide				Chippindale (pers. comm.)	
15	5				Magnesium	*Nitrates*						
15	6	1	1		Magnesium	*Oxides & hydroxides*	Magnesium oxide, periclase type		MgO	1309-48-4	Possibly Laurie (1914) (cf. Fiedler & Bayard, 1986)	
15	6	1	2		Magnesium	*Oxides & hydroxides*	Periclase		MgO	13317-74-4	Newton & Sharp (1987)	
15	6	2			Magnesium	*Oxides & hydroxides*	Magnesium iron oxide		(Mg, Fe)O		*Colour Index* (1971) Pigment Brown 11	
15	7				Magnesium	*Phosphates*						
15	8				Magnesium	*Sulfides*						
15	9				Magnesium	*Sulfates*						
15	10	1			Magnesium	*Organo-magnesium compounds*	Magnesium oxalate hydrate		$MgC_2O_4.H_2O$	547-66-0	Chippindale (pers. comm.)	
16	1				Manganese	*Manganese*						
16	2	1	1		Manganese	*Carbonates*	Manganese carbonate		$MnCO_3$	598-62-9	*Colour Index* (1971) 77733	
16	2	1	2		Manganese	*Carbonates*	Rhodochrosite		$MnCO_3$	14476-12-1	Related mineral form	
16	3				Manganese	*Cyanides*						
16	4				Manganese	*Halides*						
16	5				Manganese	*Nitrates*						
16	6	1	1		Manganese	*Oxides & hydroxides*	Manganese(II) oxide		MnO	1344-43-0		
16	6	1	2		Manganese	*Oxides & hydroxides*	Manganosite		MnO	1313-12-8		
16	6	2			Manganese	*Oxides & hydroxides*	Bixbyite		$(Mn^{3+},Fe^{3+})_2O_3$		Schweizer & Rinuy (1982); Nirmaier (2000)	Empirically: $Mn_{1.5}Fe_{0.5}O_3$
16	6	3			Manganese	*Oxides & hydroxides*	Manganese(III) oxide		Mn_2O_3	1317-34-6		
16	6	4	1		Manganese	*Oxides & hydroxides*	Manganese(IV) oxide, pyrolusite type		MnO_2	1313-13-9		
16	6	4	2		Manganese	*Oxides & hydroxides*	Pyrolusite		MnO_2	14854-26-3		
16	6	5	1		Manganese	*Oxides & hydroxides*	Manganese(II, III) oxide, hausmannite type		$Mn^{II}Mn_2^{III}O_4$	1317-35-7		
16	6	5	2		Manganese	*Oxides & hydroxides*	Hausmannite		$Mn^{II}Mn_2^{III}O_4$	1309-55-3	Nirmaier (2000)	
16	6	6			Manganese	*Oxides & hydroxides*	Manganese(II) hydroxide		$Mn(OH)_2$			
16	6	7			Manganese	*Oxides & hydroxides*	Manganese(III) hydroxide		$Mn(OH)_3$			
16	6	8			Manganese	*Oxides & hydroxides*	Manganite (??)		MnO(OH)			
16	6	9			Manganese	*Oxides & hydroxides*	Manganese(II, IV) oxide hydrate		$MnO.MnO_2.H_2O$			
16	6	10			Manganese	*Oxides & hydroxides*	Manganese oxide hydroxide		MnO(OH)	12025-99-9		
16	7	1	1		Manganese	*Phosphates*	Manganese(III) phosphate		$MnPO_4$	14986-93-7	Synthetic analogue	
16	7	1	2		Manganese	*Phosphates*	Purpurite		$MnPO_4$ or (Mn, Fe)PO_4		Currently available from Kremer Pigmente, Germany	
16	7	2			Manganese	*Phosphates*	Manganese iron phosphate hydrate		$2(Fe, Mn)PO_4.H_2O$			Older formula for purpurite; probably erroneous

16	7	3			Manganese	*Phosphates*	Manganese ammonium phosphate		$(NH_4)_2Mn_2(P_2O_7)_2$?		
16	8				Manganese	*Sulfides*					
16	9				Manganese	*Sulfates*					
16	10				Manganese	*Organo-manganese compounds*					
17	1				Mercury	*Mercury*					
17	2				Mercury	*Carbonates*					
17	3				Mercury	*Cyanides*					
17	4	1			Mercury	*Halides*	Mercury iodide, α-type		α-HgI_2	7774-29-0	Mérimée (1830) and others; Townsend (1993); chem. lit.
17	4	2			Mercury	*Halides*	Mercury iodide, β-type		β-HgI_2		Mérimée (1830) and others; Townsend (1993); chem. lit.
17	5				Mercury	*Nitrates*					
17	6	1			Mercury	*Oxides & hydroxides*	Mercury(II) oxide		HgO	21908-53-2	Salter (1869) 173 as 'Red precipitate'
17	7				Mercury	*Phosphates*					
17	8	1	1	1	Mercury	*Sulfides*	Mercury(II) sulfide, cinnabar type	'Dry' process	HgS		Widely recognised
17	8	1	1	2	Mercury	*Sulfides*	Mercury(II) sulfide, cinnabar type	'Wet' process	HgS		Widely recognised
17	8	1	2		Mercury	*Sulfides*	Cinnabar		HgS		Widely recognised
17	8	2	1		Mercury	*Sulfides*	Mercury(II) sulfide, hypercinnabar type		HgS		
17	8	2	2		Mercury	*Sulfides*	Hypercinnabar		HgS		
17	8	3	1		Mercury	*Sulfides*	Mercury(II) sulfide, metacinnabar type		HgS		
17	8	3	2		Mercury	*Sulfides*	Metacinnabar		HgS		
17	9	1			Mercury	*Sulfates*	Mercury sulfate		$HgSO_4$	7783-35-9	Related compound
17	9	2			Mercury	*Sulfates*	Mercury sulfate hydroxide (?? Mercury oxide sulfate)			[---]	Harley (1982) and others as 'Turbith mineral'
17	9	3			Mercury	*Sulfates*	Schuetteite		$Hg_3SO_4O_2$		Related mineral
17	10				Mercury	*Organo-mercury compounds*					
18	1				Molybdenum	*Molybdenum*					
18	2				Molybdenum	*Carbonates*					
18	3				Molybdenum	*Cyanides*					
18	4				Molybdenum	*Halides*					
18	5				Molybdenum	*Nitrates*					
18	6	1			Molybdenum	*Oxides*	Molybdenum(III) oxide		Mo_2O_3	1313-29-7	Bersch (1901)[6]; *Colour Index* (1971) 77769
18	6	2			Molybdenum	*Oxides: molybdates*	Copper molybdate				Salter (1869) 289
18	6	3	1		Molybdenum	*Oxides: molybdates*	Lead molybdate		$PbMoO_4$	10190-55-3	Related compound
18	6	3	2		Molybdenum	*Oxides: molybdates*	Wulfenite		$PbMoO_4$	14913-82-7	Bimson (1980)
18	6	4			Molybdenum	*Oxides: molybdates*	Tin molybdate		[---]		Bersch (1901)
18	7				Molybdenum	*Phosphates*					
18	8				Molybdenum	*Sulfides*					
18	9				Molybdenum	*Sulfates*					
18	10				Molybdenum	*Organo-molybdenum compunds*					
19	1	1			Nickel	*Nickel*	Nickel		Ni	7440-02-0	Bieganska *et al.* (1988) as metal flake pigment

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[6] Bersch refers to the 'blue modification of molybdenum oxide' as a component (with 'stannic molybdate') in the pigment he calls *molybdenum blue*.

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
19	2				Nickel	*Carbonates*						
19	3				Nickel	*Cyanides*						
19	4				Nickel	*Halides*						
19	5				Nickel	*Nitrates*						
19	6				Nickel	*Oxides & hydroxides*						
19	7	1			Nickel	*Phosphates*	Nickel phosphate hydrate		$Ni_3(PO_4)_2.7H_2O$		Bersch (1901); *Colour Index* (1971)	
19	8				Nickel	*Sulfides*						
19	9				Nickel	*Sulfates*						
19	10				Nickel	*Organo-nickel compounds*						
20	1				Palladium & platinum	*Palladium & platinum*						
20	2				Palladium & platinum	*Carbonates*						
20	3				Palladium & platinum	*Cyanides*						
20	4	1			Palladium & platinum	*Halides*	Palladium ammonium chloride		[---]		*Colour Index* (1971) 77790 as ‘Palladium red’	
20	4	2			Palladium & platinum	*Halides*	Potassium hexachloroplatinate(IV)		$K_2[PtCl_6]$	16921-30-5	Field (1835) and elsewhere as ‘Platina yellow’; *Colour Index* (1971)	
20	5				Palladium & platinum	*Nitrates*						
20	6				Palladium & platinum	*Oxides & hydroxides*						
20	7				Palladium & platinum	*Phosphates*						
20	8				Palladium & platinum	*Sulfides*						
20	9				Palladium & platinum	*Sulfates*						
20	10				Palladium & platinum	*Organo-palladium/ platinum compounds*						
21	1				Silicon	*Silicon*						
21	2				Silicon	*Carbonates*						
21	3				Silicon	*Cyanides*						
21	4				Silicon	*Halides*						
21	5				Silicon	*Nitrates*						
21	6	1	1		Silicon (silica)	*Oxides & hydroxides*	Silica, amorphous	From mineral source	SiO_2		Patton (1973)	Described as ‘cryptocrystalline’
21	6	1	2		Silicon (silica)	*Oxides & hydroxides*	Silica, amorphous	From biogenic source (diatoms)	SiO_2		Widely recognised. Walsh *et al*. (2004)	
21	6	1	3		Silicon (silica)	*Oxides & hydroxides*	Silica, amorphous	From mineralised biogenic source (diatomite)	SiO_2		Widely recognised. Walsh *et al*. (2004)	
21	6	1	4		Silicon (silica)	*Oxides & hydroxides*	Silica, amorphous	From mineralised biogenic source (radiolarite)	SiO_2			

21	6	2		Silicon (silica)	*Oxides & hydroxides*	α-Quartz	SiO_2	14808-60-7	Widely recognised & chem./min. lit.	
21	6	3		Silicon (silica)	*Oxides & hydroxides*	β-Quartz	SiO_2	14808-60-7	Widely recognised & chem./min. lit.	
21	6	4		Silicon (silica)	*Oxides & hydroxides*	Tridymite	SiO_2	15468-32-3	Related mineral form	
21	6	5		Silicon (silica)	*Oxides & hydroxides*	Cristobalite	SiO_2	14464-46-1	Walsh *et al.* (2004)	
21	6	6		Silicon (silica)	*Oxides & hydroxides*	Silica hydrate	$(SiO_2)_x.(H_2O)_y$; $3 = x/y = 10$		Boland & Wagner (1973)	
21	7			Silicon	*Phosphates*					
21	8			Silicon	*Sulfides*					
21	9			Silicon	*Sulfates*					
21	10			Silicon	*Organo-silicon compounds*					
22	1	1		Silicates	*Amorphous silicates*	Glass	SiO_2(vit)			
22	1	2		Silicates	*Amorphous silicates*	Glass, cobalt doped	SiO_2(vit)Co_x		Widely recognised. Revs.: Riederer (1968); Mühlethaler & Thissen (1993)	'Smalt'
22	2	1		Silicates	*Chain silicates*	Actinolite	$Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$		*Colour Index* (1971) 77718	
22	2	2		Silicates	*Chain silicates*	Aegirine	$(Na,Fe^{3+})Si_2O_6$	14567-85-2	[Possible relict component in green earth]	
22	2	3	1	Silicates	*Chain silicates*	Lead silicate, alamosite type	$PbSiO_3$		*Colour Index* (1971) 77625/PW 16	
22	2	3	2	Silicates	*Chain silicates*	Alamosite	$PbSiO_3$		Related mineral	
22	2	4		Silicates	*Chain silicates*	Anthophyllite	$(Mg, Fe^{2+})_7Si_8O_{22}(OH)_2$		Type of asbestos (e.g. Heaton, 1928)	
22	2	5		Silicates	*Chain silicates*	Augite	$(Ca,Mg,Fe)_2Si_2O_6$		[Possible relict component in green earth]	
22	2	6		Silicates	*Chain silicates*	Calcium silicate hydrate	$(SiO_2)_x.(CaO)_2.(H_2O)_y$; $x/z = 3.3$		Boland & Wagner (1973)	
22	2	7		Silicates	*Chain silicates*	Calcium silicate hydrate	$CaSiO_3.nH_2O$		Kranich (1973)	
22	2	8		Silicates	*Chain silicates*	Calcium silicate	Ca_2SiO_4	1344-95-2	Lawrence (1960); *Colour Index* (1971); then chem./min. lit., e.g. *Merck Index* (1996)	
22	2	9		Silicates	*Chain silicates*	Calcium silicate	Ca_3SiO_5		Lawrence (1960); *Colour Index* (1971); then chem./min. lit., e.g. *Merck Index* (1996)	
22	2	10		Silicates	*Chain silicates*	Crossite	$Na_2(Mg,Fe^{2+})_3(Al,Fe^{3+})_2Si_8O_{22}(OH)_2$		Found in association with glaucophane. Cameron *et al.* (1977); Filippakis *et al.* (1976); Profi *et al.* (1976)	
22	2	11		Silicates	*Chain silicates*	Diopside	$Mg,CaSi_2O_6$	13774-18-0	Plesters (1993) 49 as impurity with lazurite	
22	2	12		Silicates	*Chain silicates*	Enstatite	$Mg_2Si_2O_6$	13776-74-4	Related mineral (may occur as thermal modification of other magnesium silicates)	
22	2	13		Silicates	*Chain silicates*	Glaucophane	$Na_2(Mg,Fe^{2+})_3Al_2Si_8O_{22}(OH)_2$	12173-39-6	Cameron *et al.* (1977); Filippakis *et al.* (1976); Profi *et al.* (1976)	
22	2	14		Silicates	*Chain silicates*	Hornblende	$Ca_2(Mg,Fe^{2+})_4AlSi_7AlO_{22}(OH)_2$		Related to *Colour Index* (1971) 77718/Pigment White 26	
22	2	15		Silicates	*Chain silicates*	Jadeite	$Na(Al,Fe^{3+})Si_2O_6$	12003-54-2	[Precursor mineral for glaucophane]	
22	2	16		Silicates	*Chain silicates*	Riebeckite	$Na_2(Fe^{2+}Mg)_3(Fe_2^{3+})_2.Si_8O_{22}(OH)_2$		Cameron *et al.* (1977); Filippakis *et al.* (1976); Profi *et al.* (1976)	

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
22	2	17			Silicates	*Chain silicates*	Tremolite		$Ca_2Mg_5Si_8O_{22}(OH)_2$	14567-73-8	*Colour Index* (1971) 77718	
22	2	18			Silicates	*Chain silicates*	Calcium silicate		$CaSiO_3$	1344-95-2	Lawrence (1960); *Colour Index* (1971); then chem./min. lit., e.g. Merck (1996)	See also: Wollastonite
22	2	18			Silicates	*Chain silicates*	Wollastonite, form 1		$CaSiO_3$	13983-17-0	Lawrence (1960); *Colour Index* (1971); then chem./min. lit., e.g. Merck (1996)	
22	2	19			Silicates	*Chain silicates*	Wollastonite, form 2		$CaSiO_3$	14567-51-2	Lawrence (1960); *Colour Index* (1971); then chem./min. lit., e.g. Merck (1996)	Para-wollastonite
22	2	20			Silicates	*Chain silicates*	Wollastonite, form 3		$CaSiO_3$	14567-52-3	Lawrence (1960); *Colour Index* (1971); then chem./min. lit., e.g. Merck (1996)	Psuedo-wollastonite
22	2	21			Silicates	*Chain silicates*	Cupro-wollastonite		$(Ca,Cu)_3(Si_3O_9)$		Noll & Hangst (1975); Schilling (1988); Green (1995)	'Egyptian green'
22	3	1			Silicates	*Framework silicates*	Albite		$NaAlSi_3O_8$	12244-10-9	Duang *et al.* (1987)	
22	3	2			Silicates	*Framework silicates*	Analcime		$Na,AlSi_2O_6.H_2O$	1318-10-1		
22	3	3			Silicates	*Framework silicates*	Andesine		An40Ab60 – An30Ab70		Intermediate member of series with albite	
22	3	4			Silicates	*Framework silicates*	Anorthite		$KAlSi_3O_8$		End-member of series with albite	
22	3	5			Silicates	*Framework silicates*	Anorthoclase		$(Na,K)AlSi_3O_8$		Common clay mineral; not currently recorded as a pigment	
22	3	6			Silicates	*Framework silicates*	Bytownite		$(Na,Si.Ca,Al)AlSi_2O_8$		Intermediate member of series with albite	
22	3	7			Silicates	*Framework silicates*	Gmelinite		$(Na_2,Ca)Al_2Si_4O_{12}.6H_2O$		Kakoulli (1997)	
22	3	8			Silicates	*Framework silicates*	Hackmanite		$Na_8Al_6Si_6O_{24}(Cl_2,S)$		Related mineral; not currently recorded as a pigment	
22	3	9			Silicates	*Framework silicates*	Sodalite		$Na_4Al_3Si_3O_{12}Cl$	1302-90-5	Related mineral not known as a pigment (base structure related to ultramarine)	
22	3	10	1		Silicates	*Framework silicates*	Ultramarine		$Na_7Al_6Si_6O_{24}S_3$	57455-37-5	Widely recognised; rev.: Plesters (1993)	Buxbaum (1998) gives $Na_{6.9}Al_{5.6}Si_{6.4}O_{24}S_{4.2}$ as the typical composition of a commercial product
22	3	10	2		Silicates	*Framework silicates*	Lazurite		$(Na,Ca)_8[(Al,Si)_{12}O_{24}](S,SO_4)$		Widely recognised; rev.: Plesters (1993)	
22	3	11			Silicates	*Framework silicates*	Ultramarine red/violet		$Na_7Al_6Si_6O_{24}S_3$	12769-96-9	*Colour Index* (1971) Pigment Red 259/Pigment Violet 15; Buxbaum (1998)	Lattice structure as for ultramarine, but sulfur chromophores possibly S_3Cl^-, S_4 or S_4^- rather than S_3^{2-}
22	3	12			Silicates	*Framework silicates*	Hauyne		$(Na,Ca)_{4-8}Al_6Si_6(O,S)_{24}.(SO_4,Cl)_{1-2}$		Derrick *et al.* (1999) 134–138	
22	3	13			Silicates	*Framework silicates*	Heulandite		$(Na,Ca)_{2-3}Al_3(Al,Si)_2Si_{13})_{36}.12H_2O$	1318-63-4	Related mineral	

22	3	14			Silicates	*Framework silicates*	Labradorite	(Ca,Na)(Si,Al)$_4$O$_8$		Intermediate member of series with albite. Schroeder (1954) specifically as extender	
22	3	15			Silicates	*Framework silicates*	Laumontite	$CaAl_2Si_4O_{12}.4H_2O$			
22	3	16			Silicates	*Framework silicates*	Microcline	$KAlSi_3O_8$		Jercher *et al.* (1998); Chippindale (pers. comm.)	
22	3	17			Silicates	*Framework silicates*	Nepheline	(Na,K)AlSiO$_4$		As component of nepheline syenites (used as fillers and extenders)	
22	3	18			Silicates	*Framework silicates*	Oligoclase	An30Ab70 – An90Ab10		Intermediate member of series anorthite albite	
22	3	19			Silicates	*Framework silicates*	Orthoclase	$KAlSi_3O_8$	12251-44-4	Related mineral	
22	3	20			Silicates	*Framework silicates*	Sanidine	$KAlSi_3O_8$		Walsh *et al.* (2004)	
22	3	21			Silicates	*Framework silicates*	Stellerite	$Ca_2Al_4Si_{14}O_{36}.14H_2O$		Kakoulli (1997)	
22	3	22			Silicates	*Framework silicates*	Stilbite	$Ca_2NaAl_5Si_{13}O_{36}.16H_2O$		Min. lit. (as commonly forming solid solution with stellerite)	
22	3	23			Silicates	*Framework silicates*	Wairakite	$CaAl_2Si_4O_{12}.2H_2O$		Walsh *et al.* (2004)	
22	4	1			Silicates	*Nesosilicates*	Ellestadite	Ca$_5$(SiO$_4$,PO$_4$,SO$_4$)$_3$(F,OH,Cl)			
22	4	2			Silicates	*Nesosilicates*	Lead-ellestadite	Pb$_5$(SiO$_4$,PO$_4$,SO$_4$)$_3$(F,OH,Cl)		Corbeil *et al.* (1996)	See also: Ellestadite
22	4	3			Silicates	*Nesosilicates*	Forsterite	Mg_2SiO_4	15118-03-3	Plesters (1993) 49 as impurity with lazurite	
22	4	4			Silicates	*Nesosilicates*	Olivine	(Mg,Fe)SiO$_4$		Related mineral	
22	5	1	1		Silicates	*Orthosilicates*	Zirconium silicate	$ZrSiO_4$	10101-52-7	*Colour Index* (1971) 77995	
22	5	1	2		Silicates	*Orthosilicates*	Zircon	$ZrSiO_4$	14940-68-2	*Colour Index* (1971) 77995	
22	6	1			Silicates	*Ring silicates*	Chrysocolla	(Cu,Al)$_2$H$_2$Si$_2$O$_5$(OH)$_4.x$H$_2$O		Spurrell (1895); Gettens (1938); Scott *et al.* (1998)	
22	6	2			Silicates	*Ring silicates*	Dioptase	$CuSiO_3.H_2O$	15606-25-4	Tubb (1987); Scott (2001)	
22	7	1	1		Silicates	*Sheet/ring silicates*	Barium copper silicate, effenbergerite type	$BaCuSi_4O_{10}$	16482-38-5	FitzHugh & Zycherman (1983)	
22	7	1	2		Silicates	*Sheet/ring silicates*	Effenbergerite	$BaCuSi_4O_{10}$		Mineral analogue	
22	7	2			Silicates	*Sheet/ring silicates*	Barium copper silicate, 'purple' type	$BaCuSi_2O_6$		FitzHugh & Zycherman (1992)	
22	7	3			Silicates	*Sheet/ring silicates*	Barium copper silicate	$BaCu_2Si_2O_7$		Finger *et al*. (1989); Wiedemann & Bayer (1997)	
22	7	4			Silicates	*Sheet/ring silicates*	Barium copper silicate	$Ba_2CuSi_2O_7$		Finger *et al*. (1989); Wiedemann & Bayer (1997)	
22	7	5	1		Silicates	*Sheet/ring silicates*	Calcium copper silicate, cuprorivaite type	$CaCuSi_4O_{10}$	10279-60-4	Widely recognised. Revs.: Riederer (1997)	
22	7	5	2		Silicates	*Sheet/ring silicates*	Cuprorivaite	$CaCuSi_4O_{10}$		Mineral analogue	
22	8	1			Silicates	*Sheet silicates: Micas: Bioti*	Biotite	K(Mg,Fe^{2+})$_3$(Al,Fe^{3+}).Si$_3$O$_{10}$(OH,F)$_2$		*Colour Index* (1971) 77019	
22	8	2			Silicates	*Sheet silicates: Micas: Bioti*	Phlogopite	K[Mg$_3$(OH)$_2$Si$_3$AlO$_{10}$]	61076-94-6	*Colour Index* (1971) 77019	
22	8	3	1	1	Silicates	*Sheet silicates: Micas: Muscovite*	Muscovite	KAl$_2$(Si$_3$Al)O$_{10}$(OH,F)$_2$	1318-94-1	*Colour Index* (1971) 77019; Watchman *et al.* (1993)	
22	8	3	1	2	Silicates	*Sheet silicates: Micas: Muscovite*	Muscovite, var. fuchsite	KAl$_2$(AlSi$_3$)O$_{10}$(F,OH)$_2$		Current availability from Kremer Pigmente	See: Muscovite
22	8	4			Silicates	*Sheet silicates: Micas: Lepidolite*	Lepidolite	Kli$_2$Al(Al,Si)$_3$O$_{10}$(F,OH)$_2$		*Colour Index* (1971) 77019	
22	8	5			Silicates	*Sheet silicates: Micas:*	Celadonite	K(Mg,Fe^{2+})(Fe^{3+},Al)Si$_4$O$_{10}$(OH)		Grissom (1986); Odin & Delamare (1986)	
22	8	6			Silicates	*Sheet silicates: Clays: Illites*	Illite	(K,H)Al$_2$(Si, Al)$_4$O$_{10}$(OH)$_{2-x}$H$_2$O	12173-60-3	Couraud (1987); Watchman *et al.* (1993); Ford *et al.* (1994)	

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
22	8	7			Silicates	*Sheet silicates: Clays: Sepiolites*	Palygorskite		$(Mg,Al)_5(Si,Al)_8O_{20}(OH)_2.8H_2O$	12174-11-7	Gettens (1961) and others [as substrate for 'Maya blue']	Previously known as 'attapulgite'
22	8	8			Silicates	*Sheet silicates: Clays: Sepiolites*	Sepiolite		$Mg_4Si_6O_{15}(OH)_2.6H_2O$	63800-37-3	Van Olphen (1966) and Littmann (1980) [as alternate substrate for 'Maya blue']	
22	8	9			Silicates	*Sheet silicates: Clays: Smectites*	Beidellite		$Na_{0.5}Al_2(Si_{3.5}Al_{0.5})O_{10}(OH)_2.n(H_2O)$		As component of bentonite (Heaton (1928); Lawrence (1960); then min. lit.)	
22	8	10			Silicates	*Sheet silicates: Clays: Smectites*	Montmorillonite		$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}.(OH)_2.n(H_2O)$	1318-93-0	As component of bentonite (Heaton (1928); Lawrence (1960); then min. lit.)	
22	8	11			Silicates	*Sheet silicates: Clays: Smectites*	Volkonskoite		$Ca_{0.3}(Cr^{3+},Mg,Fe^{3+})_2.(Si,Al)_4O_{10}(OH)_2.4(H_2O)$		Available from Kremer Pigmente, 2001	
22	8	12			Silicates	*Sheet silicates: Clays: Vermiculites*	Vermiculite		$(Mg,Fe^{2+},Al)_3(Al,Si)_4O_{10}.(OH)_2.4(H_2O)$	1318-00-9		
22	8	13			Silicates	*Sheet silicates: Clays: Kaolinite – Serpentine*	Kaolinite		$Al_4[Si_4O_{10}](OH)_8$	1318-74-7	Stos-Fertner *et al.* (1979); Watchman *et al.* (1993); Huxtable & Pickering (1979); Grissom (1986)	
22	8	14			Silicates	*Sheet silicates: Clays: Kaolinite – Serpentine*	Dickite		$Al_2Si_2O_5(OH)_4$	1318-45-2		
22	8	15			Silicates	*Sheet silicates: Clays: Kaolinite – Serpentine*	Halloysite		$Al_2Si_2O_5(OH)_4.2H_2O$	12068-50-7	Scott & Hyder (1993)	
22	8	16			Silicates	*Sheet silicates: Clays: Kaolinite – Serpentine*	Nacrite		$Al_2Si_2O_5(OH)_4$	12279-65-1	Related mineral	
22	8	17			Silicates	*Sheet silicates: Chlorite*	Clinochlore		$(Mg,Fe^{2+})_5Al(Si_3Al)O_{10}(OH)_8$			
22	8	18			Silicates	*Sheet silicates: Chlorite*	Penninite					
22	8	19			Silicates	*Sheet silicates: Serpentine*	Antigorite		$(Mg,Fe^{2+})_3Si_2O_5(OH)_4$	61076-98-0	Ford *et al.* (1994)	
22	8	20			Silicates	*Sheet silicates: Serpentine*	Lizardite		$Mg_3Si_2O_5(OH)_4$	12161-84-1		
22	8	21			Silicates	*Sheet silicates: Serpentine*	Orthochrysotile		$Mg_3Si_2O_5(OH)_4$	12001-29-5	Type of asbestos (e.g. Heaton (1928))	
22	8	22			Silicates	*Sheet silicates: Serpentine*	Parachrysotile		$Mg_3Si_2O_5(OH)_4$		Type of asbestos (e.g. Heaton (1928))	
22	8	23			Silicates	*Sheet silicates: Serpentine*	Clinochrysotile		$Mg_3Si_2O_5(OH)_4$		Type of asbestos (e.g. Heaton (1928))	
22	8	24			Silicates	*Sheet silicates: Anomalous sheet silicates sub-group*	Talc		$Mg_3Si_4O_{10}(OH)_2$	14807-96-6	*Colour Index* (1971) 77718	
22	8	25			Silicates	*Sheet silicates: Anomalous sheet silicates sub-group*	Pyrophyllite		$Al_2Si_4O_{10}(OH)_2$	12269-78-2	Patton (1973e)	
22	8	26			Silicates	*Sheet silicates: Anomalous sheet silicates sub-group*	Prehnite		$Ca_2Al_2Si_3O_{10}(OH)_2$			
22	9	1			Silicates	[Unknown structure]	Aerinite		$Ca_4(Al,Fe^{3+},Mg,Fe^{2+})_{10}.Si_{12}O_{36}(CO_3).12H_2O$		Casas (1991)	
22	9	2			Silicates	[Unknown structure]	Lead oxide silicate		$PbSiO_3.3PbO$		Dunn (1973a) as coating on 'basic lead silico sulfate'	
22	9	3			Silicates	[Unknown structure]	Lead oxide silicate hydrate		$3PbO.2SiO_2.H_2O$		Dunn (1973a); Gellner *et al.* (1934)	
22	9	4			Silicates	[Unknown structure]	Sodium aluminium silicate		$9Na_2O.67SiO_2.12Al_2O_3$		Patton (1973d) as 'sodium silico aluminate'	Formula is stated to be 'typical'
23	1	1			Silver	*Silver*	Silver		Ag	7440-22-4	[Known use as leaf]	

23	2			Silver	*Carbonates*				
23	3			Silver	*Cyanides*				
23	4	1		Silver	*Halides*	Silver chloride	$AgCl_2$	7783-90-6	Seccarroni (pers. comm.) as 'silver white'
23	5	1		Silver	*Nitrates*	Silver nitrate	$AgNO_3$	7761-88-8	*Art of Drawing* (1757); de Massoul (1797) [Uncertain]
23	6			Silver	*Oxides & hydroxides*				
23	7			Silver	*Phosphates*				
23	8			Silver	*Sulfides*				
23	9	1		Silver	*Sulfates*	Silver sulfate	$AgSO_4$	10294-26-5	*Art of Drawing* (1757); de Massoul (1797) [Uncertain]
23	10			Silver	*Organo-silver compounds*				
24	1	1		Sodium	*Sodium*				
24	2	1		Sodium	*Carbonates*	Sodium carbonate	Na_2CO_3	497-19-8	Related compound
24	2	2		Sodium	*Carbonates*	Sodium hydrogen carbonate	$NaHCO_3$	144-55-8	Moffatt *et al.* (1997)
24	2	3		Sodium	*Carbonates*	Sodium bicarbonate carbonate hydrate	$Na_3(HCO_3)(CO_3).2H_2O$		Related compound
24	2	4		Sodium	*Carbonates*	Trona	$Na_3(HCO_3)(CO_3).2H_2O$		Related mineral
25	1			Strontium	*Strontium*				
25	2	1	1	Strontium	*Carbonates*	Strontium carbonate	$SrCO_3$		Synthetic analogue
25	2	1	2	Strontium	*Carbonates*	Strontianite	$SrCO_3$		Olsson *et al.* (2001); Matteini *et al.* (2002)
25	3			Strontium	*Cyanides*				
25	4			Strontium	*Halides*				
25	5			Strontium	*Nitrates*				
25	6			Strontium	*Oxides & hydroxides*				
25	7	1	2	Strontium	*Phosphates*	Goyazite	$SrAl_3(PO_4)_2(OH)_5.(H_2O)$		Huq *et al.* (2001)
25	8			Strontium	*Sulfides*				
25	9	1		Strontium	*Sulfates*	Strontium sulfate	$SrSO_4$	7759-02-6	Zerr & Rübencamp (1908)
25	9	2		Strontium	*Sulfates*	Celestite	$SrSO_4$	14291-02-2	Related mineral
25	10			Strontium	*Organo-strontium compounds*				
26	1	1		Sulfur	*Elemental sulfur*	Sulfur, amorphous type	S(am)	7704-34-9	Fiedler & Bayard (1986), as component of early pale cadmium yellows
26	1	2		Sulfur	*Elemental sulfur*	Sulfur, orthorhombic type	S_8	10544-50-0	Stodulski *et al.* (1984)
27	1	1		Tin	*Tin*	Tin	Sn	7440-31-5	Duncan *et al.* (1990)
27	2			Tin	*Carbonates*				
27	3			Tin	*Cyanides*				
27	4			Tin	*Halides*				
27	5	1		Tin	*Nitrates*				
27	6	1	1	Tin	*Oxides & hydroxides*	Tin(II) oxide, romarchite type	SnO		Synthetic analogue
27	6	1	2	Tin	*Oxides & hydroxides*	Romarchite	SnO		Smith *et al.* (1989)
27	6	2	1	Tin	*Oxides & hydroxides*	Tin(IV) oxide, cassiterite type	SnO_2	18282-10-5	*Colour Index* (1971) 77861/ Pigment White 15
27	6	2	2	Tin	*Oxides & hydroxides*	Cassiterite	SnO_2		*Colour Index* (1971) 77861/ Pigment White 15
27	6	3		Tin	*Oxides & hydroxides*	Tin(IV) oxide, hexagonal type	SnO_2		Related form

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
27	6	4			Tin	*Oxides & hydroxides*	Tin(IV) oxide, orthorhombic type		SnO_2		Related form	
27	7				Tin	*Phosphates*						
27	8	1	1		Tin	*Sulfides*	Tin(II) sulfide		SnS	1314-95-0	Related form	
27	8	1	2		Tin	*Sulfides*	Herzenbergite		SnS		Related form	
27	8	2	1		Tin	*Sulfides*	Tin(II,IV) sulfide		β-Sn_2S_3		Related form	
27	8	2	2		Tin	*Sulfides*	Ottemannite		β-Sn_2S_3		Related form	
27	8	3	1		Tin	*Sulfides*	Tin(IV) sulfide		SnS_2	1315-01-1	Smith *et al.* (1981); Speleers (1999)	
27	8	3	2		Tin	*Sulfides*	Berndtite		SnS_2		Mineral analogue	
27	9				Tin	*Sulfates*						
27	10				Tin	*Organo-tin compounds*						
28	1				Titanium	*Titanium*						
28	2				Titanium	*Carbonates*						
28	3				Titanium	*Cyanides*						
28	4				Titanium	*Halides*						
28	5				Titanium	*Nitrates*						
28	6	1	1		Titanium	*Oxides & hydroxides*	Titanium(IV) oxide, anatase type		TiO_2	13463-67-7	Widely recognised (rev.: Laver (1997))	
28	6	1	2		Titanium	*Oxides & hydroxides*	Anatase		TiO_2	1317-70-0	Chippindale (pers. comm.)	
28	6	2	1		Titanium	*Oxides & hydroxides*	Titanium(IV) oxide, brookite type		TiO_2		Related form	
28	6	2	2		Titanium	*Oxides & hydroxides*	Brookite		TiO_2	12188-41-9	Mineral analogue	
28	6	3	1		Titanium	*Oxides & hydroxides*	Titanium(IV) oxide, rutile type		TiO_2		Widely recognised (rev.: Laver, 1997)	
28	6	3	2		Titanium	*Oxides & hydroxides*	Rutile		TiO_2	1317-80-2	Mineral analogue	
28	6	4			Titanium	*Oxides & hydroxides*	Potassium titanate		$(K_2O)_{1/x}(TiO_2)_4$		Riches (1973)	
28	6	5			Titanium	*Oxides & hydroxides*	Titanium barium oxide ('barium titanate')		$BaTiO_3$	12047-27-7	Laver (1997)	
28	6	6			Titanium	*Oxides & hydroxides*	Titanium barium nickel oxide		$2NiO.3BaO.17TiO_2$			
28	6	7			Titanium	*Oxides & hydroxides*	Titnium lead oxide ('lead titanate')		$PbTiO_3$	12060-00-3	*Colour Index* (1971) 77645/PY 47	
28	6	8			Titanium	*Oxides & hydroxides*	Titanium zinc oxide ('zinc titanate')		$ZnTiO_3$	12036-43-0	*Colour Index* (1971) 77980; Kim *et al.* (2001)	
28	6	9			Titanium	*Oxides & hydroxides*	Titanium zinc oxide		Zn_2TiO_4		Kim *et al.* (2001)	
28	6	10			Titanium	*Oxides & hydroxides*	Titanium zinc oxide		$Zn_2Ti_3O_8$		Kim *et al.* (2001)	
28	6	11			Titanium	*Oxides & hydroxides*	Titanium antimony chromium oxide		$(Ti_{0.90}Sb_{0.05}Cr_{0.05})O_2$	68186-90-3	*Colour Index* (1971) 77310	
28	6	12			Titanium	*Oxides & hydroxides*	Titanium antimony nickel oxide		$(Ti_{0.85}Sb_{0.10}Ni_{0.05})O_2$	8007-18-9	*Colour Index* (1971) 77788	
28	7				Titanium	*Phosphates*						
28	8				Titanium	*Sulfides*						
28	9				Titanium	*Sulfates*						
28	10				Titanium	*Organo-titanium compounds*	Titanium phthalate				Laver (1997)	
29	1				Tungsten	*Tungsten*						
29	2				Tungsten	*Carbonates*						

29	3			Tungsten	*Cyanides*					
29	4			Tungsten	*Halides*					
29	5			Tungsten	*Nitrates*					
29	6	1		Tungsten	*Oxides & hydroxides*	Tungsten hydroxide	WHO			
29	6	2		Tungsten	*Oxides & hydroxides*	Tungsten oxide	WO			
29	6	3		Tungsten	*Tungstates*	Barium tungstate	$BaWO_4$	7787-42-0	Salter (1869) 414–415	
29	6	4		Tungsten	*Tungstates*	Cadmium tungstate	$CdWO_4$	7790-85-4	*Colour Index* (1971) 77208	
29	6	5	1	Tungsten	*Tungstates*	Calcium tungstate	$CaWO_4$	7790-75-2	Zerr and Rübencamp (1908); *Colour Index* (1971) 77250	
29	6	5	2	Tungsten	*Tungstates*	Scheelite	$CaWO_4$	14913-80-5	Related mineral	
29	6	6		Tungsten	*Tungstates*	Cobalt tungstate	$CoWO_4$	10101-58-3	*Colour Index* (1971) 77376	
29	6	7	1	Tungsten	*Tungstates*	Lead tungstate, raspite type	$PbWO_4$	7759-01-5	Riffault *et al.* (1874)	
29	6	7	2	Tungsten	*Tungstates*	Raspite	$PbWO_4$	14567-59-0 or 15502-08-6		Related mineral
29	6	8	1	Tungsten	*Tungstates*	Lead tungstate, stolzite type	$PbWO_4$		Related mineral	
29	6	8	2	Tungsten	*Tungstates*	Stolzite	$PbWO_4$		Related mineral	
29	7			Tungsten	*Phosphates*					
29	8			Tungsten	*Sulfides*					
29	9			Tungsten	*Sulfates*					
29	10			Tungsten	*Organo-tungsten compounds*					
30	1			Uranium	*Uranium*					
30	2			Uranium	*Carbonates*					
30	3			Uranium	*Cyanides*					
30	4			Uranium	*Halides*					
30	5			Uranium	*Nitrates*					
30	6	1		Uranium	*Oxides*	Uranium(IV) oxide	UO_2	1344-57-6	Salter (1869); *Colour Index* (1971)	
30	6	2		Uranium	*Oxides*	Uranium(VI) oxide	UO_3	1344-58-7		
30	6	3		Uranium	*Oxides*	Uranium (III) oxide	U_2O_3		Hackh (1969)	
30	6	4		Uranium	*Oxides*	Uranium(IV,VI) oxide (Uranium uranate)	U_3O_8	1344-59-8		
30	6	5		Uranium	*Oxides*	Uranium peroxide	$(UO_2^{2+})(O_2^{2-})(H_2O)_2$			
30	6	6		Uranium	*Oxides with Group 2 elements (Sr, Ba)*	Barium uranium oxide	BaU_7O_2			
30	6	7		Uranium	*Oxides with Group 2 elements (Sr, Ba)*	Strontium uranium oxide	$SrUO_4$	14312-10-8		
30	6	8		Uranium	*Oxides with Group 3–11 elements*	Uranium persulfomolybdate			Salter (1869)	
30	7			Uranium	*Phosphates*					
30	8			Uranium	*Sulfides*					
30	9			Uranium	*Sulfates*					
30	10			Uranium	*Organo-uranium compounds*					
31	1			Vanadium	*Vanadium*					
31	2			Vanadium	*Carbonates*					
31	3			Vanadium	*Cyanides*					
31	4			Vanadium	*Halides*					
31	5			Vanadium	*Nitrates*					
31	6			Vanadium	*Oxides*					
31	6	1		Vanadium	*Oxides with Group 3–11 elements (Cu)*	Copper vanadate	CuV_2O_6		Nord & Tronner (1998)	
31	6	2	1	Vanadium	*Oxides with Group 14–15 elements (Pb)*	Lead chloride vanadate	$Pb_5(VO_4)_3Cl$	12157-94-7	Synthetic analogue	

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
31	6	2	2		Vanadium	*Oxides with Group 14–15 elements (Pb)*	Vanadinite		$Pb_5(VO_4)_3Cl$	1307-08-0	Rouveret & Walter (1998)	
31	7				Vanadium	*Phosphates*						
31	8				Vanadium	*Sulfides*						
31	9				Vanadium	*Sulfates*						
31	10				Vanadium	*Organo-vanadium compounds*						
32	1	1			Zinc	*Zinc*	Zinc		Zn	7440-66-6	Bieganska *et al.* (1988); Buxbaum (1998) 209	Anticorrosive pigment
32	2	1	1		Zinc	*Carbonates*	Zinc carbonate		$ZnCO_3$	3486-35-9	*Colour Index* (1971) 77950	
32	2	1	2		Zinc	*Carbonates*	Smithsonite		$ZnCO_3$		Mineral analogue	
32	2	2	1		Zinc	*Carbonates*	Zinc carbonate hydroxide, hydrozincite type		$2ZnCO_3.3Zn(OH)_2$	12070-69-8	*Colour Index* (1971) 77951	
32	2	2	2		Zinc	*Carbonates*	Hydrozincite		$2ZnCO_3.3Zn(OH)_2$		Mineral analogue	
32	3				Zinc	*Cyanides*						
32	4				Zinc	*Halides*						
32	5				Zinc	*Nitrates*						
32	6	1	1	1	Zinc	*Oxides & hydroxides*	Zinc oxide	Acicular form	ZnO	1314-13-2	Widely recognised; rev.: Kühn (1986)	
32	6	1	1	2	Zinc	*Oxides & hydroxides*	Zinc oxide	Nodular form	ZnO	1314-13-2	Widely recognised; rev.: Kühn (1986)	
32	6	2			Zinc	*Oxides & hydroxides*	Zinc oxide hydrate		[---]		Toch (1916) as ‘Zinox’	Uncertain composition
32	6	3			Zinc	*Oxides & hydroxides*	Zincite		(Zn,Mn)O		Related mineral	
32	7	1			Zinc	*Phosphates*	Zinc phosphate		$Zn_2P_3O_7$	7779-90-0	*Colour Index* (1971) 77965	
32	7	2			Zinc	*Phosphates*	Zinc phosphate hydrate		$Zn_3(PO_4)_2.4H_2O$		*Colour Index* (1971) 77964/PW 32	
32	8	1	1		Zinc	*Sulfides*	Zinc sulfide		ZnS	1314-98-3	e.g. Heaton (1928)	
32	8	1	2		Zinc	*Sulfides*	Matraite		ZnS		Related mineral	
32	8	2			Zinc	*Sulfides*	Zinc sulfide hydrate		$ZnS.H_2O$		*Colour Index* (1971) 77975	
32	8	3			Zinc	*Sulfides*	Zinc oxide sulfide				*Colour Index* (1971) 77975 as ‘Griffith’s zinc white’; also Bersch (1901) ?	
32	8	4			Zinc	*Sulfides*	Sphalerite		ZnFeS	12169-28-7	Related mineral	
32	9	1			Zinc	*Sulfates*	Zinc sulfate		$ZnSO_4$	7733-02-0	Zerr & Rübencamp (1908)	
32	10				Zinc	*Organo-zinc compounds*						
33	1				Zirconium	*Zirconium*						
33	2				Zirconium	*Carbonates*						
33	3				Zirconium	*Cyanides*						
33	4				Zirconium	*Halides*						
33	5				Zirconium	*Nitrates*						
33	6	1	1		Zirconium	*Oxides & hydroxides*	Zirconium oxide, arkelite type		ZrO_2		*Colour Index* (1971) 77990/PW 12; Blumenthal & Jacobs (1973); Brochwicz *et al.* (1993)	
33	6	1	2		Zirconium	*Oxides & hydroxides*	Arkelite		ZrO_2		Related mineral	
33	6	2	1		Zirconium	*Oxides & hydroxides*	Zirconium oxide, baddeleyite type		ZrO_2		*Colour Index* (1971) 77990/PW 12; Blumenthal & Jacobs (1973)	Common modern pigmentary form
33	6	2	2		Zirconium	*Oxides & hydroxides*	Baddeleyite		ZrO_2		Related mineral	
33	7				Zirconium	*Phosphates*						

33	8				Zirconium	*Sulfides*						
33	9				Zirconium	*Sulfates*						
33	10				Zirconium	*Organo-zirconium compounds*						
34	1	1	1		Carbon[7]	*Crystalline carbons*	Carbon, graphite type		C		Winter (1983)	
34	1	1	2		Carbon	*Crystalline carbons*	Graphite		C	7782-42-5	Winter (1983); Hsu Wei-yeh *et al.* (1983)	
34	1	1	3		Carbon	*Crystalline carbons*	Graphite, disordered type		C		Winter (1983)	
34	1	1	4		Carbon	*Crystalline carbons*	Chaoite		C		Winter (1983)	
34	1	1	5		Carbon	*Crystalline carbons*	Lonsdaleite		C		Winter (1983)	
34	1	2	1		Carbon	*Fullerenes*	Fullerene	Synthesised forms	C_{60} & C_{70}		Not currently known	
34	1	2	2	1	Carbon	*Fullerenes*	Fullerene	From shungite	C_{60} & C_{70}			Shungite, which is rich in fullerenes, currently supplied as a pigment
35	1	1			Alkaloids							
36	1	1			Azo[8]	*Monoazo pigments*	*et seq.* by CI number					
36	2	1			Azo	*Disazo pigments*	*et seq.* by CI number					
36	3	1			Azo	*β-Naphthol pigments*	*et seq.* by CI number					
36	4	1			Azo	*Naphthol AS pigments*	*et seq.* by CI number					
36	5	1			Azo	*Benzimidazolone pigments*	*et seq.* by CI number					
36	6	1			Azo	*Disazo condensation pigments*	*et seq.* by CI number					
36	7	1			Azo	*Metal complex pigments*	*et seq.* by CI number					
36	8	1			Azo	*Isoindolinone and Isoindoline pigments*	*et seq.* by CI number					
37	1	1			Basic	*Berberins*	Berberin	From *Berberis* spp.			Tingry (1830)	‘Berberis’ for a ‘brownish Dutch pink’
38	1	1			Benzophenone							
39	1	1			Betalain							
40	1	1	2		Carotinoid	*Carotenes*	β-Carotene	From *Cuscuta* spp.			Wallert (1995c)	
40	2	1	2		Carotinoid	*Bixins*	Bixin	From *Bixa orellana* L.			Field (1835) 120; Salter (1869) 256	‘Annatto’
40	3	1			Carotinoid	*Crocins*	Crocin				Related compound	
40	3	2	2		Carotinoid	*Crocins*	Crocetin	From *Crocus sativus*			*Strasburg MS* (1966)	‘Saffron’
41	1	1			Diaryl	*Curcumins*	Curcumin	From *Curcuma longa* L.			Watin (1785) 26–27; Osborn (1845) 52; Lee *et al.* (1985)	‘Turmeric’
41	1	2			Diaryl	*Curcumins*	Dimethoxycurcumin				Related compound (Schweppe (1992))	
41	1	3			Diaryl	*Curcumins*	Bisdimethoxycurcumin				Related compound (Schweppe (1992))	
42	1	1			Flavonoid[9]	*Flavones*[10]	Luteolin	From *Reseda luteola* L.			Widely recognised; e.g. see: Osborn (1845) 49	‘Weld’
42	2	1			Flavonoid	*Flavonols*[11]	Catechin					

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[7] Carbon arrangement follows that given in: Winter, J. ‘The characterization of pigments based on carbon’ *Studies in Conservation* **28** (1983) 49–66, with modifications. Carbon-based blacks are listed separately in section B.

[8] Azo arrangement follows that given in the *Colour Index* (1971) and Herbst, Willy and Hunger, Klaus, *Industrial organic pigments: production, properties, applications*, second ed., VCH, Weinheim (1997).

[9] Flavonoid arrangement follows that given in: Harborne, J.B. and Baxter, H. (eds.) *The Handbook of Natural Flavonoids*, 2 Vols, John Wiley & Sons, Chichester, UK (1999).

[10] This sub-group also includes the flavone *O*-glycosides.

[11] This sub-group also includes the flavonol *O*-glycosides.

(*continued*)

A: Generic compounds (*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
42	2	2			Flavonoid	*Flavonols*	Epichatechin					
42	2	3			Flavonoid	*Flavonols*	Rhamnetin	From *Rhamnus* spp.				
42	2	4			Flavonoid	*Flavonols*	Quercetin					
42	3	1			Flavonoid	*C-Glycosylflavones*						
42	4	1			Flavonoid	*Biflavonyls*						
42	5	1			Flavonoid	*Anthocyanins*						
42	6	1			Flavonoid	*Chalcones*						
42	7	1			Flavonoid	*Dihydrochalcones*						
42	8	1			Flavonoid	*Aurones*						
42	9	1	2		Flavonoid	*Flavanones*	Pinocembrin	From *Xanthorrhoea* spp.				NB: Pinocembrin is also found in honey
42	10	1	2		Flavonoid	*Dihydroflavanols*	Aromadendrin	From *Acacia catechu* (L.f.) Willd. and other *A.* spp.			Salter (1869) 354–355 as ‘Catechu brown’	‘Catechu’
42	11	1			Flavonoid	*Flavans/ Proanthocyanins*						
42	12	1			Flavonoid	*Isoflavonoids/ Neoflavonoids*	Brazilin					
42	12	2			Flavonoid	*Isoflavonoids/ Neoflavonoids*	Brazilein					
42	12	3			Flavonoid	*Isoflavonoids/ Neoflavonoids*	Hematoxylin					
42	12	4			Flavonoid	*Isoflavonoids/ Neoflavonoids*	Hematein					
43	1	1			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Fe(III) and M(I) ions (Na, K, NH$_4$)*	Iron(III) hexacyanoferrate(II)		$Fe_4[Fe(CN)_6]_3$		Berrie (1997)	Traditional formulation, probably inaccurate representation
43	1	2			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Fe(III) and M(I) ions (Na, K, NH$_4$)*	Ammonium iron hexacyanoferrate(II)		$(NH_4)Fe^{III}[Fe^{II}(CN)_6].nH_2O$, $n = 14–16$	25869-00-5	Assumed modification in ‘Monthier’s blue’	
43	1	3			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Fe(III) and M(I) ions (Na, K, NH$_4$)*	Potassium iron hexacyanoferrate(II)		$KFe^{III}[Fe^{II}(CN)_6].nH_2O$, $n = 14–16$		Berrie (1997)	
43	1	4			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Fe(III) and M(I) ions (Na, K, NH$_4$)*	Sodium iron hexacyanoferrate(II)		$NaFe^{III}[Fe^{II}(CN)_6].nH_2O$, $n = 14–16$		Berrie (1997)	
43	2	1			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 3–12 ions (including Co, Cu, Zn)*	Cobalt hexacyano-ferrate(II)				Salter (1869) as ‘Cobalt Prussian blue’	
43	2	2			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group*	Dicopper hexacyano-ferrate(II) hydrate		$Cu_2Fe(CN)_6.xH_2O$		Bersch (1901) 280 as ‘Hatchett brown’; *Colour Index* (1971)	

						3–12 ions (including Co, Cu, Zn)					CI 77430/Pigment Brown 9	
43	2	3			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 3–12 ions (including Co, Cu, Zn)*	Copper dipotassium hexacyanoferrate(II)		$CuK_2Fe(CN)_6$		Bersch (1901) 280 as 'Hatchett brown'; *Colour Index* (1971) CI 77430/Pigment Brown 9	
43	2	4			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 3–12 ions (including Co, Cu, Zn)*	Titanium hexacyano-ferrate(II)				Salter (1869) 290; Riffault *et al.* (1874); Terry (1893) 135; Laver (1997)	
43	2	5			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 3–12 ions (including Co, Cu, Zn)*	Tungsten tin hexacyanoferrate(II)(?)				*Colour Index* (1971) 77515	
43	2	6			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 3–12 ions (including Co, Cu, Zn)*	Vanadium hexacyanoferrate(II)				Salter (1869) 291 as 'vanadium green'	
43	2	7			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 3–12 ions (including Co, Cu, Zn)*	Zinc hexacyano-ferrate(II)				Terry (1893) 137 as 'zinc green'; *Colour Index* (1971) 77530	
43	3	1			Hexacyano-ferrate(II)	*Hexacyanoferrate(II) pigments with Group 15 ions (including Sb)*	Antimony hexacyanoferrate(II)				Bersch (1901); *Colour Index* (1971) 77510	
44	1	1	1		Indigoid	*Base compounds*	Indigo	Synthetic		482-89-3	Widely recognised	
44	1	1	2	1	Indigoid	*Base compounds*	Indigo	From *Indigofera tinctoria* L.			Widely recognised	
44	1	1	2	2	Indigoid	*Base compounds*	Indigo	From *Isatis tinctoria* L.			Widely recognised	
44	1	1	3		Indigoid	*Base compounds*	Indigo	From genetically modified bacteria (*Pseudomonas* spp. & *Escheria coli*)				
44	1	2			Indigoid	*Base compounds*	Indirubin			479-41-4		
44	2	1			Indigoid	*Halogenated compounds*[12]	6-Bromoindigo				Cooksey (2001)	
44	2	2			Indigoid	*Halogenated compounds*	6,6′-Dibromoindigo				Cooksey (2001)	
44	2	3			Indigoid	*Halogenated compounds*	6,6′-Dibromoindirubin				Cooksey (2001)	
44	2	4			Indigoid	*Halogenated compounds*	6-Bromoisatin				Cooksey (2001)	
44	3	1			Indigoid	*Sulfonated compounds*	Disodium 3,3′-dioxo-[$\Delta^{2,2'}$-biindoline]-5,5′-disulfonate			860-22-0	Balfour-Paul (1998)	'Indigo carmine'
44	3	2			Indigoid	*Sulfonated compounds*	Disodium 3,3′-dioxo-[$\Delta^{2,2'}$-biindoline]-5,7′-disulfonate				Balfour-Paul (1998)	'Indigo carmine'
44	4	1			Indigoid	*Thioindigoid compounds*	Thioindigo				Herbst & Hunger (1997)	

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[12] For various other precursor or transient brominated compounds that occur in Tyrian purple, see Cooksey (2001).

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
44	4	2			Indigoid	*Thioindigoid compounds*	4,4′,7,7′-Tetrachlorothioindigo				Herbst & Hunger (1997)	CI Pigment Red 88
44	4	3			Indigoid	*Thioindigoid compounds*	4,4′-Dimethyl-6,6′-dichlorothioindigo				Herbst & Hunger (1997)	CI Pigment Red 181
45	1	1			Orceins	*Orcein*	α-amino-orcein				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	Orcein is a composite; CAS #1400-62-0
45	1	2			Orceins	*Orcein*	α-hydroxy-orcein				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
45	1	3			Orceins	*Orcein*	β-amino-orcein				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
45	1	4			Orceins	*Orcein*	β-hydroxy-orcein				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
45	1	5			Orceins	*Orcein*	β-amino-orceinimine				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
45	1	6			Orceins	*Orcein*	α-amino-orcein				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
45	1	7			Orceins	*Orcein*	α-hydroxy-orcein				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
45	1	8			Orceins	*Orcein*	α-amino-orceinimine				Harley (1982) as 'litmus', then chem. lit. (Schweppe (1992))	
46	1	1			Porphyrins	*Chlorophylls*	Chlorophyll a			1406-65-1	Mills & White (1994) 146 as major component of 'sap green', then chem. lit.	
46	1	2			Porphyrins	*Chlorophylls*	Chlorophyll b			1406-65-1	Mills & White (1994) 146 as major component of 'sap green', then chem. lit.	
46	1	3			Porphyrins	*Chlorophylls*	Chlorophyll c			1406-65-1	Mills & White (1994) 146 as major component of 'sap green', then chem. lit.	
46	2	1			Porphyrins	*Hemoglobins*	Hemoglobin			9008-02-0	cf. Bristow (1996) 232, n.13, then chem. lit.	
46	2	2			Porphyrins	*Hemoglobins*	Heme				cf. Bristow (1996) 232, n.13, then chem. lit.	
46	2	3			Porphyrins	*Hemoglobins*	Hemin			16009-13-5	cf. Bristow (1996) 232, n.13, then chem. lit.	
46	2	4			Porphyrins	*Hemoglobins*	Bilirubin[13]			635-65-4	Thompson (1956) as 'Bile yellow' (?) then biochem.	Found in bile
46	2	5			Porphyrins	*Hemoglobins*	Biliverdin			114-25-0	Thompson (1956) as 'Bile yellow' (?) then biochem.	Found in bile
46	3	1			Porphyrins	*Phthalocyanines*[14]	Phthalocyanine			574-93-6		
46	3	2			Porphyrins	*Phthalocyanines*	Copper phthalocyanine			147-14-8		
46	3	3			Porphyrins	*Phthalocyanines*	Polychloro copper phthalocyanine					
46	3	4			Porphyrins	*Phthalocyanines*	Polychloro polybromo copper phthalocyanine					
47	1	1			Quinones	*Anthraquinones*	Alizarin			72-48-0	Schweppe & Winter (1997)	
47	1	2			Quinones	*Anthraquinones*	Purpurin			81-54-9	Schweppe & Winter (1997)	
47	1	3			Quinones	*Anthraquinones*	Pseudopurpurin				Schweppe & Winter (1997)	

47	1	4		Quinones	*Anthraquinones*	Rubiadin			Schweppe & Winter (1997)	
47	1	5		Quinones	*Anthraquinones*	Munjistin			Schweppe & Winter (1997)	
47	1	6		Quinones	*Anthraquinones*	Morindone			Schweppe & Winter (1997)	
47	1	7		Quinones	*Anthraquinones*	Xanthopurpurin			Schweppe & Winter (1997)	
47	1	8		Quinones	*Anthraquinones*	Rubiadin-1-methyl ether			Schweppe & Winter (1997)	
47	1	9		Quinones	*Anthraquinones*	Hystazarin-3-methyl ether			Schweppe & Winter (1997)	
47	1	10		Quinones	*Anthraquinones*	Anthragallol		602-64-2	Schweppe & Winter (1997)	
47	1	11		Quinones	*Anthraquinones*	Anthragallol-2-methyl ether			Schweppe & Winter (1997)	
47	1	12		Quinones	*Anthraquinones*	Anthragallol-1,2-dimethyl ether			Schweppe & Winter (1997)	
47	1	13		Quinones	*Anthraquinones*	Anthragallol-1,3-dimethyl ether			Schweppe & Winter (1997)	
47	1	14		Quinones	*Anthraquinones*	Soranjidiol			Schweppe & Winter (1997)	
47	1	15		Quinones	*Anthraquinones*	6-Methylxanthopurpurin			Schweppe & Winter (1997)	
47	1	16		Quinones	*Anthraquinones*	Lucidin			Schweppe & Winter (1997)	
47	1	17		Quinones	*Anthraquinones*	Ibericin			Schweppe & Winter (1997)	
47	1	18		Quinones	*Anthraquinones*	2-Hydroxyanthraquinone			Schweppe & Winter (1997)	
47	1	19		Quinones	*Anthraquinones*	1-Hydroxy-2-methyl-anthraquinone			Schweppe & Winter (1997)	
47	1	20		Quinones	*Anthraquinones*	3-Hydroxy-2-methyl-anthraquinone			Schweppe & Winter (1997)	
47	1	21		Quinones	*Anthraquinones*	Alizarin-1-methyl ether			Schweppe & Winter (1997)	
47	1	22		Quinones	*Anthraquinones*	Xanthopurpurin-1-methyl ether			Schweppe & Winter (1997)	
47	1	23		Quinones	*Anthraquinones*	Xanthopurpurin-3-methyl ether			Schweppe & Winter (1997)	
47	1	24		Quinones	*Anthraquinones*	2-Benzylxanthopurpurin			Schweppe & Winter (1997)	
47	1	25		Quinones	*Anthraquinones*	6-Methylquinizarin			Schweppe & Winter (1997)	
47	1	26		Quinones	*Anthraquinones*	Damnacanthol			Schweppe & Winter (1997)	
47	1	27		Quinones	*Anthraquinones*	Damnacanthal			Schweppe & Winter (1997)	
47	1	28		Quinones	*Anthraquinones*	Nordamnacanthal			Schweppe & Winter (1997)	
47	1	29		Quinones	*Anthraquinones*	Physcion			Schweppe & Winter (1997)	
47	1	30	2	Quinones	*Anthraquinones*	Aloe-emodin	From *Aloe* spp.		Widely recognised; e.g. see: Mills & White (1987)	
47	1	31		Quinones	*Anthraquinones*	Chrysophanol				Occurs in various species used for pigment production, including *Aloe* and *Cassia*, and probably also *Rheum*
47	1	32		Quinones	*Anthraquinones*	Emodin				
47	1	33		Quinones	*Anthraquinones*	Rhein				
47	1	34		Quinones	*Anthraquinones*	Rheidin				
47	1	35		Quinones	*Anthraquinones*	Sennoside A–D				
47	1	36		Quinones	*Anthraquinones*	Kermesic acid			Widely recognised	'Kermes'
47	1	37		Quinones	*Anthraquinones*	Flavokermesic acid			Schweppe & Roosen-Runge (1986); White & Kirby (2001)	'Kermes'

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[13] Bilirubin and biliverdin are naturally occurring tetrapyrroles, but classed here with hemoglobin, of which they are decomposition products.

[14] As a result of the structure of phthalocyanine many substitutions can be achieved and at least 70 metal phthalocyanines have been prepared; further, as a result of the 16 reactive sites on the four benzene units, over 5000 further compounds have also been made. Polymorphism has been widely recognised in these compounds with the discovery of various crystal forms of copper and other metal phthalocyanines; however, few of these have found substantial use as pigments. Only the principal pigmentary forms are listed here.

(*continued*)

α	β	γ	δ	ε	GROUP	SUB-GROUP	CHEMICAL NAME	VARIANT FORM	CHEMICAL FORMULA	CAS Number	LITERATURE	NOTES
47	1	38			Quinones	*Anthraquinones*	Laccaic acid A				Widely recognised	‘Lac’
47	1	39			Quinones	*Anthraquinones*	Laccaic acid B				Schweppe & Roosen-Runge (1986); White & Kirby (2001)	
47	1	40			Quinones	*Anthraquinones*	Laccaic acid C					
47	1	41			Quinones	*Anthraquinones*	Laccaic acid D					
47	1	42			Quinones	*Anthraquinones*	Laccaic acid E					
47	1	43			Quinones	*Anthraquinones*	Laccaic acid F					Only known from Thai stick lac (Whiter & Kirby, 2001)
47	1	44			Quinones	*Anthraquinones*	Erythrolaccin					
47	1	45			Quinones	*Anthraquinones*	Isoerythrolaccin					
47	1	46			Quinones	*Anthraquinones*	Deoxyerythrolaccin					
47	2	1			Quinones	*Anthraquinones: Anthanthrones*						
47	3	1			Quinones	*Anthraquinones: Anthrapyrimidines*						
47	4	1			Quinones	*Anthraquinones: Flavanthrones*						
47	5	1			Quinones	*Anthraquinones: Indanthrones*						
47	6	1			Quinones	*Anthraquinones: Pyranthrones*						
47	7	1	2		Quinones	*Benzoquinones*	Carthamin	From *Carthamus tinctorius* L.			Watin (1785); Harley (1982)	‘Safflower’
47	8	1	2		Quinones	*Naphthoquinones*	Alkannin	From *Alkanna tinctoria* Tausch.			Tingry (1830) as alkanet, then chem. lit.	‘Alkanet’
47	8	2	2		Quinones	*Naphthoquinones*	Alkannan	From *Alkanna tinctoria* Tausch.			Tingry (1830) as alkanet, then chem. lit.	
47	8	3			Quinones	*Naphthoquinones*	Shikonin					
47	8	4	2		Quinones	*Naphthoquinones*	Juglone	From *Juglans* spp.		481-39-0		
48	1	1	2		Xanthones	*Xanthones*	Carajurin	From *Bignonia chica* Humb. et Bonpl.		Salter (1869) as	‘chica’; *Colour Index* (1971) Natural Orange 5	
48	1	2			Xanthones	*Xanthones*	Euxanthone				Related compound (Indian yellow)	
48	1	3			Xanthones	*Xanthones*	Euxanthic acid				Related compound (Indian yellow)	
48	1	4			Xanthones	*Xanthones*	Euxanthic acid, calcium salt				Widely recognised as ‘Indian yellow’; rev.: Baer *et al.* (1986)	
48	1	5			Xanthones	*Xanthones*	Euxanthic acid, magnesium salt				Widely recognised as ‘Indian yellow’; rev.: Baer *et al.* (1986)	
48	1	6	2		Xanthones	*Xanthones*	Dracorubin	From *Daemonorops* spp.				‘Dragon’s blood’. Group assignment according to Schweppe (1992)

48	1	7	2	Xanthones	*Xanthones*	Dracorhodin	From *Daemonorops* spp.		‘Dragon’s blood’. Group assignment according to Schweppe (1992)
48	1	8	2	Xanthones	*Xanthones*	Gentisin	From *Gentiana lutea* L.	Salter (1869) 180; Schweppe (1992)	‘Wongshy red’ (obsc.)
48	2	1	2	Xanthones	*Hydroxanthones*	Gambogic acid	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	2	2	Xanthones	*Hydroxanthones*	Isogambogic acid	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	3	2	Xanthones	*Hydroxanthones*	Morellic acid	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	4	2	Xanthones	*Hydroxanthones*	Isomorellic acid	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	5	2	Xanthones	*Hydroxanthones*	Morellin	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	6	2	Xanthones	*Hydroxanthones*	Morellinol	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	7	2	Xanthones	*Hydroxanthones*	Isomorellinol	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	8	2	Xanthones	*Hydroxanthones*	Desoxymorellinol	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	9	2	Xanthones	*Hydroxanthones*	Dihydroisomorellin	From *Garcinia* spp.	Winter (1997)	Gamboge constituent
48	2	10	2	Xanthones	*Hydroxanthones*	Neogambogic acid	From *Garcinia* spp.	Winter (1997)	Gamboge constituent

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GENUS/SPECIES	FAMILY	TRIVIAL DYE NAME	DYE COMPONENTS[1]	LITERATURE	NOTES
PLANTS:[2]					
***Acacia* spp.** *A. catechu* (L.f.) Willd.	Leguminosae	Catechu (tannin)	Catechin [Epichatechin; Quercetin; Quercitron]	Salter (1869) as 'Catechu brown'	Salter also describes speculative pigments formed with metal salts
***Aesculus* spp.** *A. hippocastanum* L.	Hippocastanaceae	Chestnut brown	**Quercitron**	Salter (1869) as 'Hypocastanum' and 'Chestnut brown'	
***Alkanna* spp.** *A. tinctoria* Tausch.; *A. lehmannii* Tineo	Boraginaceae	Alkanet	**Alkannin**; **Alkannan**	Papageorgiou *et al.* (1999)	
***Aloe* spp.** *A. barbadensis* Miller; *A. epatia*; *A. ferox*; *A. perryi*	Liliaceae	Aloe	**Aloe-emodin**; **Chrysophanol**		
***Berberis* spp.** *B. vulgaris* L. (and numerous others)	Berberidaceae	Berberis	**Berberine**; Oxyacanthine; Magnoflorine; Berberrubine; Berbamine; Jatrorrhizine; Columbamine; Palmatine; Tetrahydropalmatine	Boyle (1731) cf. Harley (1982) 118	
***Bignonia* spp.** *B. chica* Humb. et Bonpl.	Bignoniaceae	'Chica' or 'Chica Marrone'	Carajurin	Salter (1869)	
***Bixa* spp.** B. orellana *L.*	Bixaceae	Annatto	**Bixin**; Crocetin	Dossie (1758); Harley (1982) 118	
***Caesalpinia* spp.** *C. bonduc* (L.) Roxb.; *C. crista* L.; *C. echinata* Lam.; *C. japonica* Sieb. & Zucc.; *C. sappan* L.; *C. violacea* (Miller) Standley	Leguminosae	Brazilwood; Limawood; Sappan wood; Pernambuco wood; Peachwood	Brasilein	Widely recognised	*C. violacea* was formerly *C. brasiliensis* L.
***Carthamus* spp.** *C. tinctorius* L.	Compositae	Safflower	Carthamin; Safflon A; Safflon B; Tinctormine	Harley (1982) 146–147	
***Cassia* spp.** *C. angustifolia* Vahl.; *C. auriculata* L.; *C. fistula* L.; *C. senna* L.; *C. tora* L.	Leguminosae	Cassia	**Aloe-emodin**; **chrysophanol**; **Rhein**; **Rheidin**; **Sennoside A–D**	Salter (1869)	
***Centaurea* spp.** *C. cyanus* L.	Compositae	Cornflower blue	Apigenin (glucoside); Isoswertisin; Naringin; Cyanidin; Pelargonidin; Succinylcyanin	Harley (1982) 65–66	
***Chrozophora* spp.** C. tinctoria (L.) *A. Juss.*	Euphorbiaceae Syn.: *Croton tinctorium* L.	Turnsole	Azolitminum	Turner (1998) from Alcherius/Lebegue (Merrifield (1849); Harley (1982) 61–63	
***Cichorium* spp.** *C.* intybus L.	Compositae	Chicory brown	Cyanidin and Delphinidin malonylglucosides *C. endivia* also contains Kaempferol	Salter (1869)	Probable modern use as a wood stain. Used after roasting of the root.
***Commelina* spp.** *C. communis* L.	Commelinaceae	Dayflower	Commelinin; **Flavocommelin; Swertisin; Awobanin; Flavocommelitin**	Shimoyama *et al.* (1995); used in *Ukiyo-e* prints	
***Coprosma* spp.** *C. lucida* Forst.; *C. acerosa* Cunn.	Rubiaceae	Madder	**Lucidin**; **Anthragallol-2-methyl ether**; Anthragallol-1,2-dimethyl ether; Rubiadin; Soranjidiol; Anthragallol; 3-Hydroxy-2-methylanthraquinone; Rubiadin-1-methyl ether	Schweppe & Winter (1997)	
***Cotinus* spp.** *C. coggyria* Scop.	Anacardiaceae	'Young fustic'	Fisetin [Sulfuretin (spp.), Cyanidin; Delphinidin; Petunidin glucosides; Idaein]		
***Crocus* spp.** *C. sativus* L.	Iridaceae	Saffron	**Crocetin** α, β, δ; Carotin; Lycopene; Zeanthene	Harley (1982) 104	
***Croton* spp.** *C. aromaticus*; *C. draco*; *C. gossypiifolius*	Euphorbiaceae	Dragon's blood	**Nordin**	Edwards *et al.* (1997); Pearson & Prendergast (2001)	

***Curcuma* spp.** *C. longa* L.; *C. zedoaria* (Christm.) Roscoe	Zingiberaceae	Turmeric	**Curcumin**; **Dimethoxycurcumin**; **Bisdimethoxycurcumin**	Dossie (1758); Harley (1982) 118; Lee *et al.* (1985)	
***Cuscuta* spp.** *C. tinctoria* Mart.; *C. americana* Linn.; *C. odontolepis* Engelmann	Convolvulaceae (Cuscutaceae)	Cuscuta	**β- and γ-Carotenes**	Wallert (1995c)	
***Daemonorops* spp.** *D. draco*; *D. propinquus*	Palmae	Dragon's blood	**Dracoflavan A**, **Dracooxepine**, **Dracorubin**, **Nordracorubin** plus various methoxyflavan compounds		
***Damnacanthus* spp.** *D. major* Sieb. and Zucc. (var. *parvifolius* Koidz.)	Rubiaceae	Madder	*D. macrophyllus* contains Pelargonidin 3-rutinoside	Schweppe & Winter (1997)	
***Dracaena* spp.** *D. draco* (L.) L.; *D. ombet* Kotschy & Peyr.; *D. schizantha* Baker; *D. serrulata* Baker; *D. cinnabari* Balf. f. (and others)	Dracaenaceae	Dragon's blood	**Dracoresinotannol**, **Dracoresene** plus terpenes and other flavonoid compounds	Edwards *et al.* (1997)	Exact species use for pigment production uncertain; those listed are principals.
***Eucalyptus* spp.** *E. resinifera* Sm.; *E. terminalis* F. Muell.	Myrtaceae	Dragon's blood	[Variously tannins and flavonoids; See Schweppe, 1992]	Edwards *et al.* (1997)	Formed as an ant gall
***Galium* spp.** *G. verum* L.	Rubiaceae	'Ladies bedstraw'	**Pseudopurpurin**; 2-hydroxyanthraquinone, alizarin-1-methyl ether, alizarin, xanthopurpurin, rubiadin, purpurin, lucidin; 2-methoxyanthraquinone and others	Schweppe & Winter (1997)	*G. mollugo* also contains apigenin and luteolin glucosides
***Garcinia* spp.** *G. hanburyi*; *G. morella*; *G. cambogia* Desrouss.; *G. elliptica* Wall.; *G. heterandra* Wall.	Guttiferae	Gamboge	**Gambogic acid**; **Morellic acid**; **Isomorellic acid**	Winter (1997)	
***Gardenia* spp.** *G. jasminoides* Ellis	Rubiaceae	Gardenia seed	**Crocetin**	Yü (1955)	
***Genista* spp.** *G. tinctoria* L.	Leguminosae	Genista	**Genistein**, **Luteolin**. Other *G.* spp. also contain formononetin, prunetin, orobol 7-*O*-sophoroside and orientin 4′-glucoside	Norgate, cf. Harley (1982) 107; Sanyova & Wouters (1994)	
***Gentiana* spp.** *G. lutea* L.	Gentianaceae	'Wongshy red' (obsc.)	Gentisin, Isogentisin	Salter (1869) 180; Schweppe (1992)	*G.* spp.: Gentiocyanins A–C, isorientin & derivatives, isosaponarin & isoscoparin. Individual spp. contain a variety of other flavonoids.
***Glycyrrhiza* spp.** *G. glabra* L.	Leguminosae	Liquorice	*G. glabra*: Glabranin, glabrene, glabridin, glabrol, glabrone, glycycoumarin, glyzaglabrin, glyzarin, hispaglabridin A & B, isoglycocoumarin, isoliquiritigenin (glycoside), isoliquiritin, isomucronulatol, kaempferol (glucoside), licochalcone A & B, licoflavanone, licoricidin, licuroside, neoisoliquiritin, prunetin and rhamnoliquiritin	White (1986)	
***Haematoxylum* spp.** *H. campechianum* L.; *H. brasiletto* Karsten	Leguminosae	'Logwood' (also 'Campeachy wood') and 'Peachwood' respectively	Haematin	Harley (1982) 64–65 for logwood	
***Indigofera* spp.** *I. tinctoria* L.; *I. suffruticosa* Mill. ssp. suffruticosa & ssp. guatemalensis Kort & Thijsse; *I. arrecta* Hochst. ex A. Rich; *I. argentea* L.	Leguminosae	Indigo	Indigotin; indirubin	Widely recognised; rev.: Schweppe (1997)	Use of spp. other than *I. tinctoria* as pigments uncertain
***Iris* spp.** *I. germanica* L.	Iridaceae	Iris green	*I.* spp.: Irigenin, malvidin, negretein, petanin, petunidin *I. germanica:* **Mangiferin** [Schweppe, 1992]	*Art of Drawing* (1731), cf. Harley (1982) 86	
***Isatis* spp.** *I. tinctoria* L.; *I. aleppica* Scop.; *I. alpina* Vill.; *I. indigotica*	Cruciferae	Woad (indigo)	Indigo	Harley (1982) 66–67	Use of spp. other than *I. tinctoria* as pigments uncertain

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[1] Dye components were primarily derived from Schweppe (1992) unless superseded by more recent studies; these alternate sources are noted in the literature column. Flavonoids were also checked from Harborne and Baxter (1999).
[2] Current plant taxonomy has been checked using: Mabberley, D.J. *The Plant-Book. A portable dictionary of the vascular plants*, second ed., Cambridge University Press, Cambridge (1997).

(*continued*)

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GENUS/SPECIES	FAMILY	TRIVIAL DYE NAME	DYE COMPONENTS[1]	LITERATURE	NOTES
***Juglans* spp.** *J. nigra* L.; *J. regia* L.	Juglandaceae	Walnut	Juglone	Thompson (1935)	
***Lilium* spp.**	Liliaceae	e.g. 'Lily green'	Chyophanol; Aloe-emodin	*Art of Drawing* (1731), cf. Harley (1982) 86	Probably erroneous – likely to refer to iris
Maclura* spp**. ***M. tinctoria (L.) Steudel	Moraceae	'Old fustic'	Morin [Dihydromorin; 5,7-Dihydroxy-6-*C*-prenyl-flavanone]	Harley (1982) 104–105	Formerly *Chlorophora tinctoria* (L.) Gaud. and *Morus tinctoria* L.; also 'mulberry'
***Morinda* spp.** *M. citrifolia* L.; *M. umbellate* L.; *M. longiflora* G. Don.	Rubiaceae	Madder	**Soranjidiol**; **Morindone**; **Rubiadin-1-methyl ehter**; Alizarin-1-methyl ether; Rubiadin-1-methyl ether; Alizarin; Rubiadin; Damnacanthol; Damnacanthal; Nordamnacanthal; Xanthopurpurin; Morindanigrin	Schweppe & Winter (1997)	
***Morus* spp.**	Moraceae	Mulberry	Rutin; Morin; Mulberin; Cyclomulberin; Mulberrochromin	Boyle (1731) cf. Harley (1982) 118	Probably erroneous (see text)
***Oldenlandia* spp.** *O. umbellate* L.	Rubiaceae	Madder	**Anthragallol-1,3-dimethyl ether**; **Anthragallol-1,2-dimethyl ether**; **Alizarin**; 2-Hydroxyanthraquinone; Alizarin-1-methyl ether; Hystazarin monoethyl ether	Schweppe & Winter (1997)	
***Parietaria* spp.** *P. judaica* L.; *P. officinalis* L.	Urticaceae	Nettle		Bosch (1961), used as green in Islamic bookbinding	Doubtful use
***Pentaglottis* spp.** *P. sempervirens* (L.) L. Bailey	Boriginaceae	Alkanet			
***Petroselinum* spp.** e.g. *P. crispum* (Miller) A.W. Hill	Umbelliferae	Parsley	**Apigenin-7-apiosylglucoside**; Apigenin-7-D-glucoside; Apigenin-7-glucoaposide; Luteolin-7-apiosylglucoside; Luteolin-7-diglucoside	Turner (1998) from Alcherius/Lebegue (Merrifield (1849)	
***Phellodendron* spp.** *P. amurense* Rupr.	Rutaceae	Amur cork tree	**Phellodendrine**; **Magnoflorine**; **Berberine**; **Palmatine**; Candidaeine; Jatrorrhizine	Shimoyama *et al.* (1995) in *Ukiyo-e* prints; Gibbs & Seddon (1998)	
***Polygonum* spp.** *P. tinctorium* Ait.	Polygonaceae	Knotgrass	Indigotin, indirubin	Shimoyama *et al.* (1995) in *Ukiyo-e* prints	
***Quercus* spp**. *Q. velutina* Lam.	Fagaceae	Quercitron	Quercetin [Quercetagetin; Flavine]	Harley (1982) 114–115	Formerly *Q. tinctoria*
***Reseda* spp.** *R. luteola* L.	Resedaceae	Weld	Luteolin		
***Rhamnus* spp.** *R. cathartica L.; R. frangula* L.; *R. saxatilis* Jacq.	Rhamnaceae	Persian-/Avignon-/ Yellow-berries	**Rhamnetin**; **Quercetin**; **Emodin** [Rhamnocathartin; Rhamnotannic acid; Rhamnin; Frangulin] Rhein; Physicon, Palmitin A,B,C,D; Sennidin	Widely recognised (e.g. Harley, 1982)	Syn. (*R. saxatilis*): *R. infectoria*
***Rheum* spp.** *R. palmatum*	Polygonaceae	Rhubarb	Chrysophanol; Chrysophanic acid; Emodin; Aloe-emodin		
***Rubia* spp.** *R. tinctorum* L.; *R. peregrina* L.; *R. cordifolia* L.; *R. sikkimensis* Kurz; *R. iberica* C. Koch; *R. akane* Nakai	Rubiaceae	Madder	**Alizarin**; **Pseudopurpurin**; **Purpurin**; **Munjistin**; **Ibericin**; **Lucidin**; Xanthopurpurin; Rubiadin; 2-Hydroxyanthraquinone; Xanthopurpurin-3-methyl ether; Alizarin-1-methyl ether; Anthragallol; Nordamnacanthal; 1,4-Dihydroxy-6-methylanthraquinone; 1-Hydroxy-2-methylanthrraquinone; 1,8-dihydroxy-3-methyl-6-methoxyanthraquinone	Widely recognised (e.g. Schweppe & Winter, 1997)	
***Ruta* spp.** *R. graveolens* L.	Rutaceae	Rue	Rutin; Quercitin	Turner (1998) from Alcherius/Lebegue (Merrifield (1849)	
***Sambucus* spp.** *S. ebulus* L.	Caprifoliaceae (Sambucaceae/ Adoxaceae)	Turnsol?	Cyanidin glycoside	*Nurnberg Kunstbuch*; cf. Ploss (1962)	

***Sanguisorba* spp.** *S. officinalis* L.	Rosaceae	Cremisi		Merrifield (1849)	
***Serratula* spp.** S. tinctoria L.	Asteraceae	Sawwort	Apigenin; Luteolin		
***Sophora* spp.** *S. japonica* L.	Leguminosae	Sophora yellow	Kaempferol	Yü (1955)	
***Sorghum* spp.** *S. vulgare* Pers. var. Durra Hubbard et Rehd.	Graminaceae	'Sorgho red' (obsc.)	Pelargonidin; Petunidin; Cyanidin		
***Tragopogon* spp.** *T. pratensis* L.	Compositae	Plant: 'Yellow goat's beard' Pigment: Giallo santo		Merrifield (1849) 708	
***Uncaria* spp.** *U. gambier* (Hunt.) Roxb.	Rubiaceae	Japan earth; Pale catechu	**D-Catechin**; Gambirtannin; Oxogambirtannin; Dihydrogambirtannin; Quercetin; Rutin	Harley (1982) 156	
***Vaccinium* spp.** *V. mytillus* L.	Ericaceae	Bilberry	Delphinidin-, Cyanidin-, Petunidin- and Malvidin-glycosides	Boltz (1549); *Nurnberg Kunstbuch* (?)	
***Viola* spp.**	Violaceae	Violet	Violanin	BM MS Additional 23080, cf. Harley (1982) 86	
***Xanthorrhoea* spp.** *X. australis*; *X. johnsonii*; *X. preissii*	Xanthorrhoeaceae	Grass tree	**Pinocembrin**; Xanthorrhoein; Xanthorrhoeol; Hydroxyxanthorrhoein	Mills & White (1994)	
LICHENS:[3]					
***Bryoria* spp.** *B. capillaris*; *B. glabra*; *B. trichodes*	Parmeliaceae			Moerman (1998)	Burnt to produce a black
***Evernia* spp.** *E. prunastri*	Parmeliaceae			Wallert (1986)	
***Lasallia* spp.** L. *papulosa* (Ach.) Llano; L. *pustulata* (L.) Mérat	Umbilicareaceae	Cudbear	Cryophoric acid; Orceinol		
***Ochrolechia* spp.** *O. parella* (L.) Massal; *O. tartarea (*L.) Massal.	Pertusariaceae	Archil; Cudbear; Litmus; Orseille; Parelle		Diadick Casselman (2002)	Formerly *Lecanora* Also given as *Ochrolechia* spp.
***Parmelia* spp.** *P. omphalodes* (L.) Ach.; *P. saxatilis* (L.) Ach.	Parmeliaceae		β-Orceinol; Atranorine; Salazinic acid; Labaric acid	Wallert (1986)	
***Physcia* spp.**	Physciaceae				
***Roccella* spp.** *R. babingtonii*; *R. fimbrata*; *R. fuciformis* (L.) D.C.; *R. montagnei* Bél.; *R. phycopsis* (Ach.); *R. tinctoria*	Roccellacae	Litmus; Orchil	**Orceinol**; **Erythrine**;	Harley (1982) 63–64	
***Variolaria* spp.** *V. orcina*				Wallert (1986)	
***Xanthoria* spp.** *X. elegans*	Teloschistaceae			Moerman (1998)	
SCALE INSECTS:[4]					
***Dactylopius* spp.** *D. coccus* Costa; *D. confusus* Cockerell; *D. ceylonicus* Green; *D. tomentosus* Lam.	Dactylophidae	Cochineal	Carminic acid	Schweppe & Roosen-Runge (1986)	
***Kermes* spp.** *K. ballotae*; *K. vermilio Planch*	Kermesidae	Kermes	Kermesic acid [Flavokermesic acid]	Schweppe & Roosen-Runge (1986); Sanyova & Wouters (1994)	*K. vermilio* is the primary source
***Kermococcus* spp.** *K. illicis* L.	Kermesidae	Kermes	Kermesic acid	Schweppe & Roosen-Runge (1986)	Mentioned in literature; however, a dyestuff cannot be derived from it
***Kerria* spp.** *K. (Kerria) lacca lacca* Kerr; *K. (Kerria) chinensis chinensis* Mahdihassan	**Kerriidae**	Lac	Laccaic acids A–B [Laccaic acids C–E]	Schweppe & Roosen-Runge (1986); Cardon (1990)	*K. lacca* also known historically as *Coccus laccae*, *Laccifer lacca* and *Tachardia lacca*
***Porphyrophora* spp.** *P. polonica* L. & *P. hameli* Brandt	Margarodidae	Polish cochineal (*P. polonica*) Armenian/Ararat cochineal (*P. hamelii*)	**Carminic acid** [Kermesic acid; Flavokermesic acid]	Schweppe & Roosen-Runge (1986)	

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[3] Current lichen terminology is complex, but has been checked where possible from the following sources. *Parmelia* spp.: Farr, E.R.; Hale, B.W.; DePriest, P.T. *Parmeliaceae*: *Searchable List of Names in the Parmelioid Genera (Lichens)* (1999) (http://persoon.si.edu/parmeliaceae/; May 2003).

[4] Current terminology for the scale insects has been checked using ScaleNet (http://www.sel.barc.usda.gov/scalenet/scalenet.htm; May 2003). Additional information on historical terminology has been provided by Dr Yair Ben-Dov, Department of Entomology, Agricultural Research Organisation, Israel (pers. comm., 14/06/02).

(*continued*)

B: COMMON NATURAL ORGANIC COMPOSITES (*continued*)

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GENUS/SPECIES	FAMILY	TRIVIAL DYE NAME	DYE COMPONENTS[1]	LITERATURE	NOTES
SHELLFISH:[5]					
***Bolinus* spp.** *B. brandaris* (Linnaeus, 1758)	Muricidae: Muricinae	'Tyrian purple'	Bromoindigo compounds		Formerly *Murex (phyllonotus) brandaris*
***Nucella* spp.** *N. lapillus* (Linnaeus, 1758)	Muricidae: Thaidinae	'Tyrian purple'	**Bromoindigo compounds**		
***Phyllonotus* spp.** *P. trunculus* (Linnaeus, 1758)	Muricidae: Muricinae	'Tyrian purple'	**Bromoindigo compounds**		Formerly *Murex (phyllonotus) trunculus*
***Purpura* spp.** *P. patula* (Linnaeus, 1758); *P. p. pansa* (Gould, 1853); *P. aperta* (Blainville, 1832)	Muricidae: Thaidinae	'Tyrian purple'	**Bromoindigo compounds**		Some confusion over *P. patula/pansa* species differentiation. Also, some sources give this as *Policopurpura*.
***Rapana* spp.** *R. venosa* (Valenciennes, 1846); *R. bezoar* (Linnaeus, 1767)	Muricidae: Rapaninae	'Kaimurasaki' (='Tyrian purple')	**Bromoindigo compounds**		Syn. (for *R. venosa*): *R. thomasiana* (Crosse, 1861)
***Stramonita* spp.** *S. haemastoma* (Linnaeus, 1766)	Muricidae: Thaidinae	'Tyrian purple'	**Bromoindigo compounds**		
***Thais (Reisha)* spp.** *T. bronii* (Dunker, 1860); *T. clavigera* (Kuster, 1860)	Muricidae: Thaidinae	'Kaimurasaki' (='Tyrian purple')	**Bromoindigo compounds**		
SEPIA:					
***Sepia* spp**. *S. officinalis* L. (probably also *S. o. hierredda* and *S. o. vermicularata*)	**Sepiidae**	Sepia	Eumelanin		

B.II. CARBON-BASED BLACKS, HYDROCARBONS, ETC.

α	β	γ	δ	GROUP	SUB-GROUP	NAME	VARIANT FORM	LITERATURE	NOTES
CARBON-BASED BLACKS:									
1	1	2	1	**Carbon**	*Chars*	Bark chars	From *Betula* spp. ('Swedish black')	Winter (1983)	
1	1	2	2	**Carbon**	*Chars*	Bark chars	From *Quercus suber/occidentalis* spp. ('Cork')	Winter (1983)	
1	1	2	3	**Carbon**	*Chars*	Fruitstone chars	*et. seq.* From various fruit kernels, e.g. of peach (*Prunus persica*), cherry (*Prunus* spp.), date (*Phoenix dactylifera*), almond (*Prunus amygdalus*), walnut (*Juglans* spp.), coconut (*Cocos nucifera*) *etc.*	Winter (1983)	
1	1	2	4	**Carbon**	*Chars*	Paper chars		Winter (1983)	
1	1	2	5	**Carbon**	*Chars*	Wood chars	From *Fagus* spp. (notably *F. sylvatica*)	Winter (1983)	
1	1	2	6	**Carbon**	*Chars*	Wood chars	From *Vitis* spp.	Winter (1983)	
1	1	3	1	**Carbon**	*Cokes*	Bone cokes	*et. seq.* From various bone sources	Winter (1983)	
1	1	3	2	**Carbon**	*Cokes*	Ivory cokes	*et. seq.* From various ivory sources		
1	1	3	3	**Carbon**	*Cokes*	Yeast cokes	From *Saccharomyces* spp.	Winter (1983)	
1	1	4	1	**Carbon**	*Flame carbons*	From hydrocarbon sources	'Acetylene black'	Winter (1983)	
1	1	4	2	**Carbon**	*Flame carbons*	From hydrocarbon sources	'Channel black'	Winter (1983)	
1	1	4	3	**Carbon**	*Flame carbons*	From hydrocarbon sources	'Lamp black'	Winter (1983)	
1	1	4	4	**Carbon**	*Flame carbons*	From combustion of wood	'Chinese ink' (from combustion of pine wood (*Pinus* and other spp.))	Winter (1983)	
1	1	4	5	**Carbon**	*Flame carbons*	From combustion of wood	Bistre (e.g. from *Fagus* spp.)	Winter (1983)	

HYDROCARBONS:						
2	1	1		**Hydrocarbons**	*Coals*	Peat
2	1	2		**Hydrocarbons**	*Coals*	Coal
2	2	1		**Hydrocarbons**	*Coals*	Lignite
2	2	2		**Hydrocarbons**	*Coals*	Anthracites
2	2	3		**Hydrocarbons**	*Coals*	Humic earths
2	2	4		**Hydrocarbons**	*Synthetics*	Petrochemical derived asphalts
2	2	5		**Hydrocarbons**	*Bitumen*	Naturally derived asphalts
2	2	6		**Hydrocarbons**	*Amber*	Amber
TANNINS:						
3	1	1		**Tannins**[6]	*Gallotannins*	Catechin

B.III. EARTH PIGMENTS

α	β	γ	δ	GROUP	SUB-GROUP	NAME	VARIANT FORM	LITERATURE	NOTES
EARTH PIGMENTS:									
1	1	1		**Earth pigments**	*Ochres*			Widely recognised	
1	2	1		**Earth pigments**	*Siennas*			Widely recognised	
1	3	1		**Earth pigments**	*Umbers*			Widely recognised	
1	4	1		**Earth pigments**	*Wads*			[See this volume]	
1	5	1		**Earth pigments**	*Green earths*			Widely recognised. Rev.: Grissom (1986)	

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[5] Current terminology for the Muricidae has been checked using the following sources: Abbott, R. Tucker *American Seashells: The Marine Mollusks of the Atlantic and Pacific Coasts of North America,* second ed., Van Nostrand Reinhold, New York (1974); Higo, Shun'ichi; Callomon, Paul; Goto, Yoshihiro, *Catalogue and Bibliography of the Marine Shell-bearing Mollusca of Japan,* Elle Scientific Publications, Japan (1999); Radwin, G.E.; D'Attilio, A., *Murex shells of the world. An illustrated guide to the Muricidae,* Stanford University Press, Stanford (1976); Sabelli, Bruno; Giannuzzi-Savelli, Riccardo; Bedulli, Daniele *Catalogo*, *Annotato dei Molluschi Marini del Mediterraneo* (*Annotated Check-list of Mediterranean Marine Mollusks*), 3 vols, Libreria Naturalistica Bolognese, Bologna (1990).

[6] So-called 'condensed' tannins are now generally classed as flavonoids (proanthocyanidins).

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