Ancient Egyptian Materials and Technology

This is a study of the procurement and processing of raw materials employed by the ancient Egyptians over the five millennia of the Predynastic and Pharaonic periods (*c.* 5500–332 BC). During this time, there were not only variations in the preferred materials for particular types of artefacts, but also gradual processes of technological change, and the industries of the Chalcolithic period were complemented and sometimes superseded by the innovations of the Bronze and Iron Ages. Among the topics covered are stone quarrying, the building of temples and pyramids, techniques for preserving meat, fish and poultry, the making of glass and faience, the baking of bread, the brewing of beers, the preparation of soils and perfumes and the mummification of humans and animals. Each chapter has been written by one or more specialists, drawing not only on conventional Egyptological skills but also on expertise in the natural sciences as applied to archaeological data.

Paul Nicholson is senior lecturer in Archaeology at Cardiff University. His publications include *Egyptian Faience and Glass* (1993), and (with Ian Shaw) *The British Museum Dictionary of Ancient Egypt* (1995). **Ian Shaw** is a lecturer at the Institute of Archaeology, University College London. He is the author of *Egyptian Warfare and Weapons* (1991) and *Timeline of the Ancient World* (1993), and editor (with Robert Jameson) of *A Dictionary of Archaeology* (1999).

Ancient Egyptian Materials and Technology

Edited by
Paul T. Nicholson
and Ian Shaw

CAMBRIDGE
UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge CB2 1RP, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge, CB2 2RU, United Kingdom http://www.cup.cam.ac.uk
40 West 20th Street, New York, NY 10011–4211, USA http://www.cup.org
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

First published 2000

Printed in the United Kingdom at the University Press, Cambridge

Typeset in Scala 10/12pt [VN]

A catalogue record for this book is available from the British Library

Library of Congress Cataloguing in Publication data

Ancient Egyptian Materials and Technology / edited by Paul T. Nicholson and Ian Shaw.
p. cm.
Includes index.
ISBN 0 521 45257 0 (hardback)
1. Building materials – Egypt. 2. Technology – Egypt. 3. Egypt – civilization – To 332 BC. 4. Raw materials – Egypt. I. Nicholson, Paul T. II. Shaw, Ian, 1961–
TA402.5.E3A53 1999
620.1'1'0932 – dc21 98–3434 CIP

ISBN 0 521 45257 0 hardback

Contents

Part I: Inorganic materials

Part II: Organic materials

Part III: Food technology

Figures

Tables

Contributors

BARBARA ASTON, Daly City, California
NEIL BOULTON, Department of Archaeological Sciences, University of Bradford
JANINE D. BOURRIAU, The McDonald Institute for Archaeological Research, University of Cambridge
ROSALIE DAVID, The Manchester Museum, University of Manchester
JOANN FLETCHER, Manchester, UK
ROWENA GALE, Royal Botanic Gardens at Kew
PETER GASSON, Royal Botanic Gardens at Kew
JAMES HARRELL, Department of Geology, University of Toledo, Ohio
JULIAN HENDERSON, Department of Archaeology, University of Nottingham
NIGEL HEPPER, Richmond, Surrey
CARL HERON, Department of Archaeological Sciences, University of Bradford
SALIMA IKRAM, American University in Cairo
BARRY KEMP, The McDonald Institute for Archaeological Research, University of Cambridge
GEOFFREY KILLEN, St Ives, Cambridgeshire
OLGA KRZYSZKOWSKA, Institute of Classical Studies, University of London
BRIDGET LEACH, Department of Conservation, British Museum
LORNA LEE, Department of Conservation, British Museum
ROBERT MORKOT, DCAE, University of Exeter
MARY ANNE MURRAY, Institute of Archaeology, University College London
RICHARD NEWMAN, Research Laboratory, Museum of Fine Arts, Boston, Massachusetts
PAUL T. NICHOLSON, School of History and Archaeology, Cardiff University
JACK OGDEN, Cambridge
EDGAR PELTENBURG, Department of Archaeology, University of Edinburgh
JACKE PHILLIPS, The McDonald Institute for Archaeological Research, University of Cambridge
STEPHEN QUIRKE, Petrie Museum, University College, London
PAMELA ROSE, The McDonald Institute for Archaeologic Research, University of Cambridge
DELWEN SAMUEL, Institute of Archaeology, University College London
MARGARET SERPICO, Wainwright Fellow, London
IAN SHAW, Institute of Archaeology, University College London
JOHN TAIT, Institute of Archaeology, University College London
CAROL VAN DRIEL-MURRAY, Instituut voor Pre- en Protohistorische Archeologie, Amsterdam
GILLIAN VOGELSANG-EASTWOOD, Department of Egyptology, University of Leiden
WILHEMINA WENDRICH, University of Leiden
RAYMOND WHITE, London

Note

It should be noted that the order of authors given at the st of each chapter does not necessarily indicate seniority authorship. Where authors have collaborated extensiv on chapters and it is not possible to identify particul sections, the authors generally appear in alphabetical ord Where sections are readily identifiable, the authors usua appear in order of their individual contributions, and the are further marked in the text.

Acknowledgements

We would like to thank Sal and Barbie Garfi for their redrawing and inking of most of the line-drawings and Ian Dennis for his work on supplementary illustrations. Nigel Hepper kindly allowed us to reproduce many of his botanical drawings. We are also indebted to Stuart Laidlaw and the Photographic Department of the Institute of Archaeology, University College London, for producing many of the photographs throughout the book. We would like to thank the Committee of the Egypt Exploration Society, the Trustees of the British Museum, London and the Trustees of the Metropolitan Museum of Art, New York for their generous permission to use a number of line-drawings and photographs from their publications. We are grateful to numerous other colleagues and institutes for permission to use other illustrations and those are credited in the list of figures. We are extremely grateful to the Humanities Research Board of the British Academy for a grant covering the cost of preparation and inking of line-drawings. We are indebted to New Hall, Cambridge University, the Institute of Archaeology, University College London (Shaw), the Department of Archaeology, University of Sheffield, and the School of History and Archaeology, Cardiff University (Nicholson) for their support during the time that the book was being produced. We are grateful to Jane Collins of the School of History and Archaeology for her assistance in printing out the typescript. We would particularly like to thank Professor Keith Branigan of the University of Sheffield, and his wife Mrs N. Branigan and Dr Caroline M. Jackson, for their assistance in holding a seminar for the contributors at the Department of Archaeology in January, 1994. We are most grateful to Dr Jessica Kuper, Archaeology and Anthropology Editor at CUP, for her patience and advice during the commissioning and preparation of the book. Finally, we would like to thank the contributors for taking part in the project and for their unstinting efforts over several years.

Paul T. Nicholson and Ian Shaw
August, 1999

Abbreviations

AGSE	*Annals of the Geological Survey of Egypt*
AIHV	Association Internationale pour l'Histoire du Verre
AJA	*American Journal of Archaeology*
AO	*Archiv für Orientforschung*
ARCE	The American Research Center in Egypt
ASAE	*Annales du Service des Antiquités de l'Egypte, Cairo*
a.s.l.	above sea level
BAR	*British Archaeological Reports*
BES	*Bulletin of the Egyptological Seminar*
BIE	*Bulletin de l'Institut d'Egypte, Cairo*
BIFAO	*Bulletin de l'Institut Français d'Archéologie Orientale*
BL	*Bulletin de Liaison*
BM	British Museum
BMFA	*Bulletin of the Museum of Fine Arts, Boston*
BMMA	*Bulletin of the Metropolitan Museum of Art*
BMP	British Museum Press
BMQ	*British Museum Quarterly*
BSA	*Bulletin of Sumerian Agriculture*
BSAE	British School of Archaeology in Egypt
BSFE	*Bulletin de la Société Française d'Egyptologie*
CAJ	*Cambridge Archaeological Journal*
CBA	Council for British Archaeology
CCE	*Cahiers de la Céramique Egyptienne*
CdE	*Chronique d'Egypte*
CNRS	Centre National de la Recherche Scientifique (France)
CNWS	Centre for Non-Western Studies, Leiden
CRIPEL	*Cahiers de Recherche de l'Institut de Papyrologie et Egyptologie de Lille*
CSJ	*Cairo Scientific Journal*
CUP	Cambridge University Press
DAIK	Deutsches Archäologisches Instituts, Abteilung Kairo
DE	*Discussions in Egyptology*
DOG	Deutsche Orient-Gesellschaft
EA	*Egyptian Archaeology*
EEF	Egypt Exploration Fund
EES	Egypt Exploration Society
ERA	Egyptian Research Account
ET	*Etudes et Travaux*
FAO	Food and Agriculture Organisation
GM	*Göttinger Miszellen*
GSE	Geological Survey of Egypt
HMSO	Her Majesty's Stationery Office
IEJ	*Israel Exploration Journal*
IFAO	Institut Français d'Archéologie Orientale
JAOS	*Journal of the American Oriental Society*
JARCE	*Journal of the American Research Center in Egypt Boston*
JAS	*Journal of Archaeological Science*
JEA	*Journal of Egyptian Archaeology*
JNES	*Journal of Near Eastern Studies*
Kêmi	*Kêmi: Revue de Philologie et d'Archéologie Egyptiennes et Coptes, Paris*
Kew	Museum of the Royal Botanic Gardens at Kew
KPI	Kegan Paul International
LÄ	*Lexikon der Ägyptologie*
MDAIK	*Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Kairo*
MFA	Museum of Fine Arts, Boston
MMA	Metropolitan Museum of Art, New York
OIP	Oriental Institute Press, University of Chicago
OMRO	Oudheidkundige Mededeelingen uit het Rijksmuseum van Oudheden te Leiden
OUP	Oxford University Press
PEQ	*Palestine Exploration Quarterly*
PPS	*Proceedings of the Prehistoric Society*
PSBA	*Proceedings of the Society of Biblical Archaeology, London*
RdE	*Revue d'Egyptologie*
RT	*Receuil de Travaux Rélatifs à la Philologie et à l'Archéologie Egyptiennes et Assyriennes*
SAE	Service des Antiquités de l'Egypte, Cairo
SAK	*Studien zur Altägyptischen Kultur, Hamburg*
WA	*World Archaeology*
ZÄS	*Zeitschrift für Ägyptische Sprache und Altertumskunde, Leipzig and Berlin*

1. Introduction

PAUL T. NICHOLSON AND IAN SHAW

During the last two decades the nature of Egyptology has gradually changed, and new technological and socio-economic questions are now being asked of the archaeological data. With this change has come a renewed interest in many aspects of Egyptian materials and technology. So great has this interest become that it is no longer possible for the traditional Egyptologist alone to tackle such questions as the composition of materials, provenance and the means by which different types of artefacts were produced. Many new analytical techniques have been developed and applied and the results are now available, providing a great deal more precision than was previously imaginable.

These new approaches currently being adopted in Egyptology are reflected in the structure of this book. Each chapter has been written by one or more specialists, drawing not only on conventional Egyptological skills but also on expertise in the natural sciences as applied to archaeological data. All the contributors are either involved in recent field projects in Egypt (not least the important Egypt Exploration Society excavations at Amarna and Memphis), or at the forefront of laboratory-based analysis of archaeological materials.

It will be obvious to many readers that this volume has been inspired by Alfred Lucas's classic work *Ancient Egyptian Materials and Industries*, which has long served Egyptologists as a standard work of reference. First published in 1926, Lucas's book has been revised several times, most recently in 1962, when it was updated, primarily in terms of its bibliographic references, by J.R. Harris (see Lucas 1926, 1934, 1948, 1962). Even the fourth edition still primarily reflects the analytical work of a single individual employing the necessarily limited equipment available in the 1920s (see Brunton 1947 and Gilberg 1997 for assessments of the life and work of Alfred Lucas). Despite the importance of Lucas's work, it has long been recognised that a more modern multi-disciplinary treatment is required, giving not only the result of analyses and technological investigations but also explicitly stating the means by which they were obtained.

While this current volume will not 'replace' Lucas's work, and is not intended as a revised edition of it, it is hoped that it will provide a free-standing source of reference on its subject. Thanks to modern analytical techniques, some chapters will almost entirely supersede those provided by Lucas, while others will provide updated approaches concentrating on new data and new questions. The study of ancient Egyptian material and technology is a vibrant one, with research being conducted by many scholars all over the world (a situation reflected in the diverse list of contributors here). This is quite unlike the situation in the 1920s and 1930s, when most Egyptologists were interested in linguistic and architectural questions, and Lucas was one of a relatively small group of scholars concerned with the analysis of artefacts. As a result of the new vigour of the subject, this volume will perhaps not enjoy the very long currency of Lucas's work but will, we hope, provide a solid basis for future work.

Here we are fundamentally concerned with the study of the procurement and processing of the raw materials employed by the ancient Egyptians. The book is not meant to be an art historical typology of objects produced in any given material, nor a text book on the scientific analysis of such materials. Each chapter is intended to provide an overview of the current state of research on the material in question. In some cases, this is not possible, either because modern research on certain materials (e.g. leather, meat, basketry) has only just begun or because the quantity of data has become so great in recent years that the most meaningful approaches tend to be those that focus on particular problems (as in the case of the chapters on pottery, stone and mummies).

The basic structure and coverage of the book were finalised at a seminar involving most of the contributors in 1994, when it was agreed that chapters on food technology should be included, as these represent a fruitful area of research that has almost entirely emerged in the years since Lucas's time. The contributors have made every effort to provide explicit information on the scientific analyses conducted, since the lack of such detail has been an increasing problem in judging the value of some of Lucas's conclusions. It was also agreed that some indication of the workings and limitations of relevant analytical techniques was necessary so that non-specialists would be better able to judge the results of earlier and current research.

References

Brunton, G. 1947. Alfred Lucas, 1867–1945. *ASAE*, 47: 1–6.
Gilberg, M. 1997. Alfred Lucas: Egypt's Sherlock Holmes. *Journal of the American Institute for Conservation*, 36: 31–48.
Lucas, A. 1926. *Ancient Egyptian Materials and Industries*. 1st e
London: Longman, Green and Co.
1934. *Ancient Egyptian Materials and Industries*. 2nd edn. L
don: Edward Arnold.
1948. *Ancient Egyptian Materials and Industries*. 3rd edn. L
don: Edward Arnold.
1962. *Ancient Egyptian Materials and Industries*. 4th edn., r
J.R. Harris. London: Edward Arnold.

Part I.
Inorganic materials

2. Stone

BARBARA G. ASTON, JAMES A. HARRELL AND IAN SHAW

Introduction

Although most recent research into Egyptian quarrying has tended to concentrate on the large-scale procurement of limestone, sandstone and granite in the Pharaonic period, the exploitation of stone in the Nile valley can be traced back at least as early as 40,000 BP, when the Middle Palaeolithic inhabitants of Middle Egypt were quarrying and working cobbles of chert along the limestone terraces on either side of the Nile (Vermeersch *et al.* 1990). Most of the earliest sites simply consist of pits and trenches for surface extraction, but Site 4 at Nazlet Khater, dating to the Upper Palaeolithic and radiocarbon-dated to 35,000– 30,000 BP, includes vertical shafts and underground galleries which provide a foretaste of the fully developed quarrying techniques of the Pharaonic period. The early chert quarriers used gazelle and hartebeest horns as picks, and several of these were found in the subterranean galleries at Nazlat Khater 4. The excavations also revealed many large hammerstones, apparently used for rougher quarrying.

The prehistoric quarrying of such materials as chert was essentially a question of small communities procuring locally available materials in order to produce the tools and weapons necessary for their immediate needs. Although there is evidence to show that such *ad hoc*, small-scale quarrying and mining continued to be undertaken to some extent in the Pharaonic period, in the case of certain materials (e.g. alabaster gypsum at Umm el-Sawwan, galena at Gebel Zeit and perhaps also New Kingdom procurement of travertine at Hatnub, see Kemp 1989: 191, 246–8; Castel and Soukiassian 1985, 1989; Shaw 1994: 111–14), such stones as granite, limestone and gneiss began to be exploited on a large scale for building, sculpture and stone-vessel carving. These large-scale expeditions differed in a number of ways from the quarrying undertaken by small groups of individuals: first they were official operations controlled either by the king or a local provincial governor, secondly they were often commemorated by the creation of rock-carvings and hieroglyphic inscriptions at the quarries themselves, and thirdly a new ideological and political element gradually emerged, whereby the king seems to have exercised a virtual monopoly on the quarrying and mining of many raw materials. The king was able to use this monopoly not only as a means of rewarding officials (by granting them blocks of freshly quarried stone to be carved into sarcophagi or false doors, for instance, see Lichtheim 1973: 18–23) but also as a means of gaining favour with the god's. The reliefs and inscriptions in the treasuries of some of the major Greco-Roman temples indicate that the god's shrine was intended to be a microcosm of the universe, including all the essential vegetable and mineral components (see Aufrère 1991: 731–48, 809–20; Shaw 1998: 253–6). There was therefore not only a practical impetus for mining and quarrying in terms of the acquisition of materials necessary for the creation of temples, tombs and funerary equipment, but also an ideological spur, in that the king was obliged to 'recreate' the cosmos by gathering together its fundamental elements and placing them in the temple treasuries (e.g. the use of black basalt to create temple pavements symbolising the fertile silt of the Nile valley).

The first section of this chapter discusses the general evidence for quarrying, primary processing and transportation of different types of stone in the Pharaonic period. In the second section, specific quarries of the Pharaonic, Ptolemaic and Roman periods are described in the form of an alphabetically arranged list of the various stone types. The third section comprises a short summary of research into ancient Egyptian stone-working technology. The fourth section summarises the current state of the subject in terms of techniques of identification and provenancing of stone.

Quarrying, *in situ* processing and transportation

The creation of the first tombs incorporating stone masonry, in the Early Dynastic élite cemeteries at Abydos and Saqqara (*c.* 3000–2649 BC), was the stimulus for a rapid growth in the quarrying of building stone such as limestone and granite. At the same time, the growing need for tombs to be filled with stone vessels symbolising the wealth of the deceased led to the large-scale procurement of such materials as travertine, alabaster gypsum, limestone breccia, basalt, limestone, granite, granodiorite, greywacke, sandstone, siltstone, andesite porphyry, serpentinite, tuff and anorthosite gneiss, which were the preferred materials for funerary vessels in the Early Dynastic period. It is clear from the jewellery found in some of the First-Dynasty tombs (particularly that of King Djer at Abydos) that such gemstones as turquoise and cornelian were also being heavily exploited in the first two Dynasties (and probably considerably earlier, see Beit-Arieh 1980), along with the various precious metals obtained from the Eastern Desert, the Sinai peninsula and Nubia.

During the Old Kingdom (*c.* 2649–2152 BC), the construction of numerous royal pyramid complexes in the Memphite necropolis resulted in an unprecedented demand for stone which probably peaked in the Fourth Dynasty, when the largest pyramids were built. Lehner (1985: 109) calculates that 9 million tons of limestone alone were quarried between the reigns of Sneferu and Menkaura for the pyramid complexes at Dahshur and Giza. It was also at this time that many other stones began to be exploited on a large scale for buildings: granite and granodiorite from Aswan, basalt from the Fayum and travertine from Middle Egypt.

Soft-stone quarrying methods

The vast majority of quarrying during the Pharaonic period was concerned with the procurement of the two principal 'soft stones' used for ceremonial, religious or funerary structures: limestone and sandstone (the quarries for which are discussed below). Limestone, virtually all deposits of which are found at numerous locations between Cairo and Esna, was exploited from the end of the Early Dynastic period until the Eighteenth Dynasty (after which its importance as a building stone went into decline). Sandstone, on the other hand, is found in Upper Egypt, from Esna down to Sudan, and was used in the south from the Eleventh Dynasty onwards. Most of the important surviving temples of the period between the Eighteenth Dynasty and the Roman period were constructed from sandstone.

Outcrops of limestone and sandstone most suitable for quarrying were those having a uniform colouration and fine texture, at least moderate hardness and thick layers with widely spaced vertical fractures. The ancient quarrymen would identify a single rock layer (or series of layers) with the requisite properties and then quarry it at one or more places along the margins of the Nile valley, wherever it was best developed. In many cases it was the quality of the rock rather than its accessibility that dictated where a quarry was located. This is evident from the fact that many
ancient quarries are found on the upper slopes of hills
escarpments rather than at their base, where similar
lower quality rock occurs.

Blocks of sandstone and limestone were extracted by
following means, more than one of which might so
times be combined in one quarry:

(1) large open excavations;
(2) the removal of the vertical faces or horizontal top
cliffs; and
(3) the excavation of deep adits and galleries (usuall
order to reach the best quality rock).

All three of these methods were used for limestone
travertine. However, with the exception of some Mi
Kingdom galleries in part of the Gebel el-Silsila sandst
quarry, all sandstone and hardstone quarries were 'op
cut' (i.e. not of the gallery type).

The open-cut process generally comprised a numbe
stages, beginning with the removal of surface material s
as sand or rubble. The next step usually consisted of
marking of the cleaned surface either with painted line
sequences of chisel-cut indentations in order to indi
where the rows of blocks were to be cut out (each separa
from the next by a trench ranging from at least 20 to 60
in width, depending on the sizes of the blocks). Th
trenches were then excavated to a depth which was usu
at least 30 cm below the bases of the blocks, thus leav
rows of rock stumps, as in the case of the limestone qu
beside the Fourth-Dynasty pyramid of Khafra at Giza.

In the case of limestone and travertine, the remova
blocks from a vertical cliff face was sometimes the
stage in a process of deeper gallery-style extraction (
Owen and Kemp 1994 for a discussion of the comn
ground between the excavation of rock-tombs and quar
at Amarna), usually when the better quality stone
covered by an upper layer of poorer quality material.
initial face would be scaled by a series of steps cut into
outer face of the rock. The workers would then carve o
corridor along the ceiling of the gallery, thus allowing th
to cut down behind the front row of blocks, detaching r
of blocks from the top downwards, gradually moving ba
wards deeper into the gallery.

Hard-stone quarrying methods

Of all the hard stones available in Pharaonic Egypt, g
ite and granodiorite were the only ones that were used
building purposes on anything like the scale of limest
and sandstone. The granite quarries at Aswan, which w
exploited from the First Dynasty onwards, are the o
hard-stone quarries that have been studied in any de
(e.g. Clarke and Engelbach 1930; Röder 1965; Arn
1991: 36–40; see Fig. 2.3), although there have been
cent detailed studies of both quartzite and gneiss qua
ing (see Klemm *et al.* 1984 and Stross *et al.* 1988

quartzite, and Harrell and Brown 1994 for gneiss). On the basis of surviving buildings and other monuments, Röder (1965) estimates that 45,000 cubic metres of stone were removed from the Aswan quarries in the Old Kingdom, when it seems likely that the loose boulders spread across the surface would have been exploited (Reisner 1931: 71). It was in the New Kingdom, however, that the largest quantities of granite seem to have been quarried, including numerous Eighteenth- and Nineteenth-Dynasty colossal statues and obelisks.

Undoubtedly the most important source of knowledge on granite quarrying is the so-called 'unfinished obelisk', which is located in the northern quarries (a few kilometres to the southeast of the centre of modern Aswan; see Fig. 2.4) and probably dates to the 18th Dynasty (see Engelbach 1922; Habachi 1960; Arnold 1991: 37–9). Work on this obelisk, nearly forty-two metres in length, was abandoned at a relatively late stage in the process of its extraction, when significant cracking became apparent. After removing the weathered upper layers of the granite, a trench was excavated, thus marking out the shape of the obelisk, still attached to the bedrock. The surrounding trench has a width of about 0.75 metres and is divided into a series of 0.6–metre-wide working areas (marked out by vertical red lines down the side of the trench), which would have been able to accommodate as many as fifty workmen around the obelisk at any one time. It is clear from the surviving marks made by the quarry-overseers on quarry-faces at Aswan, that the depth of each trench was regularly assessed by lowering a cubit rod into it and marking the top of the rod with a triangle. Once the trench had reached the necessary depth, the workers would gradually undercut the block, a process which was just beginning in the case of the unfinished obelisk. Finally, in order to move the quarried obelisk from its matrix, one end would have to be quarried out completely, thus allowing the obelisk to be pushed horizontally out (a considerably easier task than attempting to pull it vertically upwards out of the hole).

Quarrying tools

There is some uncertainty as to the kinds of tools used for the quarrying of soft stones during the Pharaonic period (see Arnold 1991: 33). The tool marks preserved on quarry walls suggest that some form of pointed pick or axe was used during the Old and Middle Kingdoms, followed by the use of a mallet-driven pointed chisel from the Eighteenth Dynasty onwards (Klemm 1988). In the case of a small number of blocks, a very large stone chisel seems to have been used, judging from the presence of 2.5 cm-wide grooves (see Arnold 1987: pls. 9d and 33b). R. and D. Klemm argue that the majority of the tool marks were made by soft copper chisels in the Old and Middle Kingdoms and harder copper or bronze chisels from the New Kingdom onwards (with the characteristic patterns possibly allowing specific chronological phases to be identified, e.g. a herringbone sequence of marks in the Eighteenth Dynasty). There appear, however, to be at least two problems with the Klemms' proposed sequence of copper tools: firstly the actual surviving chisels (albeit found at construction sites rather than quarries) tend to have a broad, flat cutting edge rather than a point, and secondly the harder forms of copper alloy were already available in the Old and Middle Kingdoms (see Chapter 6, this volume). Chert was also used for stone-working (for further discussion see section on the uses of chert below).

The question of the types of tools used for the extraction of granite and other hard stones is equally controversial. On the basis of long sequences of rectangular wedge holes at the Aswan quarries (see Fig. 2.5), it was once assumed that the granite was removed by inserting wetted wooden wedges into the holes and levering the blocks away from the bedrock. There are now two fundamental objections to this theory: first, that wooden wedges, even when expanded by soaking them in water, would almost certainly not have been strong enough to fracture the granite (although for an extremely laborious but successful attempt see Zuber 1956: 202), and secondly, that the wedge holes have never been dated any earlier than the Ptolemaic period, by which time iron wedges would have been available (Röder 1965). Judging from various studies of the quarries at Aswan (Arnold 1991: 37–9; Aston 1994: 15–18, fig. 6; Engelbach 1922, 1923; Klemm and Klemm 1993: 305–53; Zuber 1956) and the implications of experimental projects (Stocks 1986a, 1986b; Zuber 1956), the actual process of extraction in the Pharaonic period seems to have involved the excavation of open-cut quarries, using hammerstones (e.g. dolerite) to gradually remove the stone from the surface downwards.

There are at least three other instances of extraction marks left by pounders in Egyptian quarries. In the quartzite quarry at Gebel Gulab (on the west bank at Aswan), a broken obelisk inscribed with the name of the Nineteenth-Dynasty ruler Seti I survives *in situ* near the quarry-face from which it was extracted (see Habachi 1960: 225–32; see also Fig. 2.6). The quarry face shows definite traces of the use of stone pounders. The second instance is to be found at Qau el-Kebir, where Clarke and Engelbach (1930: 18) noted marks left by stone pounders in a limestone quarry characterised by unusually dense, hard rock. The third piece of evidence for extraction with pounders is a set of marks in the greywacke sandstone–siltstone quarry at Wadi Hammamat, which were photographed by Klemm and Klemm (1993: 414) and may well date to the Pharaonic period.

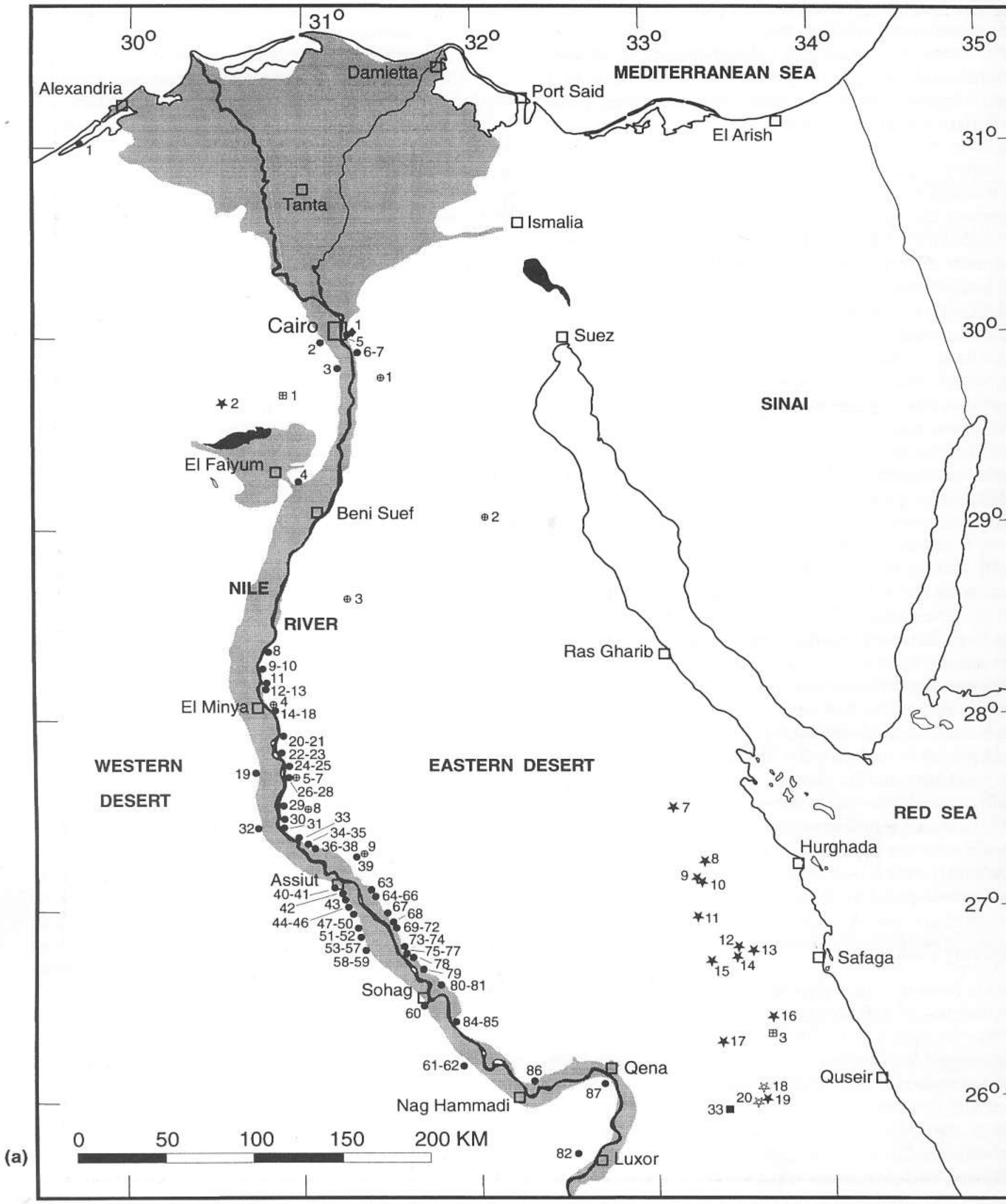
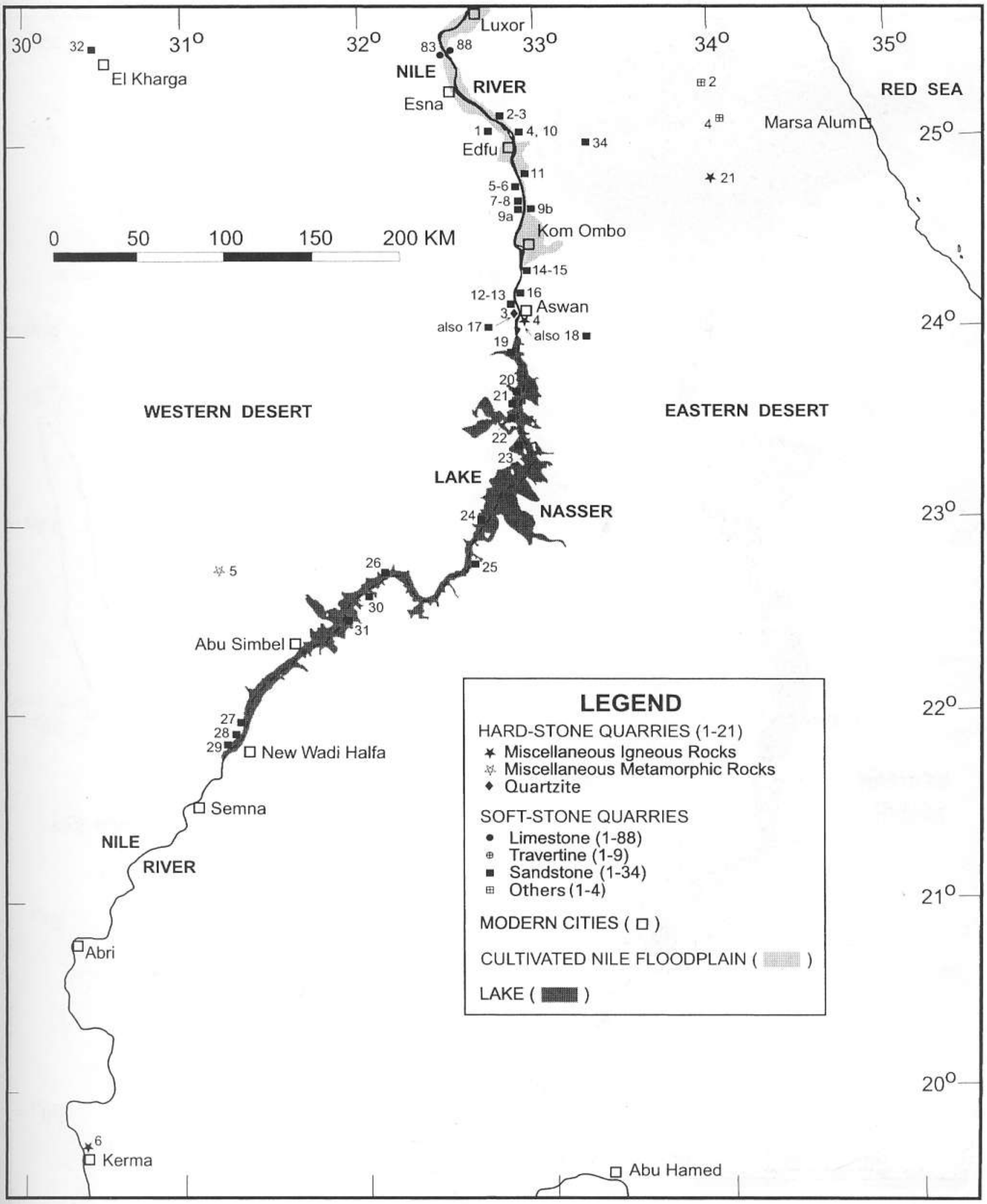


Figure 2.1 Map of Egypt from (a) Luxor to the Mediterranean and (b) Kerma to Luxor, showing locations of the known ancient hard-stone
soft-stone quarries.


30°
31°
32°
33°
34°
35°
32
El Kharga
83
88
Luxor
NILE
RIVER
Esna
2-3
1
4, 10
34
Edfu
11
5-6
7-8
9a
9b
Kom Ombo
14-15
12-13
16
Aswan
3
4
also 17
also 18
19
20
21
22
23
24
25
26
30
31
2
4
Marsa Alum
21
RED SEA
25°
24°
23°
22°
21°
20°
0 50 100 150 200 KM
WESTERN DESERT
EASTERN DESERT
LAKE
NASSER
5
Abu Simbel
27
28
29
New Wadi Halfa
Semna
NILE
RIVER
Abri
6
Kerma
Abu Hamed
LEGEND
HARD-STONE QUARRIES (1-21)
✶ Miscellaneous Igneous Rocks
✡ Miscellaneous Metamorphic Rocks
◆ Quartzite
SOFT-STONE QUARRIES
● Limestone (1-88)
⊕ Travertine (1-9)
■ Sandstone (1-34)
⊞ Others (1-4)
MODERN CITIES (□)
CULTIVATED NILE FLOODPLAIN (▨)
LAKE (■)

(b)

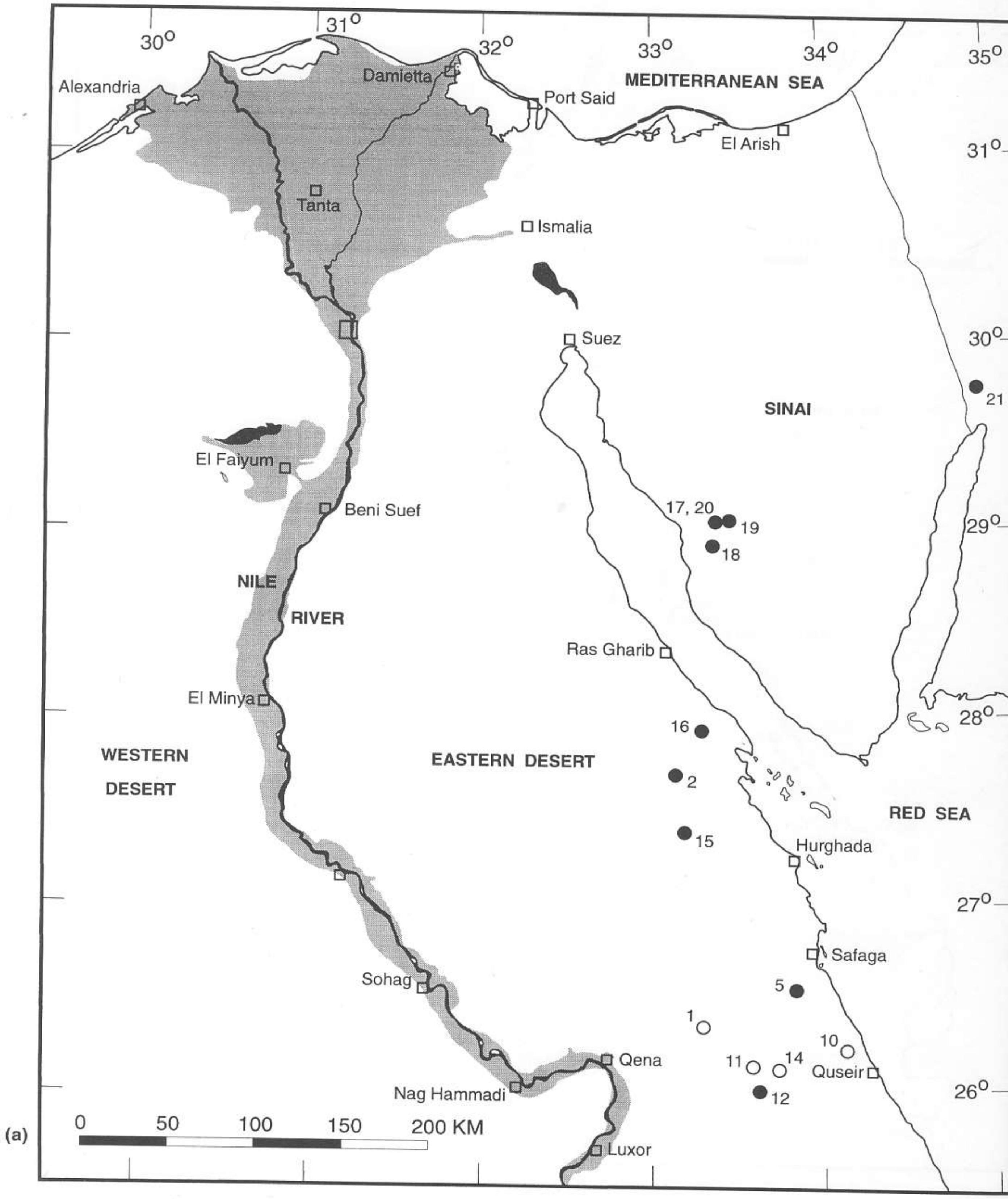
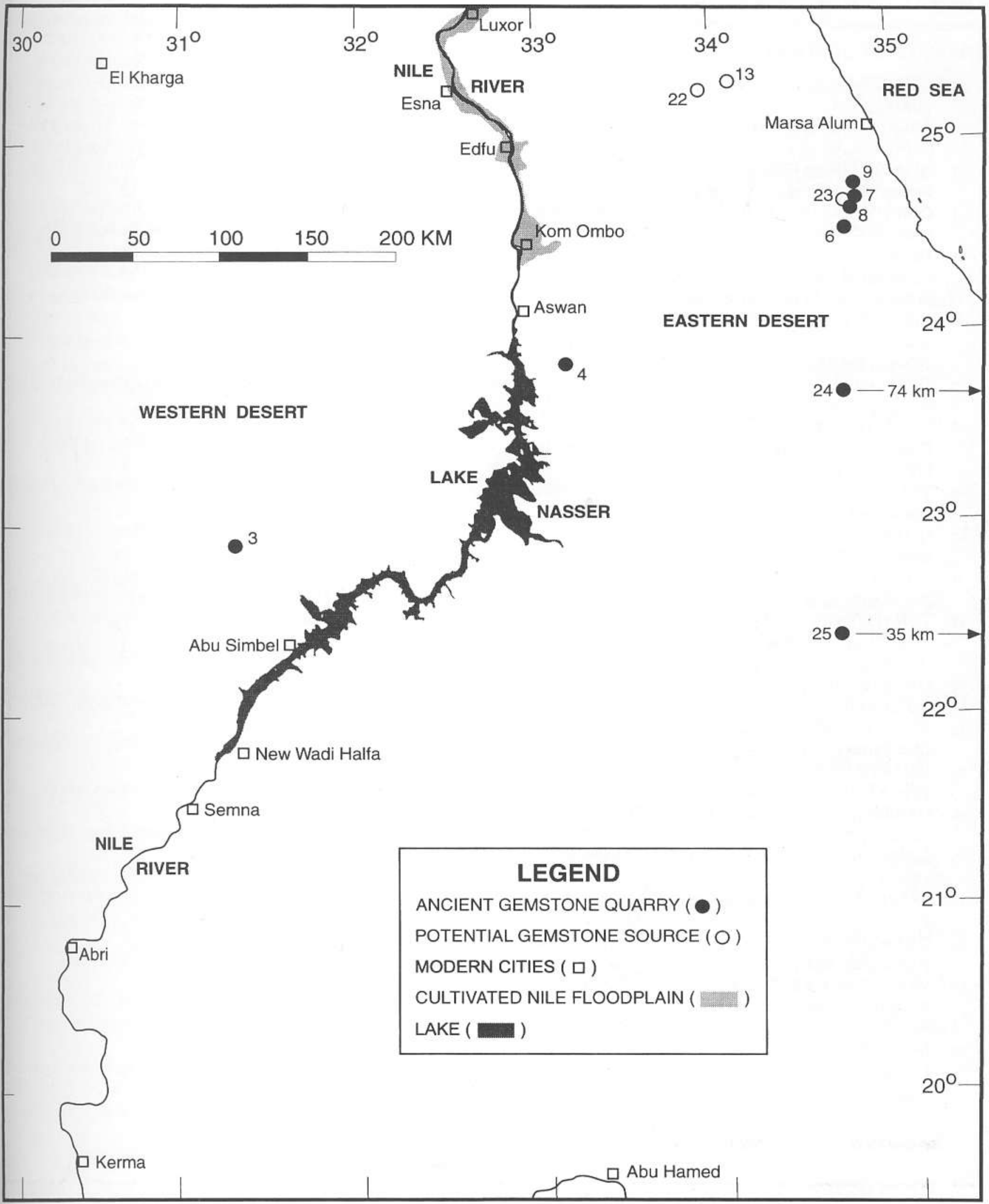


Figure 2.2 *Map of Egypt from (a) Luxor to the Mediterranean and (b) Kerma to Luxor, showing locations of quarries and probable ancie sources of gemstones.*


30°
31°
32°
33°
34°
35°
Luxor
El Kharga
NILE
RIVER
Esna
Edfu
Kom Ombo
Aswan
22
13
RED SEA
Marsa Alum
25°
9
23
7
8
6
0
50
100
150
200 KM
EASTERN DESERT
24°
4
24
74 km
WESTERN DESERT
LAKE
NASSER
23°
3
Abu Simbel
25
35 km
22°
New Wadi Halfa
Semna
NILE
RIVER
LEGEND
ANCIENT GEMSTONE QUARRY (●)
POTENTIAL GEMSTONE SOURCE (○)
MODERN CITIES (□)
CULTIVATED NILE FLOODPLAIN (▨)
LAKE (■)
21°
Abri
20°
Kerma
Abu Hamed

(b)

Table 2.1. *List of the ancient quarries shown in Figure 2.1*

HARD-STONE QUARRIES

1 QUARTZITE: at Gebel Ahmar, Cairo [30°3.15′N, 31°17.8′E] *(OK-R)*

2 BASALT: at Widan el-Faras on Gebel el-Qatrani, Fayum [29°39.6′N, 30°37.2′E] *(OK)*

3 QUARTZITE: on Gebels Gulab and Tingar near ruins of St. Simon's Monastery [24°6.4′N, 32°52.6′E] *(NK-R)*

4 GRANITE and GRANODIORITE: numerous localities between Aswan and Shellal [24°3.7′N, 32°53.7′E] *(ED-R)*

5 DIORITE-GABBRO and ANORTHOSITE GNEISSES: near Gebel el-Asr, Nubian Desert [22°47.5′N, 31°12.7′E] *(PD-OK, MK:12)*

6 GRANITE and GRANITE GNEISS: near Tumbos at the south end of the Third Cataract, Sudan [19°42.75′N, 30°23.25′E] *(NK?, L:25, NM)*

7 TUFF and TUFFACEOUS LIMESTONE: on Gebel Manzal el-Seyl near Wadi Mellaha [27°32.6′N, 33°7.8′E] *(ED)*

8 ANDESITE-DACITE PORPHYRY and GRANITE: on Gebel Dokhan and in Wadi Abu Maamel (Mons Porphyrites) [27°15.1′N, 33°18.0′E] *(R)*

9 TRACHYANDESITE PORPHYRY: in Wadi Umm Towat near Gebel Dokhan [27°10.2′N, 33°14.4′E] *(R)*

10 QUARTZ DIORITE: in Wadi Umm Balad near Gebel Dokhan [27°9.1′N, 33°16.75′E] *(R)*

11 DIORITE: in Wadi Umm Shegilat near Gebel Abu el-Hasan [26°56.6′N, 33°14.9′E] *(R)*

12 TONALITE GNEISS: between Wadis Abu Marakhat and Umm Diqal near Wadi Fatiri el-Bayda (Mons Claudianus) [26°48.55′N, 33°29.1′E] *(R)*

13 QUARTZ DIORITE: in Wadi Barud near Mons Claudianus [26°43.05′N, 33°34.5′E] *(R)*

14 TONALITE GNEISS: in Wadi Umm Huyut near Mons Claudianus [26°45.08′N, 33°27.95′E] *(R)*

15 QUARTZ DIORITE: in Wadi Fatiri el-Bayda [26°44.0′N, 33°19.3′E] *(R)*

16 GABBRO: in Wadi Umm Wikala near Wadi Semma [26°25.85′N, 33°39.7′E] *(R)*

17 GABBRO: near Wadi Maghrabiya [26°18.65′N, 33°23.7′E] *(R)*

18 SERPENTINITE: near Wadi Umm Esh [26°3.9′N, 33°6.6′E] *(R)*

19 GRANODIORITE: at Bir Umm Fawakhir near wadis Hammamat and el-Sid [26°0.65′N, 33°36.4′E] *(R)*

20 SILTSTONE, GREYWACKE and CONGLOMERATE: in Wadi Hammamat, Eastern Desert [25°59.4′N, 33°34.05′E] *(ED-R)*

21 DOLERITE PORPHYRY: in Rod el-Gamra near Gebel Urf Hamam [24°45.7′N, 33°59.3′E] *(L)*

SOFT-STONE QUARRIES

LIMESTONE

1 Numerous quarries on both sides of Mallahet Mariut n near Alexandria: between Abu Sir [30°56.8′N, 29°30.0′ and Burg el-Arab [30°55.0′N, 29°32.7′E] villages to the and Mex village [31°9.25′N, 29°50.6′E] to the NE *Pt-R)*

2 at Giza pyramids [29°58.5′N, 31°7.95′E] *(OK:4)*

3 near Saqqara pyramids: at Djoser pyramid [29°52.15′N, 31°12.9′E] *(OK:3)* and in the desert to the west [29°50.9 31°9.9′E] *(ED-OK?)*

4 near el-Lahun pyramid [29°14.2′N, 30°58.0′E] *(MK:12)*

5 at Zawyet Nasr on Gebel Mokattam near the Citadel [30°1.6′N, 31°16.2′E] *(OK/MK-NK?)*

6 on Gebel Tura near Tura village [29°56.0′N, 31°17.7′E] *(OK-R)*

7 on Gebel Hof near el-Masara village [29°54.9′N, 31°19. *(MK-R?)*

8 near el-Sawayta village [28°22.5′N, 30°48.0′E] *(NK-L?)*

9 at el-Babein tomb near Beni Khalid village [28°18.1′N, 30°44.9′E] *(NK:19–20)*

10 at and near Deir Gebel el-Tei village [28°16.9′N, 30°45. *(OK/MK?)*

11 near Tihna el-Gebel village and Akoris ruins [28°11.05′ 30°46.45′E] *(NK:20, L-R?)*

12 near el-Hawarta village [28°9.95′, 30°46.55′E] *(R?)*

13 near Nazlet Husein Ali village [28°8.4′N, 30°46.6′E] *(*

14 near Sawada village in Zawyet Sultan district [28°4.6′N 30°48.3′E] *(NK:18)*

15 near Nazlet Sultan Pasha village in Zawyet Sultan dist [28°4.1′N, 30°48.9′6E] *(NK-R)*

16 near Zawyet el-Amwat village in Zawyet Sultan district [28°3.2′N, 30°49.8′E] *(NK-R)*

17 in Wadi Sheikh Yasin in Zawyet Sultan district [28°3.1 30°50.7′E] *(NK-R)*

18 near Darb Tila Nufal track in Zawyet Sultan district [28°2.55′N, 30°51.25′E] *(NK-R?)*

19 near Dirwa village and Petosiris tomb [27°44.1′N, 30°4 *(Pt-R)*

20 near Nazlet el-Diyaba village [27°56.5′N, 30°52.85′E] *(R*

21 near Beni Hasan tombs [27°54.9′N, 30°52.2′E] *(OK/M*

22 near el-Sheikh Timay village [27°51.7′N, 30°50.7′E] *(OK/MK-Pt?)*

23 near el-Sheikh Ibada village and Antiopolis ruins [27°49.6′N, 30°52.2′E] *(MK-R?)*

24 near Deir Abu Hennis village [27°47.2′N, 30°54.8′E] *(*

25 in Wadi el-Nakla near Deir el-Bersha village [27°44.9′ 30°55.4′E] *(NK:18, L:30, Pt)*

26 near el-Bersha village [27°43.2′N, 30°53.7′E] *(age?)*

27 near el-Sheikh Said village [27°42.0′N, 30°53.3′E] *(NK:*

28 in Wadi Zebeida near Amarna ruins [27°40.9′N, 30°54 *(NK:18)*

29 opposite Dairut city on Gebel Abu Foda [27°33.6′N, 30°51.95′E] *(NK?)*

30 near Deir el-Quseir village on Gebel Abu Foda [27°29. 30°52.2′E] *(age?)*

Table 2.1. ***(cont.)***

31 in and near wadis Abu Helwa and Magberi on Gebel Abu Foda [27°25.3'6N, 30°52.7'E] *(OK/MK-NK?)*
32 near Meir village [27°26.0'N, 30°42.2'E?] *(OK/MK?)*
33 at and near Deir el-Amir Tadros monastery on Gebel Abu Foda [27°22.6'N, 30°57.8'E] *(OK/MK?, NK:19)*
34 at and near Deir Abu Mina monastery on Gebel el-Harrana [27°21.3'N, 31°0.9'E] *(age?)*
35 near el-Maabda village on Gebel el-Harrana [27°20.3'N, 31°1.9'E] *(age?)*
36 near Deir el-Gabrawi village on Gebel el-Tawila [27°20.3'N, 31°5.9'E] *(NK:19)*
37 on el-Ketf promontory on Gebel el-Harran [27°19.6'N, 31°2.8'E] *(NK:19)*
38 near Arab el-Atiat el-Bahariya village on Gebel el-Harrana [27°20.0'N, 31°3.9'E] *(Pt-R?)*
39 on Talet el-Hagar promontory near Wadi el-Asyut [27°17.45'N, 31°18.15'E] *(age?)*
40 below el-Izam monastery near Asyut city [27°9.2'N, 31°8.9'E] *(age?)*
41 between Asyut city and Drunka village [27°9.4'N, 31°10.4'E] *(OK/MK?)*
42 at and between el-Aldr Maryam and Sawiris monasteries near Deir Drunka village [27°6.2'N, 31°10.0'E] *(OK/MK?)*
43 near Deir Rifa village [27°4.55'N, 31°10.9'E] *(OK/MK-NK?)*
44 near Sidi Abu el-Haris tomb [27°2.7'N, 31°13.55'E] *(age?)*
45 between Sidi Abu el-Haris tomb and Deir el-Bileida ruins [27°2.3'N, 31°13.65'E] *(age?)*
46 at Deir el-Beleida ruins [27°1.95'N, 31°13.85'E] *(age?)*
47 near el-Balyza village [27°1.25'N, 31°14.2'E] *(age?)*
48 between el-Balyza and el-Abu Khurs village [27°0.4'N, 31°14.55'E] *(age?)*
49 between el-Abu Khurs and el-Zaraby villages [26°59.2'N, 31°14.7'E] *(age?)*
50 near el-Zaraby village [26°58.45'N, 31°15.1'E] *(OK/MK-NK?)*
51 at el-Adra Maryam monastery near Wadi Sarga and Deir el-Ganadla village [26°55.65'N, 31°16.8'E] *(OK/MK?)*
52 near el-Mashaya village [26°54.9'N, 31°17.2'E] *(age?)*
53 near el-Ghanayim Bahari village [26°53.4'N, 31°18.25'E] *(R?)*
54 near Sidi Mansur tomb [26°52.85'N, 31°18.65'E] *(age?)*
55 near el-Ghanayim Qibli village [26°52.15'N, 31°19.15'E] *(age?)*
56 near el-Aghana village [26°51.6'N, 31°14.7'E] *(age?)*
57 near el-Qarya Bil Diweir village [26°50.55'N, 31°19.9'E] *(age?)*
58 near Sid Ab Khiris tomb and Nazlet Imara village [26°47.05'N, 31°21.4'E] *(age?)*
59 near Nag el-Tawalib village [26°46.5'N, 31°22.45'E] *(age?)*
60 near Nag Hamad village and Athribis ruins [26°30.65'N, 31°39.55'E] *(Pt-R?)*
61 near el-Salmuni village and Abydos ruins [26°12.25'N, 31°52.55'E] *(MK-L?)*
62 in Wadi Naqb el-Salmuni near Abydos ruins [26°11.75'N, 31°51.95'E] *(MK-L?)*
63 near Wadi Emu [27°7.15'N, 31°21.35'E] *(age?)*
64 near el-Khawalid village [27°5.6'N, 31°23.2'E] *(age?)*
65 near el-Nazla el-Mustagidda village [27°4.65'6N, 31°23.65'6E] *(age?)*
66 between el-Nazla el-Mustagidda and Deir Tasa villages [27°3.8'N, 31°24.1'E] *(age)*
67 near el-Iqal Bahari village [26°59.55'N, 31°27.4'E] *(age?)*
68 near el-Baiyadiya village [26°57.55'N, 31°27.75'E] *(age?)*
69 near el-Iqal el-Qibi village [26°56.65'N, 31°28.75'E] *(R?)*
70 at el-Hammamiya village [26°56.25'N, 31°29.25'E] *(age?)*
71 between el-Hammamiya village and Antaeopolis ruins [26°55.45'N, 31°29.55'E] *(NK:18)*
72 at and near Qau el-Kebir/Antaeopolis ruins [26°55.5'N, 31°30.05'E] *(OK/MK-NK?, Pt-R)*
73 near el-Nawawra village [26°50.1'N, 31°32.1'E] *(age?)*
74 near el-Khazindariya village on Gebel el-Haridi [26°47.7'N, 31°32.45'E] *(NK:20)*
75 near Nazlet el-Haridi village on Gebel el-Haridi [26°46.35'N, 31°33.25'E] *(age?)*
76 near Abu el-Nasr village on Gebel el-Haridi [26°45.75'N, 31°33.85'E] *(Pt)*
77 between Abu el-Nasr and el-Galawiya villages on Gebel el-Haridi [26°45.75'N, 31°35.6'E] *(OK/MK?)*
78 near el-Galawiya village [26°45.6'N, 31°37.1'] *(age?)*
79 at Istabl Antar between el-Haradna and Urban Beni Wasil villages [26°42.8'N, 31°40.35'E] *(age?)*
80 near Qurnet Salamuni village [26°37.15'N, 31°45.3'E] *(age?)*
81 at el-Salamuni village [26°37.1'N, 31°45.75'E] *(NK?)*
82 near Wadi el-Muluk (Valley of the Kings) [25°44.85'N, 32°37.3'E] *(NK:18, L:26, R)*
83 near el-Ghrera village in Gebelein district (recently destroyed) [25°29.65'N, 32°28.1'E] *(MK – PT?)*
84 near Nag el-Ahaywa village [26°26.0'N, 31°50.3'E] *(age?)*
85 near Sidi Musa tomb on Gebel Tukh [26°24.9'N, 31°50.65'E] *(OK/MK-R?)*

Table 2.1. *(cont.)*

86 near Nag el-Buza village [26°5.75′N, 32°18.1′E] *(age)*
87 on Gebel el-Gir near Tentyris/Dendara ruins [26°6.3′N, 32°41.7′E] *(L:30-R?)*
88 near el-Dibabiya village [25°30.25′N, 32°31.3′E] *(NK:19, 3IP:21, R)*

TRAVERTINE

1 in Wadi Gerrawi near Helwan city [29°48.5′N, 31°27.4′E] *(OK:4)*
2 between Wadi Araba and Wadi Aseikhar [29°4.75′N, 32°3.1′E] *(R)*
3 in Wadi Umm Argub near wadis Muwathil and Sannur [28°39.0′N, 31°15.6′E ?] *(L?)*
4 numerous quarries in el-Qawatir area opposite el-Minya city [28°6.2′N, 30°49.4′E] *(OK/MK-NK?)*
5 in Wadi Barshawi near Amarna ruins [27°42.0′N, 30°56.3′E] *(MK-NK?)*
6 in Wadi el-Zebeida near Amarna ruins [27°41.4′N, 30°54.15′E] *(MK-NK?)*
7 near Wadi el-Zebeida and Amarna ruins [27°40.8′N, 30°55.8′E?] *(NK:19)*
8 at Hatnub near Amarna ruins [27°33.3′N, 31°1.3′E] *OK-4-6, 1IP, MK:12, NK:18)*
9 near Wadi el-Asyut [27°18.75′N, 31°20.7′E] *(NK:18)*

SANDSTONE

1 near Hierakonpolis ruins [25°4.4′N, 32°44.3′E] *(NK:R?)*
2 at el-Mahamid village near Elkab ruins [25°8.25′N, 32°46.8′E] *(NK?, Pt)*
3 at Ramesses II/Ptolemy IX temples near Elkab ruins [25°8.05′N, 32°48.95′E] *(NK:19, Pt)*
4 near el-Keijal village [25°4.3′N, 32°51.65′E] *(age?)*
5 between Nag el-Raqiein and Nag el-Hosch villages [24°44.6′N, 32°55.1′E] *(R?)*
6 at Nag el-Hosch village [24°44.2′N, 32°55.2′E] *(R)*
7 in Wadi el-Shatt el-Rigal [24°41.1′N, 32°55.2′E] *(MK, NK: 18)*
8 near Nag el-Hammam village [24°40.3′N, 32°55.4′E] *(MK-NK?)*
9 at Gebel el-Silsila – West Bank [24°39.1′N, 32°55.6′E *(NK)* and East Bank [24°38.4′N, 32°55.95′E] *(MK?, NK, Pt;R)*
10 near el-Kilh Sharq village [25°3.55′N, 32°52.7′E] *(Pt;R)*
11 at el-Bueib ruins near Wadi el-Sirag [24°48.6′N, 32°54.8′E] *(NK:18)*
12 near Nag el-Fuqani village and opposite el-Kattara village [24°12.4′N, 32°51.4′E] *(Pt)*
13 in Gharb Aswan distrit opposite Geziret Bahrif island [24°9.7′N, 32°52.05′E] *(age?)*
14 from Sidi el-Hasan tomb to Ezbet Ali Amer village in Gharb el-Gaafra district [24°21.4′N, 32°55.7′E] *(Pt-R?)*
15 from el-Hadedoon village to Sidi Abd el-Aziz tomb in Gharb el-Gaafra district [24°18.7′N, 32°54.7′E] *(Pt?)*
16 on Gebel el-Hammam near Khor Abu Subeira (destroyed) [24°13.6′N, 32°52.4′E] *(NK:18)*
17 at Gebel Qubbet el-Hawa opposite Aswan [24°6.05′N, 32°53.15′E] *(OK/MK?)*
18 near Aswan (destroyed) [24°3.7′N, 32°53.7′E] *(age?)*
19 near Dabod temple [23°53.8′N, 32°51.2′E] *(NM/Pt-R)*
20 near Qertassi temple [23°42.0′N, 32°53.1′E] *(Pt-R)*
21 near Tafa temple [23°27.9′N, 32°51.7′E] *(R)*
22 near site of Kalabsha temple [23°33.05′N, 32°51.8′E] *(P*
23 between Abu Hor and Merowa villages (may be Sabay Fm.) [somewhere between 23°29.0′N, 32°53.0′E and 23°26.0′N, 32°54.0′E] *(Pt-R?)*
24 near Qurta temple [23°2.5′N, 32°40.0′E] *(NK:18?, R?)*
25 near Agayba village in the Mitiq district [22°51.0′N, 32°33.5′E] *(age?)*
26 near Tumas village [22°45.1′N, 32°8.8′E] *(NK:18-19)*
27 opposite Gezira Dabarosa village, Sudan [21°57.0′N, 31°18.0′E] *(age?)*
28 near site of Buhen ruins, Sudan [21°53.0′N, 3 1°15.0′E] *MK:NK?)*
29 at Abd el-Qadir opposite Dorginarti island, Sudan [21°50.5′N, 31°14.0′E] *(NK?)*
30 near Qasr Ibrim ruins [22°38.9′N, 31°59.5′E] *(MK:12?, NK;R?)*
31 at Nag Deira in the Tusha East district [22°30.4'N, 31°53.5'E] *(NK?)*
32 on Gebel el-Teir in Kharga Oasis [25°31.0′N, 30°29.0′E *(L-R?)*
33 near el-Muweih ruins on Qift-Quseir road [25°56.7′N, 32°33.8′E] *(R)*
34 at Bir el-Kanayis temple in Wadi el-Kanayis on Edfu-M Alum road [25°0.25′N, 33°18.0′E] *(NK:19?, R)*

OTHER STONES

1 GYPSUM: at Umm el-Sawwan, northern Fayum [29°42.5′N, 30°53.0′E] *(ED-OK)*
2 MARBLE: at Gebel Rokham near Wadi Mia, Eastern Desert [25°17.95′N, 33°57.85′E] (*NK-R?*)
3 TALC SCHIST: in Wadi Saqiyah, Eastern Desert [26°19.7′N, 33°39.39′E] (*R*)
4 STEATITE: at Gebel Rod el-Barram, Eastern Desert [25°5.75′N, 34°4.25′E] (*R and earlier?*)

Notes on Locations and Dates: North latitude and east longitud are given in brackets for the centre of the quarry workings at each locality. Quarry dates are given in italics within parentheses. Most dates (those followed by?) are based on the type of tool marks found on the quarry walls (using the tentat chronology of R. and D. Klemm) and/or the age of nearby temples that may have been the destination of the stone. All other ages are based on inscriptions, datable antiquities and/ definite association with dated ruins. Abbreviations used: PD = Predynastic period, ED = Early Dynastic period, OK = Ol Kingdom, 1IP = First Intermediate Period, MK = Middle Kingdom, 2IP = Second Intermediate Period, NK = New Kingdom, 3IP = Third Intermediate Period, L = Late Period, Pt = Ptolemaic Period, NM = Napatan-Meroitic period and R = Roman Period. Numerals preceded by colons refer to dynasties. The "/" in the abbreviation OK/MK means "and/o and is an undifferentiated date based on tool marks. Hyphena abbreviations (e.g., "NK-R") indicate that the quarry was work during and between the periods reported. The dates reported here are based only on the surviving evidence and so it is possible that a given quarry may also have been worked earlie later than indicated.

Table 2.2. *List of gemstone sources and quarries shown in Figures 2.2*

1. AGATE, CORNELIAN, HAEMATITE and JASPER: at Wadi Abu Gerida [26°21′N, 33°18′E]
2. AMETHYST: at Wadi Abu Had [27°41′N, 33°9′E] *(PD–ED)*
3. AMETHYST and CORNELIAN: near Gebel el-Asr [22°54′N, 31°19′E] *(MK, R)*
4. AMETHYST: at Wadi el-Hudi [23°50′N, 33°10′E] *(MK)*
5. AMETHYST: at Gebel Abu Diyeiba, Safaga region [26°32′N, 33°50′E] *(R)*
6. BERYL and GARNET: at Wadi Gimal [24°31′N, 34°45′E] *(R)*
7. BERYL and GARNET: at Wadi Sikeit [24°40′N, 34°48′E] *(Pt–R)*
8. BERYL: at Wadi Nuqrus [24°37′N, 34°47′E] *(R)*
9. BERYL: at Gebel Zubara [24°45′N, 34°48′E] *(B–Is)*
10. CORNELIAN, HAEMATITE and JASPER: at Wadi Saga [26°13′N 34°08′E]
11. FLUORSPAR: at Umm Esh el-Zarga [26°08′N, 33°35′E]
12. FLUORSPAR: at Umm el-Fawakhir [26°02′N, 33°36′E] *(NK-R?)*
13. FLUORSPAR: at Gebel Ineigi [25°18′N, 34°07′E]
14. GARNET: at Gebel Mitiq [26°07′N, 33°44′E]
15. HAEMATITE: at Gebel Abu Marwat [27°23′N, 33°12′E] *(R)*
16. HAEMATITE: at Wadi Dib [27°55′N, 33°18′E] *(R)*
17. MALACHITE and TURQUOISE: at Bir Nasib [29°02′N, 33°24′E] *(MK–NK)*
18. MALACHITE and TURQUOISE: at Wadi Maghara [28°54′N, 33°22′E] *(ED–NK)*
19. MALACHITE and TURQUOISE: at Serabit el-Khadim [29°02′N, 33°28′E] *(MK–LP)*
20. MALACHITE and TURQUOISE: at Wadi Baʾba/Wadi Kharig [29°02′N, 33°25′E] *(OK-NK)*
21. MALACHITE: at Timna [29°45′N, 34°56′E] *(NK)*
22. MICROCLINE: at Wadi Higelig/Gebel Migif [25°16′N, 33°56′E]
23. MICROCLINE: at Abu Rushaid [24°38′N, 34°46′E]
24. PERIDOT: at St John's Island (Zabargad) [23°39′N, 36°10′E] *(Pt–R)*
25. SMOKY QUARTZ: at Romit [22°22′N, 35°45′E] *(R)*

Notes on Locations and Dates: North latitude and east latitude are given in brackets for the centre of the quarry workings or source at each locality. Quarry dates are given in italics in parentheses. Most dates are based on the presence of associated datable inscriptions or artefacts. Abbreviations used: PD = Predynastic period, ED = Early Dynastic period, OK = Old Kingdom, MK = Middle Kingdom, NK = New Kingdom, L = Late Period, Pt = Ptolemaic Period, R = Roman Period, B = Byzantine Period, Is = Islamic Period. Hyphenated abbreviations (e.g. NK–R) indicate that the quarry was worked during and between the periods reported. The dates reported here are based only on the surviving evidence and so it is possible that a given quarry may also have been worked earlier or later than indicated. If no date is given, then the site is a potential ancient source but no actual quarry workings have been found.

Processing of stone in situ

As far as stone blocks intended for building were concerned, the amount of processing that took place in the quarries themselves seems to have depended on the type of stone involved. The rough, freshly quarried blocks of soft stone, such as limestone and sandstone, were probably not dressed until they arrived at the storage area beside the construction site of the temple or funerary complex for which they were required. In the case of blocks of hard stone, such as granite or gneiss, however, a certain amount of stone-working may have taken place at the quarries themselves. Arnold (1991: 52) suggests that the skilled workers of hard stones may have been based almost entirely at the quarries themselves rather than the construction sites, leaving only the final polishing to be undertaken at the building itself. Against this view, however, it might be argued that such extensive stone-dressing at the quarries themselves would have resulted in unacceptable damage to the near-finished blocks as they were transported to the building site (and possible confusion on arrival at the latter). The study of mason's marks on stone blocks has, in recent years, begun to yield some important clues in terms of the links between the organisational and bureaucratic links between the quarrying and building processes (see Arnold 1990).

When stone was quarried for items of sculpture, the amount of *in situ* primary processing tended to vary from one quarry to another. One source of evidence for the extent to which items were carved in advance of transportation takes the form of a very small number of surviving depictions of the movement of statues, the best-known being the scene in the tomb of Thuthotep at Deir el-Bersha, showing a colossal statue of the deceased being dragged along by lines of workers pulling on ropes (Newberry 1894). The principal difficulty in interpreting such scenes, however, is the fact that Pharaonic artists often portrayed objects in their finished form even when they were clearly still incomplete – this is particularly evident from the many scenes in which objects are being manufactured in temple workshops. It is therefore uncertain as to whether Thuthotep's statue, for instance, was actually completely carved at the quarries, or simply shown in its finished state as an artistic convention. The archaeological evidence for some *in situ* carving of hard-stone items is fairly convincing, with the survival of near-complete colossal statues in the granite quarries on the east bank at Aswan, a quartzite obelisk of Seti I (to which even the final inscriptions had been added, see Habachi 1960) at Gebel Gulab and the granite gneiss statue of an unknown Twenty-fifth-Dynasty king in the Tumbos quarry (Dunham 1947).

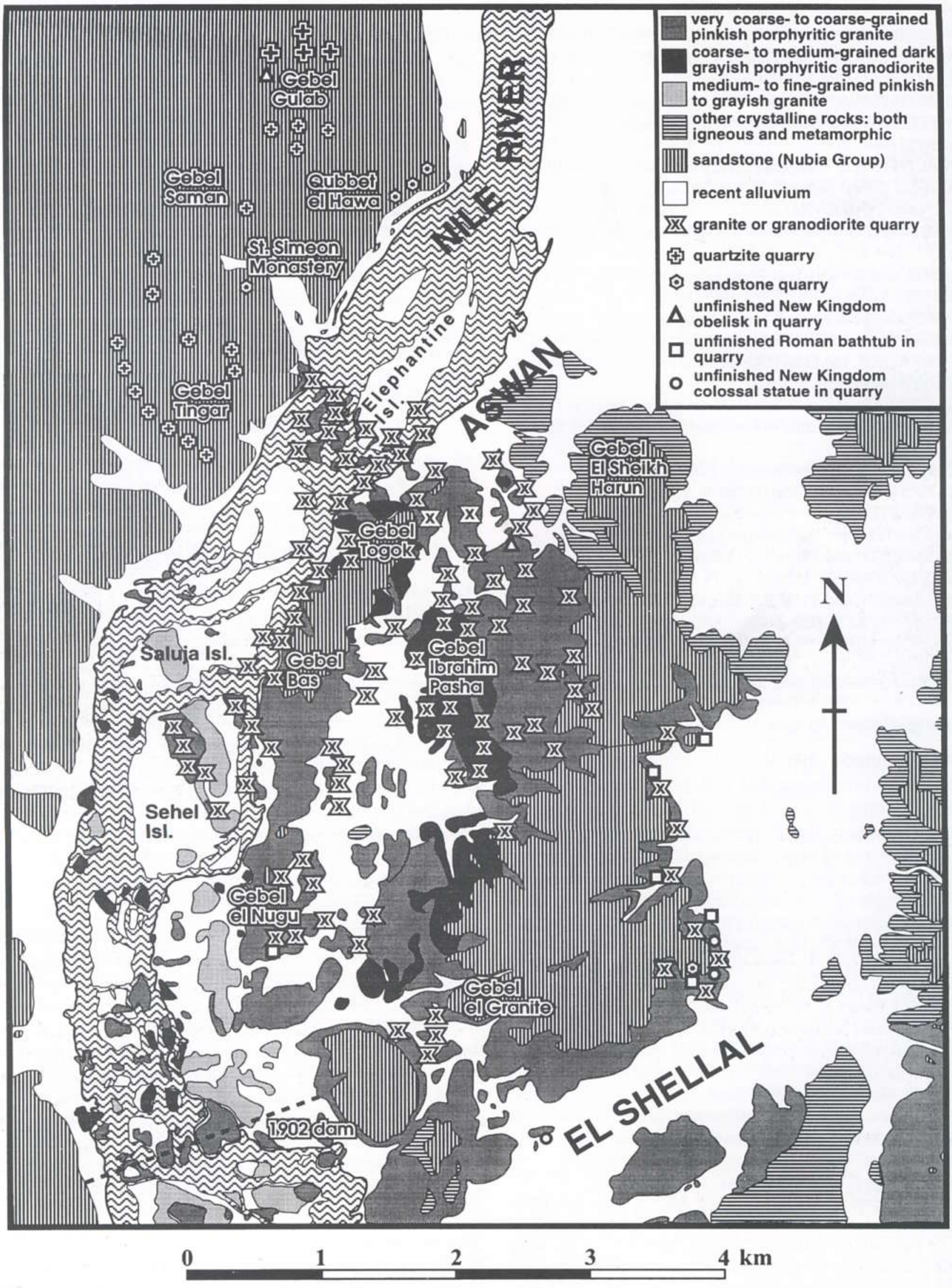


Figure 2.3 Generalised geological map of the Aswan area, showing locations of the granite, quartzite and sandstone quarries.

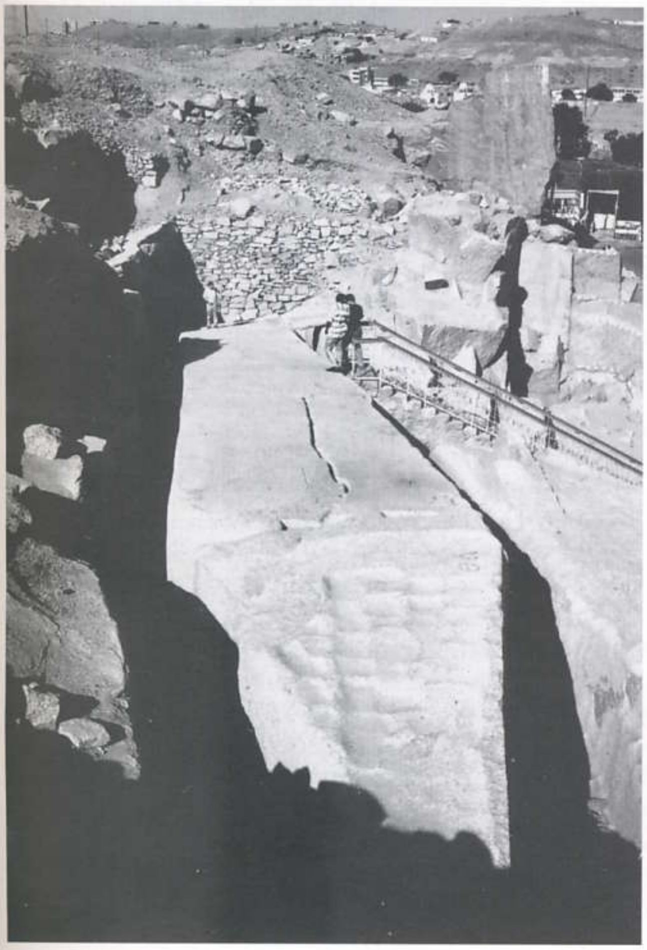


Figure 2.4 The Eighteenth-Dynasty 'unfinished obelisk' in the quarry for coarse pink granite at Aswan.

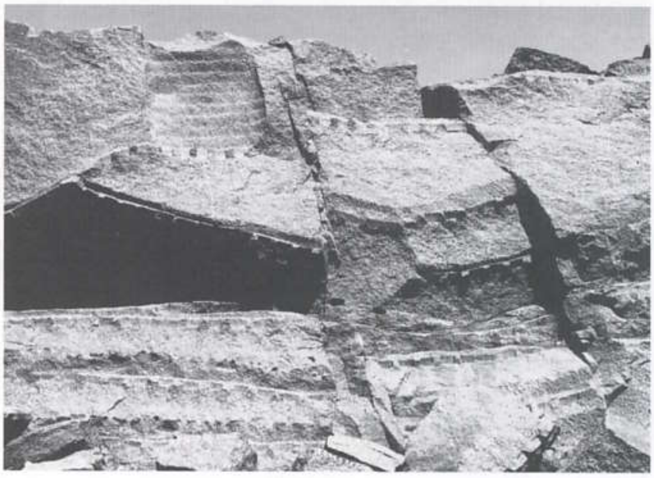


Figure 2.5 Greco-Roman extraction marks in the quarry for coarse pink granite at Aswan.

Figure 2.6 Quartzite quarry at Gebel Gulab near Aswan, from which the nearby unfinished obelisk of Seti I was extracted.

At the Umm el-Sawwan alabaster gypsum quarries, the survival of numerous unfinished vessels and fragments of chert drilling equipment show that the vast majority of the carving of vessels in this material took place *in situ*, before transportation across to the Memphite necropolis (see Caton-Thompson and Gardner 1934). At the Hatnub travertine quarries, on the other hand, there are relatively few surviving traces of stone-carving at the site, suggesting that the stone was largely carried back in the form of blocks and lumps, to be transformed into vessels and other items at the point of use.

Transportation of stone

The methods by which the quarried stone was transported varied a great deal depending on the locations of the quarries, the size of the blocks and the location of the building site or workshop for which they were intended. In the case of the construction of pyramid complexes and mastaba-tombs in the Memphite necropolis during the Old Kingdom, there were two basic sources of material: the local limestone, which formed the core of the pyramids and the walls of their mortuary and valley temples and the finer stones (e.g. Tura limestone and Aswan granite and granodiorite) which were used for more specialised purposes, such as the smooth outer casing of the pyramids, and usually had to be transported over considerable distances. As with most other raw materials, there were two basic methods of stone transportation in the Pharaonic period: river and land. Arnold (1991: 60) lists the major known examples of heavy monuments transported during the Pharaonic period.

River transport

The importance of water transport in the Egyptian economy as a whole is indicated by the fact that quarrying groups, like many other labour forces (such as the tomb-workers at Deir el-Medina), generally appear to have been organised according to a naval system, being divided in to 'crews' consisting of 'gangs' corresponding to different parts of boats (e.g. starboard and port). In the case of quarrying, this naval organisation must have owed something to the fact that the transportation of the quarried stone would have been as great a task as the procurement itself.

The evidence for the use of boats to transport stone blocks derives primarily from texts and paintings. The causeway in the Fifth-Dynasty royal funerary complex of Unas at Saqqara included depictions of columns (about 10.5 m in height) probably being brought from the Aswan quarries, presumably for Unas's mortuary temple. In addition, it has been suggested that the depictions of emaciated bedouin on Unas's and Sahura's causeways were intended to show the hardships endured in the course of quarrying the stone for the *bnbnt* (or pyramidion) which was placed on the apex of each of the pyramids (Hawass and Verner 1996). The wall-paintings in Old Kingdom private tombs often include depictions of transport-boats conveying a variety of raw materials, but only two tombs include scenes showing the transportation of stone: that of the 5th-Dynasty royal architect and builder Senedjemib Inty (tomb G2370 at Giza; Porter and Moss 1974–81: 85–7) and that of the 6th-Dynasty chief of the estate Ipy (to the west of the pyramid of Pepi I at Saqqara; Porter and Moss 1974–81: 671–2). The captions accompanying the transportation scene in the tomb of Senedjemib Inty indicate that his limestone sarcophagus was brought in a '*satj*-boat' from the Tura quarries, apparently taking about five days to make the journey (see Lepsius 1849–59, II: 76e; Sethe 1903: §66). The Sixth-Dynasty funerary autobiographies of Weni (at Abydos) and Sabni (at Aswan) both describe the building of '*wsḫt*-boats' (as well as '*s3ṯ*-boats' and 'eight-ribbed boats', in the case of Weni) which were specifically commissioned for the transportation of stone (Sethe 1903: §108). Weni also describes the excavation of five canals at Aswan, presumably in order to facilitate the movement of raw materials such as stone through the first cataract. Over 2,000 years later, the Roman historian Pliny described the digging of a canal in order to convey an obelisk to the Nile and then up to Alexandria.

Undoubtedly some of the most impressive instances of the transportation of stone date to the New Kingdom, including the depiction (in the cult temple of Hatshepsut at Deir el-Bahari) of boats carrying two obelisks from Aswan to Thebes. A number of texts from the New Kingdom also concern the movement of cargoes of stone up and down the Nile. Probably the most detailed account is provided by a set of four stone ostraca inscribed with hieratic accounts of the movement of a large number of blocks from the sandstone quarries at Gebel el-Silsila to the Ramesseum at Thebes in the reign of Rameses II (Kitchen 1991). One of these ostraca describes the delivery of sixty-four blocks carried by ten boats, each block weighing between 10,800 and 18,80 kilograms. The resultant calculation that each vessel wa carrying about six blocks, weighing a total of some 90,00 kilograms altogether, provides a useful indication of th average load carried by Pharaonic cargo-boats, allowin rough estimates of payloads to be made in the case of oth texts, such as the Twentieth-Dynasty Papyrus Amiens (se Gardiner 1941), which simply list the numbers of quarrie and boats despatched on quarrying expeditions. The siz of the blocks listed in the Ramesseum ostraca correspor quite well to the dimensions of the actual blocks making u the walls of the temple (Kitchen 1991: 86–8).

Land transport: road-building

The commemorative texts carved by the leaders of Egyptia mining and quarrying expeditions frequently mention th routes through the desert were 'opened up' for the worker and many surviving traces of specially constructed roa have been found in the surrounding areas of mines, qua ries and major structures. Indeed, Fischer (1991) ha identified various instances of the Old Kingdom titles 'ma ter of the roads' and 'official of the masters of the road both in the Memphite necropolis and in the mining are of the Wadi Hammamat and Wadi Abbad (in the Easte Desert), suggesting that the coordination and maintenan of land routes was a high priority for the Egyptian admini tration. In the case of the more extensive rock and miner sources, which were revisited year after year, considerab time and energy were clearly expended on road constru tion, the nature of each road being dictated mainly by th bulk and quantities of the materials, the character of th topography and the materials locally available for roa building (see Shaw forthcoming).

The Egyptians' official accounts of quarrying and mi ing expeditions (usually taking the form of inscriptions graffiti on the walls of the quarries themselves) routine emphasise the difficulties and hardships endured by th workmen, perhaps partly in order to increase the prestige the materials themselves, but, just as the surviving tex largely ignore such practical questions as the process building pyramids, so they rarely make reference either the building of roads or to the ways in which cargoes an stone blocks were conveyed along them. Some idea of th construction methods can, however, be deduced on th basis of a number of preserved stretches of ancient road causeways and ramps. The occasional survival of suc equipment as wooden rollers and sledges also helps to fi in the crucial gaps left by the texts.

The frequent use of wooden sledges to convey lar stone blocks or sculptures appears to be confirmed several funerary reliefs and paintings from different pe iods, such as those in the tomb of Thuthotep at Deir e Bersha (*c.* 1900 BC), mentioned above, which show a colo sal statue of the deceased being dragged along on a sled by groups of workmen, their path lubricated by wat poured in front of the runners (Newberry 1894: 16–26, pls. XII–XIX; Arnold 1991: 277–8; see also the section on flooring in Chapter 3, this volume). An early Eighteenth-Dynasty relief (*c.* 1500 BC) carved in the limestone quarries at Maʿsara, near Cairo, shows a block carried on a sledge pulled by oxen. There are occasional textual references to the use of donkeys – sometimes numbering several hundred – in the inscriptions describing quarrying expeditions to Sinai, the Tushka region and Wadi el-Hudi (Gardiner and Peet 1952: 11, 114; Simpson 1963: 52–3; Seyfried 1981: 219–20). Harrell and Bown (1995) suggest that, perhaps, blocks of freshly quarried basalt were conveyed on sledges along the paved road leading from the Gebel Qatrani outcrop by the use of a few wooden planks laid across the width of the road; these planks could have been repeatedly removed from the rear of the block and brought round to the front, thus avoiding the need for large quantities of wood.

The longest surviving Egyptian quarry 'road' is the eighty-kilometre route linking the diorite-gabbro and anorthosite gneiss quarries of the Old and Middle Kingdoms (*c.* 2649–1640 BC), near Gebel el-Asr, with the closest Nile embarkation point at modern Tushka. Rex Engelbach undertook two seasons of survey and excavation at the gneiss quarries in 1933 and 1938, including a close examination of the ancient road leading to Tushka (Engelbach 1938: 388–9; Murray 1939a: 108–11). More recently Harrell and Brown (1994) have produced a more detailed map of the area and examined the geological, aesthetic and religious significance of the type of gneiss exploited at the site. The Tushka road was not a paved or drystone structure, as the roads to Hatnub and Gebel Qatrani were; instead it appears to have been simply a cleared track. The road as a whole can be dated at least as early as the Middle Kingdom, on the basis of potsherds described by Engelbach (1938: 388).

Somewhat shorter than the Tushka road, but much better-preserved, is the road stretching for seventeen kilometres between the travertine quarries of Hatnub and the Nile valley at Amarna (Timme 1917; Shaw 1986: 195–8, 1987: 160–2). The course of the main Hatnub road, which incorporates two major causeways across *wadis*, probably dates back to the earliest years of the quarries' use in the middle of the third millennium BC. It is still relatively well-preserved, although there are increasing signs of deterioration through the use of heavy vehicles by modern travertine quarriers. The northwestern end of the road is last clearly visible near the site of Kom el-Nana, an Eighteenth-Dynasty temple complex at Amarna currently under excavation by the Egypt Exploration Society. It must originally have run further to the west, presumably ending in a small harbour, the remains of which would now be buried beneath the cultivated land adjacent to the modern village of Hagg Qandil. Inscriptions at Deir el-Bersha and Hatnub during the Middle Kingdom include references to a hilly region on the east bank of the Nile known as Tjerti, which may well have been the original name of the small settlement at the western terminus of the road (Kessler 1981: 98). In addition to the main Hatnub road there are several others in the surrounding region, leading to smaller travertine quarries in the vicinity. The Old Kingdom travertine quarries at Wadi Gerrawi, although less remote than those at Hatnub, are also said to have been linked with the Nile by a long road, some traces of which still survived in the late nineteenth century (Erman 1885: 623–4; for more recent work at Gerrawi see Dreyer and Jaritz 1983).

The Gebel Qatrani basalt quarries at the northern edge of the Fayum are linked with the Qasr el-Sagha region by a ten-kilometre road (Caton-Thompson and Gardner 1934: 136–7; Harrell and Bown 1995). This road has a nearly uniform width of 2.1 metres and is paved mainly with sandstone slabs and logs of fossil wood. Its characteristics relate to two basic factors: firstly, as with the main Hatnub road, local materials are used (i.e. sandstone slabs, as opposed to the limestone pebbles and boulders at Hatnub); secondly, the need for a built road, as opposed to a simple cleared track, must have been dictated by the bulk and quantity of the basalt blocks being quarried.

Another less substantial road, first documented by Petrie (1888: 33–6, pl. xxvi), stretches southwestwards for about twenty kilometres from the region immediately to the north of Dahshur, beside the Mastabat Faraʿun, probably as far as the northern edge of the Fayum (see also Goedicke 1962; Altenmüller and Moussa 1981; Moussa 1981). Like the 'northern' quarry road at Hatnub and the gneiss-quarriers' road northwest of Tushka, this Dahshur–Fayum route – the so-called 'Dahschurstrasse' – is said to be roughly twenty-three metres wide for most of its length. It is simply a cleared strip of ground rather than a causeway or paved structure. It may have served the Gebel el-Qatrani basalt quarries and/or the Umm el-Sawwan alabaster gypsum quarries during the Old Kingdom, but had begun to be used primarily as a military road by the Late Period (see Shaw forthcoming). Petrie also identified a second road, similar in appearance and dimensions to the 'Dahschurstrasse' and running due westwards from the same origin, apparently crossing 200 kilometres of desert to Bahariya or Siwa oases – presumably this too was a military road.

Local paths and ramps

As well as long-distance quarry roads there were numerous shorter paths and ramps constructed both at the beginning and end of the transportation process. Some have been preserved in the immediate vicinity of the structures for which the raw material was destined. Arnold (1991: 79–101) describes the employment of short drystone, mud-brick and timber roads in the construction of tombs and temples at such funerary sites as Saqqara, Sinki (southeast of Abydos), Dahshur, Meidum, Giza, Lisht and Lahun; he also discusses the evidence for the use of such tools as levers, rockers, sledges and rollers to facilitate the movement of heavy objects. Several of the Lahun Papyri, from the town associated with the pyramid of the Twelfth-Dynasty ruler Senusret II, document the dragging of stone blocks by groups of workers, presumably in the course of the construction of tombs and temples. These papyri include references to *ithw-ỉ'nru* (stone haulers) as a specialised group within the quarry workforce (Quirke 1990: 171).

Short roads and ramps were often constructed next to the mines and quarries, as at the Wadi el-Hudi amethyst mines, the Serabit el-Khadim turquoise mines, the Qau el-Kebir limestone quarries, the Gebel el-Asr gneiss quarries northwest of Tushka, and the quartzite and granite quarries at Aswan. There are also good surviving ramps in the sandstone quarries at Gebel el-Silsila. At Wadi el-Hudi, immediately to the northwest of the Twelfth-Dynasty amethyst-miners' fortress, there is a small strip of desert cleared of stones and gravel. This may be interpreted either as the southeastern terminus of a major road linking the mining area and the Aswan region (thirty-five kilometres to the northwest) or simply as a formal approach to the fortress (Shaw and Jameson 1993: 92, fig. 3).

The impressive surviving network of roads at Aswan was designed to transport the stone as efficiently as possible to the river-bank, both from the granite quarries on the east bank and the quartzite quarries to the west. On the east bank there was a long north–south road running through a *wadi* parallel to the river, which would have allowed the blocks from the granite quarries to be transported easily to suitable harbours. On the west bank there are numerous short drystone causeways (probably dating to the Greek and Roman periods, judging from the wedge-holes associated with many of the surrounding quarries) by means of which the blocks of quartzite could be dragged through the undulating and boulder-strewn terrain (Klemm and Klemm 1981: Abb. 44). The shorter stretches of road average three to four metres in width and ten to thirty centimetres in height. However, the most substantial surviving stretch of road, leading away southwestwards from the best-preserved ancient quarry-face on the west bank, is about eight metres wide and – at its highest point – about one and a half metres high, making it comparable in dimensions with the causeway near the main quarries at Hatnub.

Types of stone: sources and descriptions

The source identifications and petrological descriptions of building and sculptural stones and gemstones provided in this section are based largely on the field and laboratory work of the present authors. All of the hard-stone and travertine quarries were visited as were also most of those for limestone and sandstone, as well as the principal amethyst, beryl and turquoise mines. Quarry samples and numerous stone artefacts, mainly small vessels, were studied by thin-section petrography, and many of these were further analysed by x-ray fluorescence spectroscopy and other geochemical techniques (see discussion of analytical techniques, pp. 66–9). These petrological analys are supplemented by those of other investigators for t better-known quarries.

Table 2.3. *The Udden-Wentworth Scale (From Dietrich an Skinner 1979: 181, 189)*

Size (mm)	Fragment	Rock
>256	boulder	boulder conglomerate or brec
64–256	cobble	cobble conglomerate or brecc
2–64	pebble	pebble conglomerate or brecc
1–2	very coarse sand	sandstone
$\frac{1}{2}$–1	coarse sand	
$\frac{1}{4}$–$\frac{1}{2}$	medium sand	
$\frac{1}{8}$–$\frac{1}{4}$	fine sand	
$\frac{1}{16}$–$\frac{1}{8}$	very fine sand	
$\frac{1}{256}$–$\frac{1}{16}$	silt	siltstone
<1/256	clay	claystone, mudstone or shale

The petrological nomenclature used in this chapter that widely employed in North America and Europe (s Brown and Harrell 1991, for a review). For example, t mineralogical and textural classification recommended the International Union of Geological Sciences (IUGS) used for igneous rocks and igneous precursors of metamo phic rocks (Streckeisen 1973, 1979, see Fig. 2.7). Grain si for igneous and metamorphic rocks is characterised either aphanitic (grains not distinguishable without magn fication) or phaneritic (grains easily visible). The latter te

Table 2.4. *Mohs hardness scale (the absolute hardness measures used here are approximately equivalent to those cite in the Rosivale abrasion hardness test).*

Mohs hardness	Comparison mineral	Means of testing	Absolute hardness
1	Talc	Can be easily scratched with fingernail	0.03
2	Gypsum	Can be just scratched with fingernail	1.25
3	Calcite	Can be just scratched with copper coin	4.5
4	Fluorite	Can be easily scratched with steel knife	5.0
5	Apatite	Can be just scratched with steel knife	6.5
6	Orthoclase	Can be scratched with steel file	37.0
7	Quartz	Scratches window glass	120.0
8	Topaz		175.0
9	Corundum		1000.0
10	Diamond		140000.0

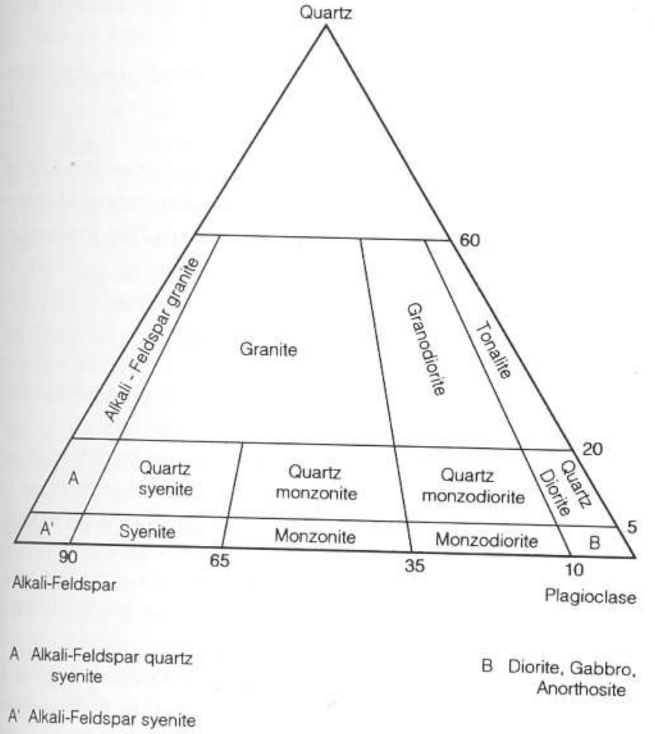


Figure 2.7 Figure showing IUGS classification of plutonic rocks (after Streckeisen 1973).

ture is subdivided into grain-size ranges of fine (less than 1 mm), medium (1–5 mm), coarse (5 mm–3 cm) and very coarse (over 3 cm) grained. Metamorphic rocks are classified on the basis of their structural fabric (foliation) and predominant mineralogy. Although there is no single scheme recommended by an international body as for igneous rocks, there is little disagreement among metamorphic petrologists on nomenclature. A similar situation exists for sedimentary rocks, where relatively few classification schemes are widely used. Accordingly, the limestone nomenclature used here is that of Dunham (1962) and Folk (1962), and the nomenclature for sandstones follows that of Dott (1964) as modified by Pettijohn *et al.* (1972). The standard Udden-Wentworth grain-size scale (see Table 2.3) is used for sandstones and other siliciclastic rocks, whereas for limestones grain size is characterised as fine (less than 2 mm), coarse (2 mm–1 cm) or very coarse (over 1 cm). In Table 2.4, the details of the Mohs hardness scale are given (see Dietrich and Skinner 1979: 21).

The system of nomenclature for different types of quartz material is similar to that used by Sax and Middleton (1992), except that, as well as dividing the main varieties into macrocrystalline (coarse-grained) or microcrystalline (fine-grained), we have subdivided the microcrystalline varieties into the groupings 'chalcedony' and 'chert', the former usually being translucent and the latter opaque (see Table 2.5). Quartz gemstones are thus covered under the headings chert, chalcedony and quartz. Sax and Middleton (1992: 13) point out, with regard to their own system of nomenclature, that 'There are in reality no abrupt transitions or absolute distinctions between the two types or between the varieties of quartz, and the system of nomenclature represents an artificial formalization of the true situation'. The same might be said of the system adopted here.

There has been much confusion over the petrological nomenclature applied to stones used in ancient Egypt. Most of it results from the incorrect use of rock names by archaeologists and other non-geologists who are not well-versed in petrology. The rest of the confusion stems from the correct use of rock names which are derived from competing or obsolete classification schemes. These may include different rock names or give different definitions for the same rock names. For example, the composition of the gneiss from the Roman quarry at Mons Claudianus has been identified as both 'tonalite' (IUGS classification in Brown and Harrell 1995) and 'granodiorite' (Cox classification in Peacock *et al.* 1994). The difference between the IUGS and Cox classifications is substantial because the former is based on quantitative mineralogy from thin-section point counts, whereas the latter uses only major oxide chemistry and does not recognise tonalite as a rock type. It is therefore important that investigators always indicate the classification scheme they are using when assigning rock names. Furthermore, the schemes used should be ones widely accepted by geologists. As in the rest of this book, we have deliberately avoided the discussion of lexicography of ancient stone names, except where it has been absolutely necessary.

Agate *see* chalcedony

Alabaster, satin spar and selenite

Definition

Alabaster is a sedimentary rock formed by chemical precipitation and consisting predominately of the mineral gypsum (hydrated calcium sulphate, $CaSO_4 \cdot 2H_2O$). Note that so-called 'Egyptian alabaster' is actually travertine, a rock

Table 2.5. *System of nomenclature for different varieties of quartz.*

Microcrystalline		Macrocrystalline
chalcedony	**chert**	**quartz**
agate	chert	rock crystal
cornelian	flint	milky quartz
chrysoprase	jasper	amethyst
onyx		prase
sardonyx		rose quartz
silicified wood		smoky quartz
		citrine

composed of the mineral calcite (see TRAVERTINE below). Alabaster is a fine-grained aggregate of gypsum, occurring in massive layers and typically white in colour. Gypsum also occurs as veins of clear, colourless, coarse-grained crystals called selenite and in veins with a fibrous texture, when it is known as satin spar.

Egyptian sources

Workable deposits of alabaster can be found in many areas of the Mediterranean and Red Sea coasts as well as in some of the oases and depressions of the Egyptian Western Desert. Selenite and satin spar occur as thin fracture-filling veins in sedimentary rocks throughout Egypt.

Only one ancient quarry is known; located in the northeast Fayum, it was called 'Umm el-Sawwan' by its discoverer, Gertrude Caton-Thompson. Here the alabaster occurs as vertical seams (approximately 30 cm thick) weathering out of a clay matrix, with thin sheets of selenite running horizontally between the seams. Pebble hand picks were scattered across the alabaster outcrop, and in the cliffs above are three workshop shelters. Mounds of gypsum debris are strewn down the slopes, containing thousands of picks, crescent-shaped flint drill bits and roughed-out alabaster vessels. There are remains of circular stone workmen's huts on top of the cliff, and a wide track, swept free of desert pebbles, leading from the northern Fayum to south Saqqara (see section on transport p. 19). The lack of stratification and the homogeneity of the workshop debris argue against an extended period of exploitation of the site; Caton-Thompson suggested a Third- to Fourth-Dynasty date on the basis of the general shapes of the pottery and stone vessels, although this criterion does not rule out the First and Second Dynasties, when alabaster vessels were, in fact, more common (Aston 1994: 49–50).

There must certainly be other localities that were worked for gypsum (particularly to make plaster) at various times in antiquity, but these have so far gone unrecognised.

Description

The alabaster used for ancient Egyptian vessels is opaque white with occasional yellow patches or reddish brown veins caused by impurities. Its characteristic feature is its extreme softness – it can be scratched with a fingernail. In the past, alabaster has often been confused with travertine although, in fact, it may readily be distinguished from travertine by its softness and lack of effervescence in hydrochloric acid.

Uses

Stone vessels of alabaster were produced in a variety of shapes from the Predynastic period to the end of the Third Dynasty. During the New Kingdom alabaster was used for kohl jars and in the Late Period for alabastra. Lucas (1962: 413) notes that two of the chariot harness saddle knobs from the tomb of Tutankhamun (KV62) are of alabaster, and ashlars of alabaster were employed in a Greco–Roman temple and other buildings at Berenike on the Red Sea coast (Harrell 1996: 107).

From as early as the Predynastic period, gypsum was calcined to make gypsum plaster, a process that requires the heating of gypsum to a modest 100–200 °C. In contrast, burning limestone to produce quicklime requires a temperature of 900 °C, and there is no evidence that lime-burning was carried out in Egypt before the Ptolemaic period. Gypsum plaster was used on walls and ceilings in houses, palaces, tombs and temples, as an adhesive for repairing pottery or stone objects, and as a backing for inlays. Other uses include jar sealings, the modelling on Old Kingdom mummies, and the Amarna portrait masks. Stone masonry was bound with gypsum mortar.

Gesso is, strictly speaking, a term for gypsum plaster, although Egyptologists have commonly used it to refer to whiting plaster which is composed of powdered limestone mixed with glue. Whiting plaster appears as early as the Third Dynasty when it was employed for mounting the blue tiles in the subterranean chambers of Djoser's Step Pyramid and 'southern tomb' at Saqqara (Lucas 1962: 4). It was frequently used in the Eighteenth Dynasty and was later employed as a coating on wooden objects to make a smooth surface for painting or gilding. Whiting plaster was also used extensively for cartonnage mummy masks and coffins.

Examples

1. Cylinder vessel from tomb 2322 at Saqqara, Second Dynasty, *c.* 2770–2649 BC (New York, MMA 12.181.103).
2. Jar from Tomb 1, north necropolis, Abu Rawash, Third Dynasty, *c.* 2649–2575 BC (Cairo JE44351).
3. Gypsum plaster 'mask' of a woman from house P47.2 at el-Amarna, Eighteenth Dynasty, *c.* 1350 BC (height 27 cm; Berlin ÄM 21261; Priese 1991: 124–5).

Bibliography

Caton-Thompson and Gardner (1934: 103–23); Lucas (1962: 74–9); Aston (1994: 47–51).

For photographs of vessels see Aston (1994: pl. 10b) in colour, and el-Khouli (1978: pls. 149: 858, 150: 948) in black-and-white.

Alabaster-calcite *see* travertine

Amazonite *see* microcline

Amethyst *see* quartz

Anhydrite

Definition

Anhydrite is anhydrous calcium sulphate, $CaSO_4$, a mineral with the same composition as alabaster gypsum, but lacking water. It is usually white, but it may be grey or tinted blue. It generally occurs as massive granular aggregates which may be termed 'anhydrock' or 'rock anhydrite', or the rock may simply be called by its mineral name.

Egyptian sources

Ordinary white anhydrite has been quarried in modern times near the Gulf of Suez (Hussein 1990: 559), but the source of the distinctive blue anhydrite used in ancient times has not yet been discovered. White anhydrite was also used in ancient times as a building stone; ashlars of this rock were the main building material for the Serapis temple and a few other buildings at Berenike. Either anhydrite or alabaster gypsum was the stone used to build the Roman fort at Abu Sha'ar and buildings in several other Greco–Roman sites along the Red Sea coast. The quarry for Berenike has not been located but was certainly somewhere on the nearby Ras Banas peninsula, where there are large deposits of both alabaster gypsum and anhydrite.

Description

The ancient Egyptians exploited an attractive blue-tinted variety of anhydrite, which takes a good polish, and plain white anhydrite was also used to a limited extent. A small cosmetic vessel from Elkab (Ashmolean 1896–1908 E.2134) has a body of white anhydrite and a rim of blue anhydrite. White anhydrite has sometimes been confused with travertine or limestone, but it may be easily distinguished from both of these by its greater softness and the fact that it does not effervesce in dilute hydrochloric acid.

Petrie called anhydrite 'blue marble', a misconception which was repeated by subsequent writers until Lucas analysed the rock and published the correct identification in the second edition of *Ancient Egyptian Materials and Industries* (1934). Like limestone and travertine, marble is composed of calcium carbonate and will effervesce briskly in hydrochloric acid whereas anhydrite will not.

Uses

The earliest known instance of the use of anhydrite was for a Predynastic bull's head amulet now in Brussels (Musées Royaux d'Art et d'Histoire E 2335). The next example chronologically is the base of a statuette from an Eleventh-Dynasty Theban tomb (TT 51) at Deir el-Bahari (New York, MMA 26.3.220), but by far the most common use of anhydrite was for small vessels during the Middle Kingdom and Second Intermediate Period. Several categories of finely modelled vessels – including some with monkeys modelled in relief, some in the shape of monkeys holding a cosmetic jar and some in the form of trussed ducks – were produced almost exclusively in anhydrite.

Examples

1. Squat cosmetic jar with two monkeys in relief, blue anhydrite, Twelfth Dynasty (height 4.2 cm; BM EA20759).
2. Squat cosmetic jar with two monkeys in relief, white anhydrite, Twelfth Dynasty, (height 2.2 cm; Cambridge, Fitzwilliam E.266.1939; Bourriau 1988: 142).
3. Trussed duck vessel, Middle Kingdom (height 15 cm; Boston, MFA 65.1749).

Bibliography

Terrace (1966); De Putter and Karlshausen (1992: 49–50); Aston (1994: 51–3).

For colour photographs see De Putter and Karlshausen 1992: pl. 4) and Aston (1994: pl. 11a).

Anorthosite gneiss *see* gneiss: anorthosite, diorite, gabbro, granite and tonalite

Azurite

Definition

This mineral is a deep blue form of copper carbonate ($Cu_3[CO_3]_2[OH]_2$), also called chessylite, which results from the oxidisation of copper sulphide. It occurs in association with copper deposits.

Egyptian sources

Found in the Eastern Desert and at Wadi Maghara and Serabit el-Khadim in the Sinai.

Description

Blue ore of copper not suited to carving.

Uses

The Egyptians may have used azurite as a blue pigment, but the evidence is so far fairly tenuous (see Chapter 4, this volume).

Bibliography

Spurrell (1895); Lucas (1962: 340); Blom-Böer (1994: 61–2).

Basalt

Definitions

'Basalt' is a volcanic igneous rock with an aphanitic groundmass consisting largely of intermediate to calcic plagioclase feldspar (labradorite and bytownite) and various ferromagnesium minerals, especially pyroxene and olivine. 'Dolerite' (or, synonymously, 'diabase') is a rock with the same composition as basalt but with a medium- to mainly fine-grained phaneritic texture. Many objects labelled as dolerite by Egyptologists are actually basalt.

Egyptian sources

Occurrences of basalt are widespread in Egypt. They include a broad, serpentine outcrop starting near Abu Rawash and continuing past Giza and across the northern Fayum; and numerous scattered, small outcrops to the northeast and east of Cairo, on the east bank of the Nile near Gebel el-Teir and on the west bank near el-Bahnasa and Abu Simbel. Despite basalt's availability at numerous localities, only one ancient quarry is known. It is located at Widan el-Faras on Gebel el-Qatrani in the northern Fayum (see Fig. 2.8), and was worked during the Old Kingdom in the Fourth to Sixth Dynasties and perhaps as early as the

Third Dynasty (see Harrell and Bown 1995). It seems likely that basalt outcrops elsewhere would also have been worked, especially after the Old Kingdom.

Description

The basalt from Widan el-Faras consists mainly of labradorite, augite pyroxene and basaltic glass with minor magnetite and rare hornblende amphibole, olivine, quartz and apatite. The rock is slightly porphyritic with moderate grey labradorite and dark green augite phenocrysts up to 7 mm across. The groundmass is mostly aphanitic but grain size occasionally ranges up to 2 mm. The brown discoloration commonly seen on this otherwise dark grey to black rock results from devitrification of glass in the groundmass.

Uses

Buildings

Basalt was widely exploited during the Old Kingdom for pavements in pyramid temples of the Memphite necropolis where it probably symbolised the black, life-giving Nile mud from which ancient Egypt derived its name, Kemet (the 'black land'). Basalt pavements (and occasionally walls) are found in the mortuary temples of the following kings: Djoser (Third Dynasty), Userkaf (Fifth Dynasty) and Pepi I (Sixth Dynasty) at Saqqara; Sahura, Neferirkara and Niuserra (Fifth Dynasty) at Abusir; and Khufu (Fourth Dynasty) at Giza. Also at Giza, extensive use of basalt was made for walls and pavement in Khufu's valley temple and causeway.

Sculpture and vessels

This rock was first used for small vessels in the late Predynastic period and continued to be commonly employed for this purpose until the Sixth Dynasty and rarely thereafter. Determining the other ancient uses of basalt is complicated by the misuse of petrological nomenclature by Egyptologists. For example, many sculptures labelled as basalt are actually siltstone or greywacke from Wadi Har mamat or non-porphyritic granodiorite from Aswan. The rocks were employed for most, if not all, of the so-calle basalt sarcophagi and pyramidia of the Old and Midd Kingdoms. It is also occasionally found that basalt objec have been mislabelled as 'black granite'. After giving du allowance to these nomenclatural errors, it appears th basalt was seldom used after the Old Kingdom and the mainly for statuary, especially in the Late Period and Gr co–Roman period.

Figure 2.8 Basalt quarry at Widan el-Faras in the northern Fayum.

Examples

1. Libation bowl, Twenty-sixth Dynasty, *c.* 664–525 B (diameter *c.* 75 cm; BM EA1386).
2. Colossal kneeling naophorous statue of Wahibra, la Twenty-sixth Dynasty, *c.* 530 BC (height 1.8 m; B EA111).
3. Sarcophagus lid (possibly royal) carved in the hig relief form of a male figure, Twenty-seventh Dynasty Persian period, *c.* 525–404 BC (BM EA90).

Bibliography

Lucas (1962: 61–62, 410); el-Hinnawi and Maksoud (1968, 1972 Heikal *et al.* (1983); De Putter and Karlshausen (1992: 51–54 Hoffmeier (1993); Klemm and Klemm (1993: 413–22); Asto (1994: 18–21); Harrell and Bown (1995).

Beryl (emerald)

Definitions

Beryl ($Be_3Al_2Si_6O_{18}$) is a beryllium aluminosilicate minera that forms naturally as hexagonal, prismatic crystals in variety of colours. Of these well-formed crystals, the gree and blue varieties (emerald and aquamarine, respectively have been of commercial interest for thousands of years although heliodor, a yellow form of beryl, does not appea to have been exploited in the ancient world. Beryl has Mohs hardness of 7.5–8; it is harder than quartz and can b scratched by few other materials, so that, although difficul to work, it holds a polish well. Deposits of beryl are asso ciated with granitic veins and high-grade metamorphi rocks. The beryl is of emerald quality only when the vein cut across particular types of ultramafic rocks.

Egyptian sources

The principal Egyptian sources of beryl lie in an area o some 1,000 square kilometres in the southeastern sector o the Eastern Desert, roughly circumscribed by Gebel Zubar in the north, Wadi Nugrus in the west, Wadi Gimal in the south, Umm Kabu in the southeast and Gebel Sikait in the east (see Hume 1934). The Sikait-Zubara mines were the only source of emeralds for Europe, Asia and Africa in the Hellenistic period and they continued to be exploited until at least the Middle Ages, when Arab writers document the appearance of larger, heavier stones from the Indian subcontinent.

There is clear documentary evidence for beryl mining in the Egyptian southeastern desert in 24 BC (Strabo, *Geography* XVII, I: 45, Jones 1917–32; and see also Pliny, *Natural History* XXXVII: 16–18, Rackham 1968), but the Sikait-Zubara mines had fallen out of use by the seventeenth century AD, and even the location of the mines seems to have been temporarily forgotten by the time James Bruce undertook his expedition through Egypt in 1768 (Bruce 1805). In 1816, the French goldsmith, Frédéric Cailliaud, searching for mines on behalf of Muhammad Ali Pasha, rediscovered the Sikait-Zubara mining region (Cailliaud 1821–62). The principal emerald-mining sites in the region were subsequently visited by Giovanni Belzoni, Sir John Gardner Wilkinson and Nestor l'Hôte in the nineteenth century, and the general geology of the region has been described by Oskar Schneider (Schneider and Azruni 1892) and W.F. Hume (1934). The region was also the subject of three scientific expeditions in the early 1900s (MacAlister 1900; Thomas 1909; Murray 1925).

Preliminary examination of surface pottery at four of the principal mining sites in the Sikait-Zubara region (Shaw *et al.* 1999) confirms that the emerald-mining took place over a long period, extending at the very least from the Ptolemaic period at Gebel Sikait to the sixteenth century AD at Gebel Zubara. The full period of exploitation in the Sikait-Zubara region as a whole must therefore have spanned more than 1,500 years. The changing strategies of mining ranged from adventitious removal of surface rock (in the Greco–Roman period) to the use of complex systems of shafts and adits (in the Byzantine and Ottoman periods). An assessment of the precise order in which different parts of the region were mined will require much more detailed sampling of the ceramics associated with each of the individual mines.

Description

In the Sikait-Zubara region, the combination of micaceous schist (i.e. metamorphosed clay-rich sedimentary rock) and granitic fluids (especially pegmatites) provided the appropriate chemistry for the formation of beryl during metamorphism. The rifting that formed the Red Sea also caused uplift of the igneous-metamorphic basement along the eastern margin of Egypt, thus creating the mountains of the Eastern Desert and exposing the emerald deposits within them. Several geologists and archaeologists have published accounts of their visits to ancient Egyptian emerald mines, particularly during the first three decades of the twentieth century. The most recent study (Grubessi *et al.* 1989, 1990) involved the use of x-ray diffraction and infrared spectroscopy (for the former see section on methods of scientific analysis below) to compare the Sikait-Zubara emeralds with those from mines elsewhere in the world.

The geoarchaeological study of several sites in the Sikait-Zubara region (Shaw *et al.* 1999) has demonstrated a number of the ways in which the conditions for growth of emeralds may arise:

(1) at the boundaries of granite intrusions into schist;
(2) adjacent to quartz veins spawned by a granite;
(3) within granite pegmatites; and
(4) in biotite schist lenses within a metamorphosed granite.

One or more of these modes of emerald formation can be found at each of the four sites.

Uses

The Egyptians used beryl only for jewellery. Lucas (1962: 390) analysed a number of supposed beryls in items of jewellery of the Pharaonic period (such as the Middle Kingdom items from Dahshur) and concluded that in all cases the stones were actually green feldspar or olivine. Although an uncut emerald was supposedly identified in a necklace from the Predynastic site of el-Kubaniya, immediately to the north of Aswan (Junker 1919; Lucas 1962: 390), there have been no modern identifications of beryl in the Pharaonic period or earlier, and the stone does not appear to have been used regularly in Egyptian jewellery until the Ptolemaic period.

Examples

1. Silver crown embossed with busts of an Egyptian god and incorporating large beryls, found beside the body of a woman in room 1 of tomb B.114 at Ballana, dating to the X-Group period, *c.* AD 400–600 (Cairo, Egyptian Museum; Object no. 11; see Emery 1938b: 148, 183, fig. 72, pl. 34a).
2. Necklace consisting of gold and hexagonal beryl beads, Roman period, unprovenanced (Yale University Art Gallery 1941.308), overall length 37 cm.

Bibliography

Cailliaud (1821); Wilkinson (1878); Schneider and Azruni (1892); MacAlister (1900); Thomas (1909); Murray (1925); Hume (1934: 110–25); Lucas (1962: 389–90); Grubessi *et al.* (1989, 1990); Hussein and El-Sharkawi (1990: 537–9); Shaw *et al.* (1999).

Breccia *see* limestone breccia

Calcite *see* travertine

Chalcedony: (agate, cornelian, chrysoprase, citrine, onyx, sardonyx, silicified wood)

Definition

Chalcedony is a translucent microcrystalline form of quartz consisting of thin layers of very small parallel-oriented fibres (from which it derives the toughness which makes it so ideal for carved objects). Its basic chemical composition is silicon dioxide (SiO_2) and it has a Mohs hardness of 6.5–7. The characteristic crusts or cavity fillings of chalcedony result from a process of precipitation from silica-bearing ground water.

The term chalcedony, in its widest sense, also embraces agate, chrysoprase, cornelian, onyx, sardonyx and silicified wood, which are all essentially coloured forms of chalcedony (i.e. fibrous microcrystalline quartz ; see Table 2.5). The colours of these various forms of chalcedony are caused by impurities. Thus the brown colouring of agate and sardonyx as well as the red colouring of cornelian are all produced by the presence of higher proportions of iron oxides, while the green colour of chrysoprase is caused by the presence of nickel oxide. Jack Ogden (pers. comm.) speculates that the Eastern Desert may possibly have contained sources of matauralite (an unusual type of green chrome-bearing chalcedony), which is attested in items of jewellery throughout the Roman empire, the only known modern source being in East Africa.

1. Agate

Definition

A form of chalcedony which occurs as spherical or almond-shaped nodules in mafic volcanic rocks, the characteristic banded or stripey appearance being caused by 'rhythmic crystallisation' (i.e. the build-up of thin layers of quartz fibres). The interiors of agates often contain crystals such as amethyst, calcite and smoky quartz, while the uppermost layers tend to form a white crust as a result of weathering. Many agates are simply grey in appearance but they can acquire bright colours and unusual structures through the natural staining of the porous chalcedony with a variety of metallic salts; fire agate, for instance, derives its iridescent colours from the interference of light passing through thin layers of regularly spaced iron oxide crystals within the chalcedony. There are a number of basic types of agate, such as 'fortification agate' (the patterns in which resemble the bastions of fortresses), 'tubular agate' (which is pierced by tubular canals) and 'ribbon agate' (in which the interior of the nodule consists of planar, parallel bands, usually surrounded by other bands which are concentric to the external surface). Ribbon agate was used for cameos and intaglios in the Greek and Roman periods.

Probably the most important variety, however, is 'banded agate', in which the differently coloured irregular layers are continuous, generally of uniform thickness and colour, and are roughly concentric to the external surface of the nodule. The bands alternate between brown or reddish-brown and white, and vary in translucency.

Egyptian sources

Agate (mostly non-banded) is abundant in Egypt, usually occurring in the form of surface pebbles. There is also at least one instance of the occurrence of agate alongside jasper (see CHERT below) and ordinary chalcedony at Wadi Abu Gerida in the Eastern Desert, about seventy kilometres northwest of Quseir (Barron and Hume 1902: 266; Hume 1937: 862).

Description

The agate found in the Eastern Desert usually has concentric bands of white and brown, and occasionally also blue concentric bands.

Uses

From the Predynastic period onwards, agate was used in jewellery in the form of unworked pebbles, beads and drop pendants. In the Pharaonic period, although agate was sometimes also used for amulets, its use in jewellery was comparatively infrequent. It was employed for small vessels in the 25th and 27th Dynasties as well as in the Roman period.

Examples

1. Vessel found in the Eastern Desert and dating to the Late Period (height 7.7 cm; Cairo JE55034).
2. Vessel found in tomb 4 at el-Kurru and dating to the early seventh century BC (Boston, MFA).
3. Fragment of an Eighteenth-Dynasty gold girdle from the tomb of the three princesses of Thutmose III, comprising a glass or faience *ḥtp* hieroglyph and a gold and agate *nb* sign (length 4 cm; New York, MMA; see Winlock 1959: 135, fig. 73).

Bibliography

Barron and Hume (1902: 266); Engelbach (1931); Lucas (1962: 386–7); Habachi and Biers (1969); Aston (1994: 68–9).

For colour photograph of a Late Period vessel (Cairo JE 55034) see Aston (1994: pl.13c).

2. Chrysoprase

Definition

Yellowish green (i.e. 'apple-green') form of chalcedony, larger broken pieces of which are often fissured with irregular colours. It is found only in serpentinite, and the colour derives from the presence of hydrated nickel silicate impurities. Darker shades of chrysoprase can sometimes be confused with prase (a leek-green massive variety of chert).

Egyptian sources

No specific ancient Egyptian sources of chrysoprase have been located.

Uses

From the Predynastic period to the Roman period chrysoprase was used occasionally for beads, amulets and pendants.

Bibliography

Schäfer (1910: 13, 34–5, 37); Lucas (1962: 392); Ogden (1982: 107–8).

3. Cornelian and sard

Definition

Cornelian (or carnelian) is a red to yellowish- or orange-red translucent form of chalcedony, the colour of which is produced by the presence of tiny amounts of iron oxide. It can sometimes be confused with red jasper, although the latter is opaque rather than translucent. The term sard is used to describe the red to brownish-red form of cornelian although in practice it can be difficult to make a clear distinction between the two stones (with some geologists distinguishing between the two in terms of the intensity of the colour rather than its hue). The red of cornelian is due to minute disseminated particles of haematite. The brown in sard probably derives from particles of goethite, a hydrated iron oxide. Both cornelian and sard can be reddened by heating (Frondel 1962: 207).

Egyptian sources

Numerous small water-worn pebbles of cornelian are found scattered across the surface of the desert between the Nile valley and the Red Sea, but larger stones occur at various specific sites in the Eastern Desert, such as the regions of Wadi Abu Gerida (about seventy kilometres northwest of Quseir, see Barron and Hume 1902: 266) and Wadi Saga (about twenty kilometres northwest of Quseir, see Barron and Hume 1902: 221) as well as at the Gebel el-Asr gneiss quarries in the Western Desert, sixty-five kilometres northwest of Abu Simbel (Engelbach 1933: 69, 1938: 370, 372; Little 1933: 79–80), although it is by no means clear in any of these three instances whether ancient expeditions were sent there specifically in order to obtain cornelian.

Description

The flesh-red and reddish-brown forms of cornelian and sard were used by the Egyptians from the Predynastic period onwards, although a yellowish form was also used in the Middle and New Kingdoms.

Uses

One of the earliest gemstones to be carved into beads, cornelian was used from the Predynastic onwards for both beads and amulets. Some Predynastic cornelian beads appear to have been glazed (e.g. at the Armant cemeteries, see Mond and Myers 1937: I, 72). In the Pharaonic period it was used for inlay on jewellery, furniture and numerous items of funerary equipment (such as coffins), as well as for rings, scarabs, amulets (particularly *wedjat*-eyes) and even small vessels. During the New Kingdom, when most inlay had begun to be made from coloured glass, cornelian was one of the few gemstones still frequently used, although it was sometimes imitated by placing rock crystal or milky quartz on red-painted cement.

Examples

1. Predynastic amulet in the form of a bovine head, of unknown provenance, dating to the fourth millennium BC (height 3.8 cm; Hildesheim, Pelizaeus Museum 5159).
2. Squat-shouldered jar with gold foil cap from the tomb of the Second-Dynasty ruler Khasekhemwy at Abydos, *c.* 2700 BC (height 4.2 cm; Cairo JE34941).
3. Eleventh-Dynasty necklace of cornelian beads capped with gold dating to the Middle Kingdom, *c.* 2140–1991 BC (length 74 cm; BM EA24773).
4. Unfinished open-work plaque comprising a scene of Akhenaten, Nefertiti and their daughters embracing one another, Eighteenth Dynasty, *c.* 1350 BC, provenance unknown but probably Amarna; this is one of the largest known worked gemstones from Egypt, and was perhaps intended to be inset into a gold pectoral, with the appearance of a crack at the base of the object probably being the reason for its abandonment (height 5.7 cm; Cambridge, Fitzwilliam EGA4606.1943; Vassilika 1995: 62–3).

Bibliography

Barron and Hume (1902: 221, 266); Engelbach (1933: 69, 1938: 370, 372); Little (1933: 79–80); Lucas (1962: 391–2); Ogden (1982: 108); Aston (1994: 67–8).

For colour photograph of a cornelian vessel (height: 2.7cm; Cairo CG 18777) see Aston (1994: pl. 15b). For colour photograph of a cornelian necklace (BM EA24773) see Andrews (1990: fig. 74c).

4. Onyx and sardonyx

Definition

The term onyx is used in gemmology to refer sometimes to a black form of chalcedony but more often to the ribbon form of agate, in which the regular bands or layers alternate between contrasting darker and lighter colours (usually black or dark brown alternating with white or light grey). Onyx differs from banded agate in that its bands are straight and parallel. Sardonyx is a variety of onyx consisting of alternating bands of white and brown or reddish-brown.

Egyptian sources

According to Lucas (1962: 387), 'onyx and sardonyx probably . . . occur in Egypt, though no mention of them can be found in the geological reports'.

Uses

Onyx was used for beads from the Predynastic period onwards, but both onyx and sardonyx became very popular after the Twenty-first Dynasty, reaching a peak of use (particularly for cameos, intaglios and ring settings) in the Ptolemaic and Roman periods. During the latter two periods, however, onyx is known to have been imported from India (through Greco–Roman ports such as Berenike on the Red Sea), therefore some of the later uses of onyx may not have employed native stone. On the other hand, the 'nicolo' cut of onyx (i.e. an onyx gem cut in such a way that the uppermost layer is bluish white) was known to the Romans as *aegyptilla*, suggesting either an Egyptian source or trade-routes passing through Egypt.

Example

Sardonyx pendant inlaid with a *wedjat*-eye of gold and fused glass, from the pyramidal tomb of the *kandake* (queen)

Amanishaketo at Meroe, late first century BC (height 1.6 cm; Berlin, ÄM 1650).

Bibliography

Petrie, Wainwright and Mackay (1912: 22); Lucas (1962: 386–7); Ogden (1982: 109).

5. Silicified wood

Definition

Also known as petrified wood, it is a pseudomorph of chalcedony formed when circulating water replaces the organic constituents of wood with quartz, thus preserving the original shape and, often, internal structure of the wood.

Egyptian sources

Silicified wood is extremely abundant in Egypt's Eastern and Western deserts as well as in the Sinai. There is a particularly large 'forest' of silicified wood near Cairo.

Description

A number of botanists (e.g. Seward 1935) have identified the various species of silicified wood found in Egypt.

Uses

Since silicified wood is a very hard material, it is difficult to carve. There are therefore only a few instances of its use in the Pharaonic period (including a scarab), although it was shaped into crude hammerstones in the Neolithic and Badarian periods.

Bibliography

Legrain (1906: 55–6); Keldani (1939); Seward (1935); Ibrahim (1943, 1953); Shukri (1944); Lucas (1962: 455–6).

Chert (chert, flint and jasper)

1. Chert and flint

Definition

Chert is an opaque microcrystalline form of quartz or chalcedony (the latter very rarely making up the majority of the rock). It is a layered siliceous rock with no essential fossil content, which occurs either in the form of beds (created by layers of silica-shelled marine organisms) or as nodules and lenses in limestone.

Most geologists distinguish between chert and flint purely in terms of colour; flint being the darker form of chert. This colour distinction, however, also happens to relate to some extent to the two forms of chert – bedded and nodular – thus, most bedded cherts are light grey (or occasionally light blueish-, yellowish- or brownish-grey), whereas most nodular cherts are dark grey, brownish-black or black. The nodular cherts are therefore often described as flint. In the sections below, chert is used in its wider sense (i.e. including both chert and flint) since Egyptologists have tended to make somewhat arbitrary distinctions between the two.

Egyptian sources

In Egypt, all chert occurs as nodules within limest
The nodules formed where quartz or chalcedony pre
tated from silica-rich groundwater and simultaneousl
placed the calcite in the limestone. In the Nile va
these nodules occur in the Eocene limestones that
out between Esna and Cairo; most of them are the da
chert that would usually be described as flint. They
also be found in Eocene and Cretaceous limestones c
ping out in many parts of the Western and Eastern
serts.

Belgian survey and excavation at the sites of Na
Khater, Beit Allam, Taramsa and Nazlet Safaha (all
ated between Asyut and Qena) have revealed occupa
sites with extensive evidence of the extraction and w
ing of cobbles of chert (Vermeersch, Paulissen and
Peer 1990). These mines may well be the earliest in
world, dating to *c.* 40,000 BP. In addition, Seton-
(1898, 1905) and Baumgartel (1960) describe exten
'flint' mines of indeterminate date in the Eastern De
at the site of Wadi el-Sheikh, to the southeast of
Suef.

Uses

The Palaeolithic and Neolithic inhabitants of Egypt
chert to manufacture tools and weapons from a very
date (*c.* 500,000 BP), but it is also clear that chert
tinued to be an important material for numerous
facts long after the appearance of copper in the Predy
tic period. Even when copper and bronze became
readily available in the Pharaonic period, chert was s
very cheap and effective material for many of the
artefacts used in daily life, as well as being a potent
dium for more ritualistic and religious objects, suc
the *pšs-kf* implement used for the 'opening of the mo
ceremony (see Van Walsem 1978–9; Macy Roth 1
and the curved knives used for such rituals as cir
cision and embalming.

In the Predynastic and Early Dynastic periods,
was used not only for tools and weapons but also
sionally for bangles, pendants and vessels. The evid
from Old Kingdom mortuary complexes such as the
Pyramid complex of the Third-Dynasty ruler Djoser at
qara suggests that chert chisels were used for fine su
working of limestone masonry blocks, although the k
of chisels suitable for fine stone-carving rarely seen
have survived (see Petrie 1890: pl. 16; Nour *et al.* 1962
15a). It has been suggested that the many crescent-sh
chert tools found in Djoser's complex were probably
to create the fluting of his columns (see Lauer and De
1950). At the Abusir necropolis, Vachala and Sro
(1989: 178) noted the presence of large numbers of h
merstones and chert tools in the vicinity of Fifth-Dyn
limestone buildings, perhaps having been used to
the stone.

Crescent-shaped chert drills were also used in the Old Kingdom to carve out the interiors of soft stone vessels, and large numbers of such implements have been found in association with semi-worked vases at the Umm el-Sawwan alabaster gypsum quarry in the northern Fayum region (Caton-Thompson and Gardner 1934: 105). Pointed chert implements seem to have been used from an early date for the process of piercing stone beads, judging from the discovery at Hierakonpolis of small chert points alongside fractured cornelian pebbles, chips of amethyst and rock crystal and flakes of obsidian (Quibell and Green 1902: 12).

The very common use of chert for tools and weapons (such as arrowheads, knives, scrapers and sickle blades) throughout the Pharaonic period is indicated by numerous pieces of archaeological, textual and artistic evidence, such as the chert tools found by Emery (1938a: 18–27) in the First-Dynasty tomb of Hemaka at Saqqara (tomb 3035); the scenes in the tomb of the early Twelfth-Dynasty provincial governor Amenemhat at Beni Hasan, depicting the manufacture and use of chert knives (BH2; see Newberry 1893: 31, pl. XI, 1894: 47, pl. IV; Griffith 1896: 33–8, pls. VII–X); the mention of chert as a prestige commodity in the Amarna Letters (see Moran 1992: 52); and the piles of partly finished chert artefacts stored in one of the Ramessid houses excavated in the city of Memphis (see Jeffreys and Giddy 1993: 19). Excavations in the Valley of the Kings have shown that the workers carving out the royal tombs of the Eighteenth to Twentieth Dynasties used large numbers of chert hammerstones and chisels which, to judge from Carter's observations of adjacent piles of flakes (Carnarvon and Carter 1912: 10) were manufactured at the place of use.

Examples

1. Ivory and chert knife from Abu Zaidan, Naqada III period, *c.* 3150–3000 BC (length 23.4 cm; Brooklyn 09.889.118).
2. Chert bangle from a First-Dynasty grave (U354) at Hu, *c.* 3000 BC (diameter 6.9 cm; BM EA67625; see Petrie 1901a: 36, pl. VII).
3. Chert saw from a house in the north suburb at Amarna, *c.* 1350 BC (length 8 cm; Cambridge, Fitzwilliam E19.1927).

Bibliography

Spurrell (1891, 1894); Seton-Karr (1898, 1905); Baumgartel (1960: 24–43); Lucas (1962: 411–2); Debono (1971, 1982); Wendorf and Schild (1975); Ginter *et al.* (1979); Weisgerber *et al.* (1980); Weisgerber (1982); Miller (1983, 1987); French (1984); Vermeersch *et al.* (1984); Vermeersch *et al.* (1990); Jeffreys and Giddy (1993); Aston (1994: 69–70).

2. Jasper

Definition

A group of brightly coloured forms of chert which contain up to 20 per cent of colourful impurities (mainly consisting of red and yellow iron oxides), thus creating the characteristic appearance, usually being multicoloured, striped, spotted or marbled. Jasper can be an opaque red, green, yellow or brown. The reddish colour is due to minute, disseminated particles of haematite, while the brownish colours are probably due to the presence of goethite (as in sard and cornelian). Whereas chert and flint form by the replacement of limestone, jasper occurs as veins in igneous and metamorphic rocks.

Egyptian sources

A large vein of green and red jasper was noted by James Bruce in the early nineteenth century, as he travelled through the Eastern Desert between Qena and Quseir (Bruce 1805: 89); this agrees with the modern observation that the largest quantities of Egyptian jasper are located in the area of the Eastern Desert to the northwest and west of Quseir. Barron and Hume (1902: 266) describe the occurrence of 'red jasper of good quality, but unfortunately in small quantity' in the region of Wadi Saga (in the Eastern Desert about twenty kilometres northwest of Quseir). They also note ocurrences of jasper at other sites in the Eastern Desert, including deposits of unspecified colour in the Hadrabia hills, and red jasper at Wadi Abu Gerida, about seventy kilometres northwest of Quseir (Barron and Hume 1902: 52, 221, 228; Hume 1937: 862), the latter being also the site of Roman-period iron ore workings. Green and yellow jasper often occur both beside and within deposits of red jasper, while pebbles of brown jasper are sometimes found in the Eastern Desert.

It has been argued on purely lexicographical grounds that a stele of the Twelfth-Dynasty ruler Amenemhat II (*c.* 1900 BC) at the Gebel el-Asr gneiss quarries in the Western Desert, sixty-five kilometres northwest of Abu Simbel (Engelbach 1933: 71; Rowe 1938: 683–5) may identify the site as a source of both gneiss and red jasper, although Engelbach (1938: 372) noted only the presence of 'multicoloured quartz' among quarry-workers' spoil at Stele Ridge in the northern part of the site (see also Shaw *et al.* forthcoming).

Description

Egyptian forms of jasper are said to be somewhat speckled and veined compared with those found in Europe. Red jasper was probably the colour most commonly used by the Egyptians; the green and brown jaspers are often confused with other stones.

Uses

Both red and green jasper were used for beads from the Badarian period onwards, with red jasper being particularly popular for New Kingdom penannular earrings and hair-rings. During the Pharaonic period, red jasper was used for beads, amulets, jewellery inlay, scarabs, small vessels and parts of composite statues (such as a foot from a composite statue excavated by Pendlebury at Amarna). A large fragment of unworked red jasper (along with pieces of unworked green feldspar) was found in a foundation deposit of Rameses IV at Deir el-Bahari (now in the collection of the Metropolitan Museum of Art, New York, see Hayes 1959: 372, fig. 234). Yellow jasper was used in Egypt for sculpture from the Eighteenth Dynasty onwards, but was not used for jewellery until the Roman period. Brownish jasper appears to have been used only in the Middle Kingdom, primarily for scarabs. Ogden (1982: 108) suggests that the Minoans may have obtained their jasper from trading connections with Egypt, since it does not seem to have been otherwise used by the Greeks.

Examples

1. Small green jasper kohl pot from tomb 1910 at Hemmamiya, Middle Kingdom or Eighteenth Dynasty (height 1.9 cm; Ashmolean 1924.415).
2. Green jasper and gold human-headed heart scarab of the Seventeenth-Dynasty ruler Sobkemsaf II, with an incised excerpt from Chapter 30b of the Book of the Dead inscribed around the plinth, *c.* 1600 BC (length 3.6 cm; BM EA7876).
3. Yellow jasper fragment of the lower part of the face of a statue of Queen Tiye, Eighteenth Dynasty, *c.* 1380 BC (height 12.6 cm; New York, MMA 1926.26.7.1396).

Bibliography

Bruce (1805: 89); Barron and Hume (1902: 52, 221, 228, 266); Hume (1937: 862); Brunton (1930: 8); Lucas (1962: 396–7); Ogden (1982: 108); Aston (1994: 69–71).

For a colour photograph of the yellow jasper lips of Queen Tiye, see Kozloff and Bryan 1992: pp. 177, 190, pl. 15. For a colour photograph of the green jasper heart scarab of Sobkemsaf II, see Andrews (1990: fig. 65d).

Chrysoprase *see* chalcedony

Cornelian *see* chalcedony

Diorite, quartz diorite and gabbro

Definitions

Diorite, quartz diorite and gabbro are phaneritic igneous rocks (i.e. with visible mineral grains). They are composed primarily of plagioclase feldspar (light grey) and either greenish black hornblende amphibole or augite pyroxene. As can be seen on the IUGS chart (Fig. 2.7), granite and granodiorite differ from diorite , quartz diorite and gabbro in having greater than 20 per cent quartz. Granite and granodiorite also contain a higher percentage of alkali feldspar which is often pink or red in colour. Diorite has less than 5 per cent quartz, while quartz diorite, which otherwise has the same mineralogy, contains 5–20 per cent quartz. Diorite and gabbro can only be distinguished from each other by their plagioclase composition, and this must be determined in thin section. Diorite is defined as having a plagioclase composition of less than 50 per cent anorthite
while gabbro has plagioclase of greater than 50 per c
anorthite.

Egyptian sources

Outcrops of these rocks are common in the Eastern Des
and one Pharaonic/Roman and five Roman quarries h
been located. Diorite was quarried at Wadi Umm Sheg
quartz diorite at Wadi Umm Balad, Wadi Barud and W
Fatiri el-Bayada, and gabbro at Wadi Maghrabiya and W
Umm Wikala (see map in Figs. 2.1a–b).

Description

In Wadi Umm Shegilat, at its confluence with W
Ghazza, is a small Roman quarry dating from the
and second centuries AD (see Fig. 2.9). The rock
mottled light grey, pale pink and greenish-black,
coarse- (up to 6 cm) to mainly coarse-grained diorite
andesine and hornblende, and minor magnetite. Gi
the coarse texture and abundant hornblende, the rock
also be described as 'pegmatitic hornblende diorite'
ton 1994: 13–15; Brown and Harrell 1995). The ho
blende forms distinct, elongated crystals which are cha
teristic of this rock. Petrie called this rock 'porph
(1901b: 43), a misnomer which was adopted by o
scholars, though the rock is not porphyritic but has gr
all about the same size. For descriptions of the qu
diorites and gabbros from the four other Roman quar
see Bibliography below.

Uses

The rocks from *wadis* Umm Shegilat, Umm Balad, Ba
Fatiri el-Bayda, Maghrabiya and Umm Wikala were q
ried for export from Egypt by the Romans who used th
for small columns, basins, cornices, pedestals and p
ment tiles. Rocks identical to the Wadi Umm She
diorite, and probably coming from the same area, were
used for vessels from the Predynastic period to the Fo
Dynasty, with an isolated example of New Kingdom
(Aston 1994: 13–15, Types A, B and C hornblende dior

Examples (of Wadi Umm Shegilat diorite)

1. Jar from tomb T5 at Naqada dating to Naqada II (
   molean 1895.213);
2. Two jars from the treasure of the three princesse
   Thutmose III (New York, MMA 26.8.37 and 38);
3. Sparingly used for wall veneer in many of the medi
   Islamic buildings of Cairo, e.g. the Mosque of Su
   Hasan, dating to 1356–63 AD, where numerous s
   are found in the walls of the madrasa sanctuary
   mausoleum. These slabs and others in Cairo are ap
   ently cut from columns taken from now-destroyed
   man buildings.

Bibliography (for Wadi Umm Shegilat diorite)

Meredith (1952: 100), Gnoli (1988: 150–2), Marchei *et al.* (
220), Galetti *et al.* (1992), Aston (1994: 13–15), and Brown
Harrell (1995).

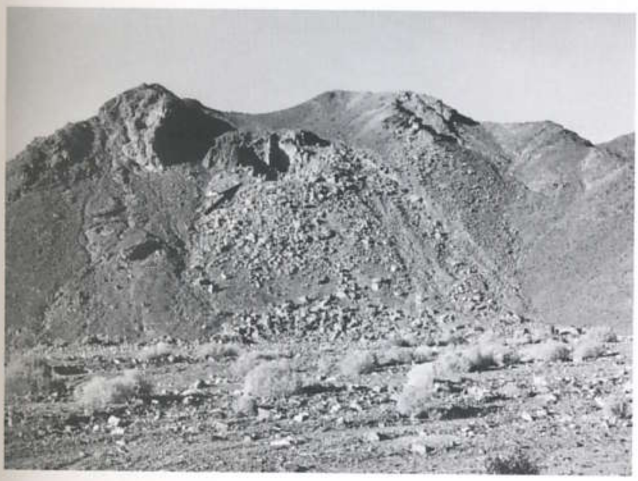


Figure 2.9 Pegmatitic diorite quarry (arrow) in Wadi Umm Shegilat, Eastern Desert.

Bibliography (for the five other Roman quarries)

Barron and Hume (1902: 26, 59, 221); Weigall (1913: 131); Scaife (1935: 87–100); Murray (1947: 43–6), Meredith and Tregenza (1949: 116; 1950: 145); Meredith (1952: 99, 106); Tregenza (1950; 1951; 1955: 47; 1958: 155–63); Gnoli (1988: 150, 154–60); Marchei *et al.* (1989: 210–11, 217, 229, 232–35); Sidebotham *et al.* (1991: 580–2), Klemm and Klemm (1993: 408–11); Harrell *et al.* (in press); Sidebotham (1996).

For colour photograph of the Naqada jar (Ashmolean 1895.213) see Aston (1994: pl. 1b) and for the New Kingdom jars (New York, MMA 26.8.37 and 38) see Winlock (1948: pl. 30:4,6).

For colour photographs of polished slabs of Wadi Umm Shegilat diorite, see Mielsch (1985: pl. 23–802), Lazzarini (1987: fig. 9); Gnoli (1988: fig. 108), and Marchei *et al.* (1989: fig. 70a). For colour photographs of quartz diorite and gabbro, see Mielsch (1985: pls. 23–798, 24–804–805, 807, 811, 815–816), Lazzarini (1987: figs. 5, 6); Gnoli (1988: figs. 105, 106, 109, 110, 116); Marchei *et al.* (1989: figs. 62, 67a, 69, 77a, 80a, 81a); Klemm and Klemm (1993: pl. 16.4).

Dolerite *see* basalt

Dolomite *see* limestone

Emerald *see* beryl

Feldspar *see* microcline

Flint *see* chert

Fluorspar (fluorite)

Definition

Fluorspar (or fluorite) is a translucent or transparent crystalline form of calcium fluoride (CaF_2) which may be either colourless or of any colour tone. It occurs in igneous rocks, ore deposits and sedimentary rocks, has a Mohs hardness of 4, and is frequently fluorescent.

Egyptian sources

There are deposits of fluorspar at numerous sites in the Eastern Desert, including Umm Esh el-Zarga and Bir Umm Fawakhir, both of which were also the sites of ancient gold mines. Hussein and El-Sharkawi (1990: 359) report that the major occurrences in Egypt are in veins (either monomineralic or together with quartz) near Gebel Ineigi (where the veins are two to three metres wide), and in the el-Bakriya, Hamret Mikpid and Homr Akarem areas. They also note that fluorspar occurs (as apparently smaller masses) in greisenised granites in many places, such as the vicinity of Gebel Muelha.

Description

Egyptian forms of fluorspar are usually transparent green or yellow.

Uses

It was used for beads from the Predynastic period onwards, and perhaps also for vessels in the Roman period (see Harden 1954: 53). The Egyptians appear to be the only known users of fluorspar in the pre-Roman period, apart from a few examples of beads and seals from western Asia.

Examples

1. Two beads forming part of a late Predynastic (Naqada II) anklet from grave 5108 at Matmar (overall length 29 cm; BM EA63695; see Andrews 1981: 29, pl. 16).
2. Cup or bowl made from a banded piece of fluorspar, probably dating to the Roman period and said to have been found in Egypt (diameter 6.75 cm; Ashmolean 1953.782; see Harden 1954).

Bibliography

Mond and Myers (1937: I, 72, 84, 103–4); Brunton (1948: 19, 23, pl. LXX); Loewental and Harden (1949); Harden (1954); Lucas (1962: 394).

Gabbro *see* diorite, quartz diorite and gabbro

Garnet

Definition

A group of magnesium, iron or calcium aluminosilicate minerals (almandine, pyrope, spessartine, grossular, andradite and uvarovite) which occur in all colours except blue. They form in gneiss, mica schists, eclogite, and calcareous and dolomitic metamorphic rocks. The most popular garnets are violet-tinged almandine or 'common' garnet ($Fe_3Al_2[SiO_4]_3$, also known as almandite) and crimson pyrope or 'Bohemian' garnet ($Mg_3Al_2[SiO_4]_3$), but in practice there is a continuous series of types ranging between these two compositional extremes. There are also some less attractive black or brown types of garnet, formed when excessive amounts of iron are present. They have a Mohs hardness of 7–7.5.

Egyptian sources

Garnets are found in many parts of Egypt, such as the Aswan region, the Eastern Desert and the Sinai peninsula, but they are said to be especially common in mica schists in the Gebel Mitiq and Wadi Gimal areas of the Eastern Desert, and in the muscovite-granite of Wadi Sikait, just to the south of the beryl mines (Hume 1937: 863–4). Hussein and El-Sharkawi (1990: 563) report that no 'gemstone quality' garnet is known to exist in Egypt. No specific ancient quarries have been found, presumably because of the stones widespread availability.

Description

Almandine and pyrope garnets are fairly common in Egypt, but their quality is often poor. The colour most frequently used by the Egyptians was dark red or reddish brown.

Uses

From the Badarian period until the end of the New Kingdom garnets were used as beads and (primarily in the Middle Kingdom) inlay. In general, however, the Egyptians seem to have used surprisingly low quantities of garnets (considering its comparatively wide availability), perhaps because the stones tend to be fairly small, with poor colours compared to other gems, and probably also because most garnets are riddled with fine fractures that cause them to be crumbly. On the other hand, the importance of Egypt as a source of garnets in pre-Roman times is not to be underestimated: it has been suggested, for instance, that the garnets in Mycenaean jewellery may well derive from trading contacts with Egypt rather than from Europe (Ogden 1982: 98).

Examples

1. Diadem made up of beads and chips of garnet, turquoise and malachite as well as sections of very small gold ring beads, which was found in the Naqada II grave of a woman at Abydos (*c.* 3200 BC); it was used to hold a piece of veil-like cloth over the face of the deceased (length 31.2 cm; BM EA37532).
2. Golden 'falcon collar' inlaid with lapis lazuli, turquoise, cornelian, garnets and green microcline, from the tomb of princess Khnumet who was buried near the pyramid of Amenemhat II at Dahshur, early Twelfth Dynasty, *c.* 1900 BC (height 3.8 cm; Cairo JE52861–2).

Bibliography

Barron and Hume (1902: 170, 218); Couyat (1912: 561); Hume (1937: 863–4); Lucas (1962: 394–5); Ogden (1982: 97–8).

Gneiss: anorthosite, diorite, gabbro, granite and tonalite

Definition

Gneiss is a layered (foliated) metamorphic rock in whi dark minerals are often segregated into parallel bands streaks. Where the gneiss is derived from older igne rocks the igneous rock name is used to indicate the ro composition and distinguish the different varieties gneiss.

Egyptian sources

Gneisses of many varieties occur throughout the Easte Desert, in the Nubian Desert west of the Nile, and in t Nile valley at Aswan and other cataracts further south Sudan. All are late Precambrian in age. Only two gne quarries are known from the Pharaonic period, one located fifteen kilometres west of Gebel el-Asr in the N bian Desert, northwest of Abu Simbel (see Fig. 2.10), a the other is near the village of Tumbos at the south end the third cataract on the Nile River in Sudan. In additio the Romans quarried gneiss at Mons Claudianus and Wa Umm Huyut in the Eastern Desert. Some of the granit quarried at Aswan may also be described as gneiss (s GRANITE AND GRANODIORITE).

1. Diorite-gabbro and anorthosite gneisses from Gebel el-Asr

The Gebel el-Asr quarry is located about sixty-five ki metres northwest of Abu Simbel; the ancient route to t quarry is marked by cairns, with Middle Kingdom potte and pieces of fallen gneiss to be found alongside the tra (Engelbach 1938: 388; Harrell and Brown 1994: 52). T quarry road terminates by a loading ramp, while two ki metres to the southeast a stele of Khufu was found on platform of gneiss blocks marking the edge of the ma quarry workings to the east. About four kilometres to t north is a ridge of quartz topped by two ancient cair which served as landmarks for both ancient and mode expeditions.

Description

The distinctive translucent gneiss utilised by the ancie Egyptians is composed primarily of light grey plagiocla and greenish black hornblende with minor biotite, chlorit magnetite and sphene. Dark and light varieties may b distinguished which originate in different parts of th quarry – the dark variety to the south and the light varie (see Fig. 2.11 for an example of the latter) to the north in th area just to the west of Quartz Ridge. As the gneiss contain no alkali feldspar and little or no quartz, the dark varie should be identified as diorite or gabbro gneiss. The tw may be distinguished by analysis of the plagioclase: gabbr contains more calcium-rich plagioclase (with a compositio

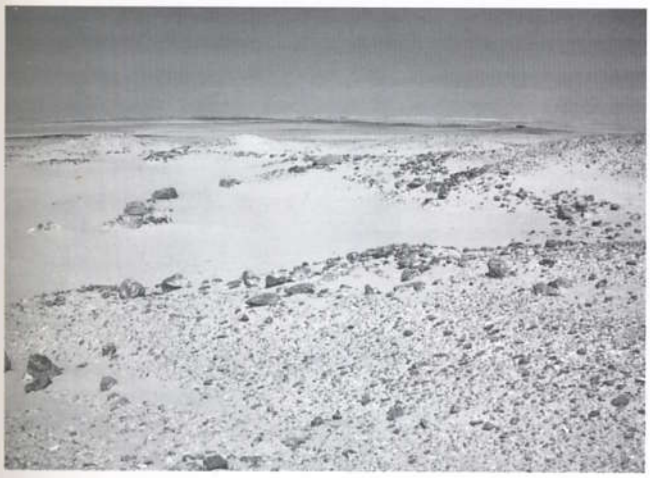


Figure 2.10 Part of the Gebel el-Asr gneiss quarries: the so-called 'great' or 'chisel' quarry is in the foreground.

Figure 2.11 Old Kingdom bowl carved from the lighter-coloured anorthosite gneiss with streaks and speckles (Ashmolean 1896–1908 E.401), Fourth Dynasty, from Mastaba *A (Kaimenu) at Elkab.*

of greater than 50 per cent anorthite) while the plagioclase in diorite is more sodium-rich.

Various scholars have obtained a range of plagioclase compositions. Klemm and Klemm (1993: 425) analysed a statue of Khafra in the Pelizaeus Museum, Hildesheim and determined that the plagioclase was andesine (An 30–50 per cent). Aston (1994: 62, 183) has analysed two stone vessels from Nag el-Deir and recorded finding labradorite (An 50–70 per cent). Harrell and Brown (1994: 52–4) analysed quarry samples which contained bytownite (An 70–90 per cent), and Little (1933: 78) examined quarry samples with a range of plagioclase compositions from oligoclase to anorthite (An 10–100 per cent). Therefore, until more analyses of ancient Egyptian objects made of gneiss are carried out, it is not certain which variety is predominant.

The dark gneiss is typically banded, although the blackish hornblende is sometimes fairly uniformly disseminated within the lighter feldspar matrix (Aston 1994: pl. 14a). The light-coloured gneiss with black streaks and speckles is unusual in having less than 10 per cent dark-colored minerals – a composition known as anorthosite gneiss.

The Gebel el-Asr banded gneiss has sometimes been called 'diorite' or 'Chephren/Khafra diorite' after the four statues of this stone found in Khafra's valley temple; however, these terms are incorrect and should be avoided. The distinct banding clearly indicates the metamorphic nature of the rock, i.e. it has been transformed by heat and pressure from an igneous diorite or gabbro into a metamorphic gneiss. On visiting the Gebel el-Asr quarry both Engelbach (1938: 389) and Harrell and Brown (1994: 54–5) noted a conspicuous blue glow to the gneiss in the strong sunlight. Harrell and Brown have suggested that this iridescence was the reason this stone was particularly prized, attracting the ancient Egyptians to this remote quarry.

Uses

Stone vessels are the earliest objects of gneiss known (see Fig. 2.11); these date from the late Predynastic period to the Sixth Dynasty, and were particularly common in the Third Dynasty (Aston 1994: 63–4). The Second-Dynasty king Peribsen had a gneiss stele carved for his tomb at Abydos (BM EA35597). Statues of gneiss were produced during the Old Kingdom and Twelfth Dynasty; the few examples of later date were almost certainly recarved from earlier sculptures. There is a notable lack of evidence of any New Kingdom (or later) activity at Gebel el-Asr and exploitation of the gneiss quarry would appear to have ceased at the end of the Twelfth Dynasty.

Examples

1. Seated statue of King Khafra with protective falcon from the king's valley temple at Giza, Fourth Dynasty, *c.* 2520–2494 BC (height 1.68 m; Cairo CG14).
2. Statue of King Sahura with a figure personifying the Koptos nome, Fifth Dynasty, *c.*2458–46 BC (New York, MMA 18.2.4).
3. Torso of a statue of King Senusret I, Twelfth Dynasty, *c.* 1971–26 BC (height 47.5 cm; Berlin, ÄM 1205).
4. Sphinx with the head of King Senusret III, Twelfth Dynasty, *c.*1878–41 BC (length 73 cm; New York, MMA 17.9.2).
5. Block statue of Khai-Hapy from Heliopolis, late Nineteenth Dynasty, *c.*1200 BC (height 49.5 cm; Vienna ÄS64).

Bibliography

Engelbach (1933, 1938); Little (1933); Murray (1939b); De Putter and Karlshausen (1992: 77–80); Klemm and Klemm (1993:

423–6); Aston (1994, 62–4); Harrell and Brown (1994); Shaw and Bloxam (1999).

For photographs of the Sahura and Senusret III statues (MMA 18.2.4 and 17.9.2) see Hayes (1953: 70, 197). For colour photographs see De Putter and Karlshausen (1992: pls. 19, 20: Khai-Hapy statue, statue head and vessel); Aston (1994: pl. 14: two vessels); Klemm and Klemm (1993: pl. 16.6: polished slab).

2. Granite gneiss and granite from Tumbos

In the Tumbos district at the southern entrance to the third Nile cataract in the Sudan, there is a large quarry that dates from the Eighteenth and Twenty-fifth Dynasties and the subsequent Napatan–Meroitic period. Two types of rock were extracted here, granite gneiss from the east bank on the north side of Tumbos village, Dabaki Island and near North Akkad village on the west bank, and granite from the nearby Tumbos Island.

Description

The gneiss is light yellowish to pinkish grey, medium- to coarse-grained and well-foliated with conspicuous banding, and consists of quartz, microcline and oligoclase feldspars, hornblende and biotite. It has the same composition as igneous 'granite' and so should be called 'granite gneiss'. The second rock type, which occurs as thick intrusive veins within the gneiss, is a moderate grey, fine- to medium-grained granite with essentially the same mineralogy as the gneiss.

Uses

Both rock types were used only at sites between the third and fourth cataracts in the Sudan, notably in the Napatan–Meroitic temples at Tabo and Kawa, and the New Kingdom and later temples at Gebel Barkal. They were used only for stelae, statues, offering tables and other sculptures.

Examples (granite gneiss)

1. Stele of Thutmose III from Gebel Barkal, Sudan, 18th Dynasty, *c.*1479–25 BC (height 1.73 m; Boston MFA 23.733).
2. Colossal striding statue of King Anlamani from Gebel Barkal, Sudan, *c.*623–593 BC (height 3.8 m; Boston MFA 23.732).
3. Reposing ram of Amun with King Taharqo standing between the forelegs from Kawa, Sudan, *c.*690–64 BC (height 1.06 m; BM EA1779) (another virtually identical ram is Ashmolean 1931.553).
4. Stele of an unknown Twenty-fifth-Dynasty king from Gebel Barkal, Sudan (height 1.24 m; Cairo JE 48865).
5. Stele of King Tanutamani from Gebel Barkal, Sudan, 664–53 BC (height 1.32 m; Cairo JE 48863).

Examples (granite)

1. Stele of King Tanyidamani from Gebel Barkal, Sudan, 110–90 BC (height 1.58 m; Boston MFA 23.736).
2. Recumbent sphinx with the head of King Tahar
from Kawa, Sudan, Twenty-fifth Dynasty, *c.* 690–
BC (length 75 cm; BM EA1770).

Bibliography

Dunham (1947); Harrell (forthcoming (b)).

3. Tonalite gneiss from Mons Claudianus

An enormous Roman quarry, known in antiquity as Mo
Claudianus (see Fig. 2.12), consists of over 130 excavati
sites within and between wadis Abu Marakhat, Umm Hu
sein and Umm Diqal. The quarry was worked during t
first to third centuries AD.

Description

The rock is mottled light grey and greenish black, mediu
grained 'tonalite gneiss' with oligoclase plagioclase, biot
mica and hornblende amphibole plus minor microcli
feldspar and accessory minerals (apatite, magneti
sphene and zircon). Foliation is well-developed, with t
dark minerals occurring in short, straight, parallel strea
but also in irregular patches. 'Quartz diorite gneiss'
another acceptable name for this rock because in ma
classification schemes tonalite is considered a quartz-ri
subvariety of quartz diorite. The metamorphic rock h
previously been misidentified as igneous 'granit
'granodiorite', 'quartz diorite' and 'diorite'.

Uses

The Mons Claudianus stone was exported throughout t
Roman Empire but objects made from it are especia
common in Rome and Tivoli, Italy. It was used mainly f
large whole columns and basins, and also for smaller o
jects such as pedestals and pavement tiles. Perhaps the be
known examples are the 12.2–metre-long columns (sev
of the eight) in the portico of the Pantheon in Rome.
examples of sculptures are known.

Bibliography

Kraus and Röder (1962a, 1962b); Gnoli (1988: 148–50); Peac
(1988, 1992); Marchei *et al.* (1989: 222–3); Galetti *et al.* (199
Klemm and Klemm (1993: 395–408); Peacock (1992); Peacock
al. (1994); Brown and Harrell (1995).

For colour photographs of polished slabs see: Mielsch (1985:
23–796), Lazzarini (1987: fig. 3), Gnoli (1988: fig. 112), Marche
al. (1989: fig. 72a) and Klemm and Klemm (1993: pls. 16.1–16.

4. Tonalite gneiss from Wadi Umm Huyut

Located six kilometres southwest of Mons Claudianus, t
small quarry near Wadi Umm Huyut was worked duri
the first and second centuries AD.

Description

The quarry produced tonalite gneiss that is mineralogica
and texturally identical to that from Mons Claudianus. T
two rocks do differ markedly, however, in their foliation:

Figure 2.12 Tonalite gneiss quarry at Mons Claudianus, Eastern Desert. The broken column in the foreground is eighteen metres long with a diameter of 2.6 metres.

Wadi Umm Huyut the dark minerals occur mainly in long wavy stringers, whereas at Mons Claudianus they form short, straight streaks.

Uses

It was quarried by the Romans for export from Egypt. Until very recently, the existence of the Wadi Umm Huyut quarry and its stone had gone unrecognised. Where found, the stone has undoubtedly been incorrectly attributed to Mons Claudianus. However, the diminutive size of the workings at Wadi Umm Huyut indicates that, unlike at Mons Claudianus, the rock was used for relatively small objects such as basins, pedestals and pavement tiles. The best of the few known examples of its use is a 2.1–metre-diameter basin from Porto, near Ostia in Italy, now used as a fountain on the Via dei Fori Imperiali beside the Parliament building in Rome.

Bibliography

Brown and Harrell (1995); Harrell *et al.* (forthcoming); Sidebotham (1996).

Granite and granodiorite

Definitions

'Granite' and 'granodiorite' are phaneritic igneous rocks with similar, gradational compositions. Granite consists largely of quartz and alkali feldspar (microcline or orthoclase) whereas granodiorite contains comparable amounts of quartz but less alkali feldspar. Both rock types also include variable amounts of sodic to intermediate plagioclase (oligoclase or andesine), mica (muscovite or biotite) and hornblende amphibole plus small amounts of various accessory minerals.

Egyptian sources

These rocks are widely distributed throughout the Eastern Desert and in the Nile valley where they form the cataracts in the Nile. They were quarried anciently at three localities: in the Nile valley at Aswan and Tumbos (see GNEISS); and in the Eastern Desert at Bir Umm Fawakhir (see map in Fig. 2.1).

1. Granite from Aswan

Description

Extensive outcrops of granite are found east of the Nile between Aswan and the Shellal district as well as on the islands in the river. Ancient quarrying occurred at scores of sites within this region (see Fig. 2.3). Two rock varieties were extracted.

Variety 1

Very coarse- to mainly coarse-grained granite with quartz, microcline, oligoclase and biotite plus minor hornblende and accessory minerals (mostly apatite, sphene, zircon and iron oxides). This is the so-called 'monumental red or pink granite' of Egypt. The rock is commonly porphyritic with microcline phenocrysts up to 4 cm across. When biotite is present in only minor amounts, the rock has a pinkish or occasionally reddish appearance, but when this mica is abundant the rock is much darker with a black and pink mottling. The granite commonly exhibits a pronounced parallel or subparallel arrangement of the feldspar and biotite grains. This is a type of foliation caused by magmatic flowage and such rocks may be described as 'gneissoid granite'. They could also be called 'granite gneiss' but most petrologists prefer to restrict this terminology to rocks with foliation caused by metamorphism.

The granite quarries are located mainly between the city of Aswan and the el-Shellal district to the south. Additional quarrying occurred along the east bank of the Nile between Aswan and Sehel Island, and also on Elephantine, Saluja, Sehel and other islands. Numerous objects were left in the quarries unfinished, including an Eighteenth-Dynasty obelisk (Fig. 2.4), three colossal statues of apparently New Kingdom date, and seven Roman bathtubs (see Fig. 2.3 for locations). These quarries were worked from the Early Dynastic period to the Roman period, but most of the visible remains are Greco-Roman (see Fig. 2.5).

Variety 2

Medium- to mainly fine-grained granite with a mineralogical composition identical to that of the Variety 1 granite. Phenocrysts are absent. This rock occurs as thin veins cutting Variety 1 and the Aswan granodiorite (see below), and occasionally contains fragments (xenoliths) of these rock types. The Variety 2 granite usually exhibits foliation, as evidenced by the parallel alignment of biotite flakes, and so may be described as 'gneissoid granite'. Variations in the amount and coloration of microcline cause the rock to vary from light grey or pinkish to occasionally a reddish colour.

The principal outcrops are on Saluja and Sehel islands, and on the east bank south of the latter island. No ancient quarry workings have been reported. The few that once existed may have been destroyed during construction of the 1902 dam when this rock was extensively quarried and used for fill. This granite variety was rarely used in ancient times, and the few known examples date from the New Kingdom onwards.

Uses

Buildings

The coarse pink granite (Variety 1) was initially used for building purposes in the First Dynasty for a pavement in the tomb of King Den at Abydos. From the Third to the Twelfth Dynasty Variety 1 was widely employed in pyramids for lining burial chambers and passages (for example, those for the Third-Dynasty king Djoser at Saqqara and the Fourth-Dynasty kings Khufu, Khafra and Menkaura at Giza), and also occasionally for exterior facing (as on the Khafra and Menkaura pyramids) and capstones (as on the Middle Kingdom pyramids of kings Amenemhat II and Khendjer at Dahshur and Saqqara, respectively). From the Second Dynasty onwards, Variety 1 was extensively used in temples for door frames, columns and wall linings (for example, door frames in the Second-Dynasty temple of King Khasekhemwy at Hierakonpolis, and interior wall lining and exterior facing in Khafra's valley temple at Giza).

Sculptures

Variety 1 was especially popular from the Early Dynastic period to the Roman period for private, royal and other statuary (from statuettes to colossi), sarcophagi, stelae, naoi, obelisks (New Kingdom only), and small vessels (until the end of the Old Kingdom); it was used for the same building and sculptural applications as the granodiorite from Aswan (see below), with no obvious preferences shown except in the case of the Eighteenth-Dynasty granodiorite statues of the lioness-goddess Sekhmet from the temple of Mut at Karnak, and the New Kingdom and Ptolemaic Apis-bull sarcophagi of granodiorite in the Serapeum at Saqqara. Far more granite was employed overall, however, and this is probably simply a consequence of its much greater abundance at Aswan. The Variety 2 granite was rarely used, undoubtedly because large, fracture-free blocks were difficult to obtain from the veins in which it occurred.

Examples (Variety 1: coarse pink granite)

1. Standing statue of an unknown king from Saqqara, late Fifth or early Sixth Dynasty, *c.* 2400–300 BC (height 74 cm; Cairo JE39103).
2. Colossal standing statue of the Twlefth-Dynasty ruler Senusret I, from Karnak, Thebes, *c.* 1971–26 BC (height 3.1 m; Cairo JE38287).
3. Standing statue of an unknown Eighteenth-Dynasty king, usurped by Rameses II and Merenptah, *c.* 1550–1307 BC (height 2.63 m; BM EA61).
4. Seated statue of King Sobkemsaf I, Seventeenth Dynasty, *c.* 1630 BC (height 1.64 m; BM EA871).
5. Two recumbent lions from Gebel Barkal, Sudan (the so-called 'Prudhoe lions'), but originally from Soleb, Eighteenth Dynasty, *c.* 1391–23 BC (height 1.1–1.2 m; BM EA1 & EA2).
6. Colossal head, possibly of King Amenhotep III, from Karnak, Thebes; Eighteenth Dynasty (height 2.9 m; BM E15).

Examples (variety 2: fine granite)

Very few objects made from Variety 2 are known, but some notable examples are:

1. Head and torso of a colossal statue of Rameses II from the Ramesseum at Thebes, Nineteenth Dynasty, *c.* 1290–24 BC (height 2.67 m; BM EA19) [the head is cut from fine pink granite and the torso from Aswan granodiorite, with a vein of the former cutting through the latter; many of the other examples of the use of this granite are similar in that the objects consist of both the granite and granodiorite].
2. Head and crown of the colossal seated statue of Rameses II at the entrance to the first pylon at Luxor temple. Part of the head and the rest of the body are Aswan granodiorite.
3. Relief in fine pink granite of Ptolemy II from a temple at the Delta-site of Sebennytos, near modern Samannud, *c.* 285–46 BC (height 1.32 m; Cincinnati Art Museum 1952.8).
4. Unprovenanced Greco-Roman funerary shrine (height 1.3 m; Alexandria 25774).
5. Greco-Roman stelae from Akhmim (height 74 cm; Cairo CG22034).

Bibliography

De Morgan *et al.* (1894); Ball (1907); Weigall (1910: 407–10); el-Shazly (1954); Attia (1955); Gindy (1956); Lucas (1962: 57–9, 412–3); Röder (1965); Ragab *et al.* (1978); Meneisy *et al.* (1979); Soliman (1980); De Putter and Karlshausen (1992: 81–6); Klemm and Klemm (1993: 305–53); Aston (1994: 15–18); Brown and Harrell (1998).

For colour photographs of polished slabs see: **Variety 1, coarse granite** Mielsch (1985: pl. 22–749); Lazzarini (1987: figs 1, 2); Gnoli (1988: fig. 111); Marchei *et al.* (1989: figs. 74a–b); De Putter and Karlshausen (1992: pl. 54c–10,11); Dodge and Ward-Perkins (1992: pl. 1d) and Klemm and Klemm (1993: pls. 10.1–10.6); **Variety 2, fine granite** Mielsch (1985: pl. 22–756, 769); Gnoli (1988: figs. 113–14); De Putter and Karlshausen (1992: pl. 54c–12) and Klemm and Klemm (1993: pl. 11.6).

2. Granodiorite from Aswan

Description

This so-called 'monumental black or grey granite' is coarse- to mainly medium-grained granodiorite to occasionally granite with quartz, alkali feldspar (microcline and minor orthoclase), biotite and hornblende plus minor accessory minerals (mostly apatite, zircon, sphene, ilmenite and magnetite). Data from numerous sources show that this rock varies gradationally from an alkali-feldspar-poor granite to granodiorite and rarely to tonalite and quartz monzodiorite. Because the vast majority of specimens analysed classify as a granodiorite, it is recommended that this rock name be applied to the variety as a whole. In the past, the rock has been incorrectly described as 'syenite'. This name now refers to a rock similar to granite but with much less quartz.

The granodiorite is frequently porphyritic with both pink alkali feldspar and light grey oligoclase phenocrysts up to 3 cm across. The phenocrysts vary in abundance from closely packed to absent and, as with the Variety I granite, permit the use of descriptive terms such as granodiorite porphyry and porphyritic granodiorite. Foliation is commonly seen and is evidenced by elongated, parallel-oriented feldspar phenocrysts. Such rocks should be called 'gneissoid granodiorite'. The abundant biotite and hornblende plus dark accessory minerals (ilmenite and magnetite) give the granodiorite an overall dark grey to nearly black appearance which is broken only by the light coloured phenocrysts. When phenocrysts are absent, the rock closely resembles dolerite for which it has been frequently mistaken.

The granodiorite quarries are located mainly on the south side of Aswan in the areas around Gebel Ibrahim Pasha and Gebel Togok (or Nagug). These were worked from the Early Dynastic period to the Roman period.

Uses

From the beginning of the Pharaonic period onwards, the granodiorite of Aswan was used for the same range of building and sculptural purposes as the Variety I granite described above, but in smaller quantities (see Fig. 2.13).

Figure 2.13 Granodiorite statue of an official, Twelfth Dynasty, from Athribis (BM EA1237).

Examples

1. Sphinx of the Twelfth-Dynasty ruler Amenemhat III from Tanis, *c.* 1844–1797 BC (length 2.4 m; Cairo CG394).
2. Seated statue of Queen Isis, mother of King Thutmose III from Karnak, Thebes, Eighteenth Dynasty, *c.* 1479–25 BC (height 98 cm; Cairo CG42072).
3. 'Scribe-statue' of Amenhotep son of Hapu as an old man, from Karnak, Thebes, Eighteenth Dynasty (height 1.4 m; Cairo CG42127).
4. Four Eighteenth-Dynasty statues of the goddess Sekhmet, two standing and two seated, from Karnak, Thebes, reign of Amenhotep III, *c.* 1391–53 BC (heights 2.1–2.3 m; BM EA57, 62, 76 and 80).
5. Two colossal seated statues of King Amenhotep III from his funerary temple in Thebes, Eighteenth Dynasty, *c.* 1391–53 BC (height 2.36 m; BM EA4–5).
6. The 'Rosetta stone' of Ptolemy V Epiphanes from Rosetta, Egypt, *c.* 205–180 BC (height 1.14 m; BM EA24) [this inscribed block is usually described in the literature as 'basalt' but only looks like this rock because of a fine, soot-like coating of dirt].

Bibliography

De Morgan *et al.* (1894); Ball (1907); Weigall (1910: 407–10); el-Shazly (1954); Attia (1955); Gindy (1956); Lucas (1962: 57–9, 412–13); Röder (1965); Ragab *et al.* (1978); Meneisy *et al.* (1979); Soliman (1980); DePutter and Karlshausen (1992: 81–6); Klemm and Klemm (1993: 305–53); Aston (1994: 15–18) Brown and Harrell (1998).

For colour photographs of polished slabs see: Marchei *et al.* (1989: fig. 73a); DePutter and Karlshausen (1992: pl. 54c–9 and 54d–13); Klemm and Klemm (1993: pls. 11.1–11.4).

3. Granodiorite from Bir Umm Fawakhir

Description

At Bir Umm Fawakhir, at the head of the wadis Hammamat and el-Sid, are several small Roman quarries dating probably from the first and second centuries AD. The rock is mottled pink and light grey, coarse- to mainly medium-grained granodiorite with oligoclase, quartz and microcline plus minor biotite and accessory minerals (apatite, magnetite, muscovite, sphene and zircon). It is gradational with granite, which is also abundant in the area, and some specimens may actually be granite.

Uses

It was quarried for export from Egypt by the Romans, who used it for small columns and pavement tiles. No sculptures are known.

Bibliography

Gnoli (1988: 148); Marchei *et al.* (1989: 227); Galetti *et al.* (1992); Meyer (1992: 3); Klemm and Klemm (1993: 355); Brown and Harrell (1995).

For colour photographs of polished slabs see: Mielsch (1985: pl. 23–786); Lazzarini (1987: fig. 7); Gnoli (1988: fig. 107); Marchei *et al.* (1989: fig. 75a); Klemm and Klemm (1993: pl. 16.3).

Green feldspar *see* microcline

Greywacke *see* siltstone, greywacke and conglomerate

Gypsum *see* alabaster

Haematite

Definition

An opaque iron oxide mineral (Fe_2O_3) which occurs as an accessory constituent in many rocks, having a hardness of 5.5–6.5 and colour ranging from metallic grey-black to earthy red-brown. The metallic variety is known as specular haematite or 'specularite'.

Egyptian sources

Haematite occurs virtually everywhere in Egypt, but deposits of relatively pure (and therefore extractable) haematite occur in the Eastern Desert at Wadi Abu Gerida, Gebel Abu Marwat, Wadi Dib (to the west of the Gebel Zeit galena mines) and Wadi Saga, all but the latter being the sites of Roman-period iron ore workings. On the tenuous basis of philological evidence alone, it has been suggested (Andrews 1990: 43) that haematite was quarried in the Eastern Desert from the Late Period onwards, but it was probably obtained from the Sinai peninsula or the Aswan region in earlier periods.

Description

The particular type of haematite favoured by the ancient Egyptians during the Pharaonic period was black in colour, with a metallic lustre, but its source is not known.

Uses

It was used for beads, amulets (particularly the plummet, carpenter's square and headrest amulets) and small vessels, and was particularly popular for kohl-sticks (and sometimes also kohl-vessels) in the Middle Kingdom and Second Intermediate Period. A kohl vessel excavated from the Eighteenth-Dynasty tomb of the three princesses of Thutmose III (New York, MMA 26.8.39) is probably of haematite, although this has not yet been scientifically determined.

Examples

1. Kohl vessel, Middle Kingdom (height 5.4 cm; BM EA32151);
2. Necklace consisting of haematite barrel-beads, Twelfth Dynasty, unprovenanced (length 44.5 cm; Cambridge, Fitzwilliam E.501.1954).
3. Weight in the form of a hippopotamus's head, Eighteenth Dynasty, unprovenanced (length 4.7 cm; Hildesheim, Pelizaeus Museum 5543).

Bibliography

Barron and Hume (1902: 44, 51, 86, 221–2, 225, 239, 257–9); Garland and Banister (1927: 85); Hume (1937: 849); Lucas (1962: 395); Aston (1994: 73).

For a colour photograph of a haematite vessel of the Second Intermediate Period from Tell el-Dab'a see Aston (1994: pl. 16b).

Jade

Definition

The term jade is commonly used to refer to two different minerals: (1) jadeite, which is a sodium aluminosilicate ($NaAlSi_2O_6$) with a Mohs hardness of 6.5–7, and (2) nephrite, which is a massive, fine-grained variety of tremolite or actinolite, two closely related calcium magnesium aluminosilicate minerals with variable amounts of iron ($Ca_2[Mg,Fe]_5Si_8O_{22}[OH]_2$), which have a Mohs hardness of 6.5. It should be noted that jadeite is a mineral in its own right, whereas nephrite is a variety of the minerals tremolite and actinolite. Jadeite, the rarer of the two types, can be white, green, brown, orange and even (rarely) lilac, while the more common nephrite usually ranges from green to creamy white.

Egyptian sources

Although there are some amphibole-rich rocks in Egypt which are related to nephrite, there are no known ancient or modern Egyptian sources of either jadeite or nephrite proper, therefore the few Egyptian artefacts tentatively identified as jade would probably be imports from Turkestan or Kashmir. Both green jasper and serpentinite are both easily mistaken for nephrite. Given the apparent lack of sources of jade in Egypt, it should be noted that many axes in Neolithic Europe are made from jade, but no European sources have yet been definitely identified (see, for example, Smith 1965).

Uses

There are no recently confirmed examples of either jadeite or nephrite from ancient Egypt. Lucas (1933: 182) calculated that the specific gravity of a double-bezel ring from the tomb of Tutankhamun (KV62) was 3.04, thus suggesting that it might possibly be nephrite (in which case it is most likely to have been imported from western Asia). However, Lucas also argued that various other artefacts in the Cairo museum that had been tentatively identified as 'jade', including a Predynastic axe-head (Cairo CG 14259), were probably 'amphiboles of the tremolite-actinolite group', i.e. nephrite (see Lucas 1962: 396–7). Petrie identified a New Kingdom heart scarab in the Petrie Museum, University College London, as 'true jade', supposedly by a variety of tests including the analysis of its specific gravity, but a more recent analysis of this object by the Natural History Museum, London, has revealed it to be a mixture of quartz, magnesite and dolomite (see Petrie 1917: 8, 29 and Ogden 1982: 100). Jack Ogden (pers. comm.) has identified a 'two-finger' amulet (New York, private collection) as jade, using X-ray diffraction analysis.

Bibliography

Petrie (1917: 8, 29); Lucas (1933: 182, 1962: 396–7); Ogden (1982: 99–100).

Jasper *see* chert

Lapis lazuli

Definition

Rock composed mainly of the blue alumino-silicate mineral lazurite ($[Na,Ca]_4[AlSiO_4]_3[SO_4,S,Cl]$), not to be confused with lazulite, a blue phosphate of iron and aluminium, commonly containing disseminated grains of brassy-coloured pyrite and veins or patches of white calcite. It can also sometimes contain other minerals, such as mica, haüynite and sodalite. The latter is sometimes mistaken for lapis lazuli, and is occasionally also used as a substitute, although it does not contain any pyrite. It has a Mohs hardness of 5–5.5 and occurs in calcareous rocks. The principal ancient source of lapis lazuli seems to have been the region of Badakhshan in northeastern Afghanistan, where four ancient quarries have so far been identified: Sar-i-Sang (see Kulke 1976; Wyart *et al.* 1981), Chilmak, Shaga-Darra-i-Robat-i-Paskaran and Stromby. The Badakshan lapis lazuli generally occurs as a mass of lenses and veins in marble formed from contact-metamorphosed limestone. The quarries lay at the centre of vast trade networks whereby lapis lazuli was exported to the early civilizations of western Asia and northeast Africa from at least the Fourth millennium BC (see Herrmann 1968; Payne 1968; Majidzadeh 1982).

Egyptian sources

Although lapis lazuli was used by the ancient Egyptians in relatively abundant quantities at least as early as the Naqada IIc phase of the Predynastic period (*c.* 3500 BC), there do not appear to have been any native Egyptian sources of the stone (*contra* Nibbi 1976; Vercoutter 1992: 59). The twelfth-century Arab geographer al-Idrisi (1836: 122) erroneously states that there was an ancient lapis lazuli mine near Kharga Oasis, but this would be geologically impossible, as there are no contact-metamorphosed limestones here. Hussein and El-Sharkawi (1990: 564, citing Ibrahim 1949 as their source) suggest that there is a possible occurrence of lapis lazuli in the vicinity of Uweinat Oasis in the extreme southwestern corner of Egypt, but this has not been verified.

The study of sulphur isotope ratios may be useful in establishing provenances for lapis lazuli, therefore it is possible that the precise origins of Egyptian artefacts made from this rock may eventually be elucidated. Herrmann (1968: 24) points out that 'the specimens of lapis lazuli collected at Sar-i-Sang cover a wide range of colours from a deep, almost violet blue through the royal blue of the gem quality to light blue, a turquoise and finally a few pieces of brilliant green'. Some of the earliest uses of lapis lazuli in Egyptian jewellery certainly suggest a Western Asiatic trade-link. A necklace of lapis lazuli beads in the late Predynastic grave T29 at Naqada, for instance, included a cylinder seal imported from Mesopotamia (Frankfort 1939: 293, pl. XLVIa).

Uses

From the Naqada I period onwards, lapis lazuli was used initially for beads and inlay (one of the earliest examples being an unprovenanced ivory figurine with inlaid lapis lazuli eyes, dated stylistically to the Naqada I period, BM EA32141). From the later Predynastic period onwards it was also carved into amulets and scarabs (see Aufrère 1991: II, 463–88 for a discussion of the symbolism of the stone; and see Bavay 1997 for a discussion of its socioeconomic significance).

It continued to be used for jewellery and seals, but it was used for vessels only between the Naqada III period and the Early Dynastic period (and in at least one instance in the Middle Kingdom, see example 3 below). Payne (1968: 58–9) argues that there was a temporary cessation in the use of lapis lazuli in Egypt during the Second and Third Dynasties; this apparent 200–year break in supply may possibly correspond to a dearth of lapis lazuli over a similar period of time in Mesopotamia (during Early Dynastic I), which may have been caused by a 'break in trading relations' with Badakshan (Herrmann 1968: 37). The el-Tod treasure, dating to the reign of the Twelfth-Dynasty ruler Amenemhat II, comprised a set of four bronze chests containing numerous gold and silver items as well as several lapis lazuli cylinder seals from Mesopotamia (e.g. Louvre E15214–5, E15217, E15225–7), which were presumably intended to be recycled by Egyptian craftsmen, as well as beads, unworked fragments, and large blocks of stone (e.g. Louvre E15302–3; for discussion of the el-Tod treasure see Desroches-Noblecourt and Vercoutter 1981: 140–48; Porada 1982; Maxwell-Hyslop 1995; and see also Chapter 6, this volume).

Lapis lazuli was used frequently in jewellery until the Third Intermediate Period, featuring in the jewellery placed in the tomb of Tutankhamun (KV62) and in the tombs of the rulers buried at Tanis (see Yoyotte 1987), but thereafter it became a less common element in jewellery. There is no evidence that powdered lapis lazuli was used as a pigment (see Chapter 4, this volume).

Examples

1. Female figurine discovered near the 'main deposit' at Hierakonpolis, First Dynasty, *c.* 2900 BC (height 8.9 cm; Ashmolean E.1057; see Quibell 1900: pl. XVIII.3; Garstang 1907: 135; Porada 1980, Moorey 1983: fig. 11).
2. Model pear-shaped mace head from tomb 1052 at Abusir el-Meleq, Naqada III, *c.* 3150–3000 BC (Berlin ÄM E.19050; see Scharff 1926: 30, pl. XLIX; Matthiae 1992: 2–6).
3. Kohl jar of Queen Merit, wife of Senusret III, Twelfth Dynasty, *c.* 1860 BC (height 3.3 cm; Cairo CG 18778).
4. Lapis lazuli and gold pendant of the Twenty-second-Dynasty ruler Osorkon II, *c.* 874–50 BC, probably from Tanis, consisting of a squatting figure of the god Osiris (perched on a solid block of lapis lazuli) flanked by his wife Isis and son Horus (height 9 cm; Louvre E.6204).

Bibliography

Idrisi (1836: 122); Ibrahim (1949); Lucas (1962: 398–400); Herrmann (1968: 21–57); Payne (1968: 58–61); Gundlach (1980); Ogden (1982: 100–1); Herrmann and Moorey (1983); Aufrère (1991: II, 463–88); Griswold (1992); Aston (1994: 72–3); Moorey (1994); Bavay (1997).

For colour photograph of kohl jar (Cairo CG 18778), see Aston (1994: pl. 16a); for colour photographs of necklace of Psusennes I (Cairo JE 8755–6) and pendant of Osorkon II (Louvre E.6204), see Andrews (1990: figs. 35 and 180).

Limestone

Definitions

Limestone is a sedimentary rock consisting predominately of calcite (calcium carbonate, $CaCO_3$). In Egypt, this rock contains fossils (molluscs, and especially echinoids and globigerinid and nummulitid foraminifera) plus one or more of the following impurities: dolomite (calcium-magnesium carbonate, $CaMg[CO_3]_2$); quartz (silica, SiO_2, as detrital sand and silt grains or diagenetic chert nodules); iron oxides (haematite, Fe_2O_3, or goethite, $HFeO_2$); and various clay minerals (all aluminosilicates). The dolomite-rich varieties are frequently incorrectly described as 'dolomite' when technically they are 'dolomitic limestones'. Limestone is typically light to moderate grey in colour when fresh but may be yellowish or pinkish on exposed,
weathered surfaces. The rock is relatively soft and ea
work due to the abundant calcite (Mohs hardness = 3)
generally high porosity. The 'hard' or 'indurated' l
stones sometimes described in the literature owe
greater durability to the presence of either more coa
crystalline calcite (in recrystallised limestones), dolo
(Mohs hardness = 3.5–4) or chert (in silicified limest
The lower porosity typically associated with the occurr
of these materials also contributes to the greater hard
Crystalline limestones have occasionally been misid
fied as 'marble'.

Egyptian sources

Outcrops of limestone are widespread in Egypt. From
northward to the Mediterranean coast, they occur al
continuously in the Nile valley and on the desert platea
the east and west. A total of eighty-eight ancient limes
quarries are known and these are identified, together
their ages, in Table 2.1 and on the maps in Figs. 2.1a–b
also Figs. 2.14–2.18 for photographs of individual quar
The quarries are distributed among the geologic fo
tions as follows: Tarawan (88), Serai (82–7), Drunka
81), Minia (20–39), Samalut (8–19), Mokattam (2–7)
Alexandria (1). These include all the larger and more
portant quarries and probably most of the minor
Limestone was almost always quarried close to where i
used for temples and pyramids. Where there are
structures without known quarries nearby, it can be a
pated that workings will be found if they are not b
under windblown sand or destroyed by modern quarr
In addition to the quarries, limestone is also encounter
innumerable tombs cut into this rock wherever out
occur.

It is currently not possible to use only petrograp
identify the specific quarry from which a limestone o
derives. However, formations can usually be iden
from thin sections and this provides at least a ge
geographic range for the limestone source. More det
provenance determinations may be possible using
taxonomy or rock chemistry, but much more work
to be done in developing the necessary petro
database.

Descriptions

The limestones encountered in ancient quarries and to
come from seven geologic formations. The genera
descriptions which follow are based mainly on q
samples (Harrell 1992). Both Folk (in brackets) and
ham classifications are provided, and geologic ages
given in parentheses.

1. *Tarawan Formation* (Upper Paleocene)

Moderately dolomitic, fine-grained, sometimes cl
sparsely fossiliferous, micritic mudstones with m
globigerinids, and lesser amounts of nummulitids
siliferous micrite].

Figure 2.14 Limestone quarry in Wadi Zebeida near Amarna.

Figure 2.15 Pillars inside an underground limestone quarry at Qau el-Kebir.

Figure 2.16 Limestone quarries (open-cut on the left and gallery on the right) at Qau el-Kebir

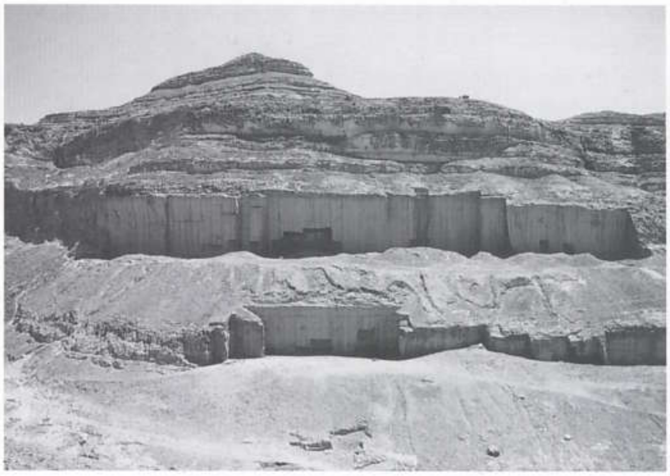


Figure 2.17 Limestone quarry at Beni Hasan.

Figure 2.18 Limestone quarry at el-Sawayta.

2. *Serai Formation of the Thebes Group* (early Lower Eocene)
Highly dolomitic, fine-grained, sometimes silty/sandy and clayey, abundantly to mostly sparsely fossiliferous mudstones, wackestones and packstones with mainly globigerinids and nummulitids [fossiliferous microsparites, and sparse to packed biomicrosparites].

3. *Drunka Formation of the Thebes Group* (late Lower Eocene)
Slightly dolomitic, fine-grained mudstones, wackestones, packstones and grainstones with mainly echinoids and non-skeletal carbonate grains, and lesser amounts of pelecypods [fossiliferous microsparites, and sparse to packed bio/oo/pel/intra microsparites and sparites].

4. *Minia Formation* (late Lower Eocene to early Middle Eocene)
Slightly dolomitic to dolomite-free, fine- to coarse-grained packstones and grainstones with mainly echinoids and nummulitids, lesser amounts of pelecypods, and exceptionally with other foraminifera (alveolinids and operculinids) dominating [packed biomicrosparites and biomicrosparudites, and biosparites and biosparudites].

5. *Samalut Formation* (early Middle Eocene)
Slightly dolomitic to dolomite-free, coarse- to mainly very coarse-grained packstones and grainstones with mainly nummulitids, and lesser amounts of echinoids [packed biomicrosparudites and biosparudites].

6. *Mokattam Formation* (late Middle Eocene)
Slightly to moderately dolomitic, fine-grained, silty/sandy, occasionally clayey mudstones, wackestones and packstones with mainly globigerinids, and lesser amounts of nummulitids and echinoids [fossiliferous microsparites, and sparse to packed biomicrosparites].

7. *Alexandria Formation* (Pleistocene)
Dolomite-free, fine-grained, occasionally silty/sandy, friable, highly porous packstones to mainly grainstones (calcarenites) with mostly non-skeletal carbonate grains (especially ooliths and coated grains) [packed oomicrosparites and oosparites].

Uses

Buildings

Limestone was perhaps the first rock used for building purposes in Egypt. The earliest examples are a possibly late Predynastic tomb at Qau el-Kebir, and some First-Dynasty tombs at Abydos and in the Memphite region. At these sites limestone was used for flooring, wall-lining and roofing in burial chambers. By the Second Dynasty it was widely employed for tombs and beginning in the Third Dynasty it was also used in the construction of pyramids and temples. Limestone continued as the principal building stone north of Thebes throughout antiquity. In the Theban region and southward it was replaced by sandstone beginning in the Eighteenth Dynasty. The southernmost limestone structures are the Third-Dynasty el-Kula pyramid near Hierakonpolis, and the Hathor temple at Gebelein dating from the Third Dynasty and later periods.

Sculptures

Although used primarily as a building stone, limestone was also widely employed for reliefs, statuary and a variety of other carved objects. This usage is more a reflection of its easy workability and availability than its aesthetic qualities. Many, if not most, limestone statues were originally painted to conceal the rock's bland appearance. The Mokattam limestone from the Tura and Maʿsara quarries, however, is of exceptional quality and was in demand throughout the Nile valley for sculptures, reliefs and pyramid casings. This rock's uniform pale grey colour and dense, fine-grained texture make it both attractive and durable. A distant second in quality are the limestones of the Serai Formation.

Limestone may have been the first rock used for statuary in Egypt, judging from the fact that various sculptures dating from either the late Predynastic period or the First Dynasty (including two colossal standing statues of the god Min) were found at Koptos, near modern Qift, and a torso deriving from a statue of similar date was found at Hierakonpolis. These sculptures are now in the Petrie Museum, University College London (the two 'Koptos lions') and the Ashmolean Museum, Oxford (the statues of Min: 1894.105c–e, a bird and a lion from Koptos: 1894.105a-b, and the torso from Hierakonpolis: 1896–1908/E.3925).

Examples

1. Stele of Rahotep from his tomb in Meidum, Fourth Dynasty, *c.* 2570 BC (height 79 cm; BM EA1242).
2. Seated figure of a scribe from Saqqara, Fifth Dynasty, *c.* 2465–2323 BC (height 51 cm; Cairo JE30272).
3. False door of Ptahshepses from his tomb at Saqqara, Fifth Dynasty, *c.* 2465–2323 BC (height 2.66 m; BM EA682).
4. Standing statue (painted) of Nenkheftka from his tomb at Deshasha, Fifth Dynasty, *c.* 2465–2323 BC (height 1.34 m; BM EA1239).
5. Colossal bust of Amenhotep III from his funerary temple in Thebes, Eighteenth Dynasty, *c.* 1391–53 BC (height 1.5 m; BM EA3).
6. Seated pair statue of a man and his wife, Eighteenth Dynasty (1.32 m high; BM EA36).

Bibliography

Lucas (1962: 52–5, 414); Meyers and Van Zelst (1977); Boukhary and Malik (1983); Mansour *et al.* (1983); Middleton and Bradley (1989); Hermina *et al.* (1989); Klitzsch (1988); Said (1990: 451–86); De Putter and Karlshausen (1992: 61–9); Harrell (1992); Klemm and Klemm (1993: 29–197); Aston (1994: 35–40).

For colour photographs of cut slabs see: Klemm and Klemm (1993: pls 1.1–5.6).

Limestone breccia

Definition

Limestone breccia is a sedimentary rock containing large, angular fragments of limestone. The term 'breccia' denotes a rock with angular fragments (in contrast to the rounded fragments in a conglomerate), but it is also essential to indicate the composition as well as the texture by prefixing the name with 'limestone'.

Egyptian sources

Limestone breccia occurs sporadically in the Nile valley and on the adjacent desert plateaux between Esna in the south and el-Minya in the north. Traces of ancient stone working have been found at Wadi Abu Gelbana, east of Akhmim (Klemm and Klemm 1993: 189), but no other ancient quarries are known.

Description

The limestone breccia used in ancient times consists of pebble-size (and, less commonly, cobble- to boulder-size) angular fragments of white or grey limestone and occasionally chert. The limestone fragments are commonly surrounded by dark red iron-rich rims, sometimes with a visibly layered structure, and they are set in a matrix of reddish brown to red, fine-grained calcite and iron oxides (haematite and goethite) with some non-carbonate impurities. Contrary to the claims of some geologists, this rock is not restricted to the top of the Issawia Formation of Pliocene age. It occurs in several Eocene limestone formations as a 'collapse breccia' formed from the collapse of the roof of a limestone cave, a feature of karst topography.

Uses

Limestone breccia was used for a wide variety of small objects in the Predynastic period, including animal figurines, maceheads, ornamental combs and gaming pieces (Petrie 1920: pls. 8:26, 26:27 and 60, 30:17, 46:32) as well as for stone vessels. It was among the earliest stones used for vessels, as it is first attested in the Naqada I period, and it occurs frequently in the First to Fourth Dynasties, although it was rarely used thereafter (only a few vessels of Middle Kingdom and New Kingdom date are known). There is one surviving statue of Late Period date (see below in list of examples).

Examples

1. Pear-shaped macehead dating to Naqada III, *c.* 3150–3000 BC (height 6.9 cm; BM EA32089).
2. Bowl of First Dynasty date from Abu Rawash, *c.* 3000–2770 (Cairo JE44332).
3. Small jar from tomb 2190 at Saqqara, dating to the Second Dynasty, *c.* 2770–2649 BC (New York, MMA 12.181.160).
4. Statue of Taweret dating to the Late Period, after 600 BC (BM EA35700; see Fig. 2.19).

Bibliography

Hermina *et al.* (1989: 213); De Putter and Karlshausen (1992: 57–8); Ahmed (1993); Klemm and Klemm (1993: 189–91); Aston (1994: 53–4).

For colour photographs see De Putter and Karlshausen (1992: pls. 8, 54a–3); Klemm and Klemm (1993: pl. 6.2); and Aston 1994: pl. 11b).

Figure 2.19 Limestone breccia statue of the hippopotamus-goddess Taweret, Late Period (BM EA35700).

Malachite

Definition

A vivid green hydrous copper carbonate ($Cu_3[CO_3]_2[OH]_2$) mineral, which occurs in the oxidation zone of copper ore deposits, often interbanded with blue azurite ($Cu_3\,[CO_3]_2[OH]_2$) and other copper-bearing materials such as green to greenish-blue chrysocolla ($CuSiO_3 \cdot 2H_2O$). It is a relatively soft gemstone, having a Mohs hardness of only 3.5–4, and effervesces in hydrochloric acid.

Egyptian sources

Malachite occurs both in the Eastern Desert and in the Sinai peninsula, with particular indications of ancient workings, alongside the procurement of copper and turquoise, at Wadi Maghara, Serabit el-Khadim, Bir Nasib and Timna, the three former in the Sinai and the latter in the Wadi Arabah, just inside the southern border of modern Israel, about thirty kilometres north of Eilat. Malachite comprised the majority of the copper ore at Serabit el-Khadim and Wadi Maghara, with azurite and chrysocolla occurring in much smaller quantities at both sites. The principal problem in interpreting the mines in the Sinai is the fact that many of the inscriptions do not make it clear whether turquoise, copper or malachite were primarily being sought by the Egyptians (or perhaps all three), and even when they clearly state the object of the expedition as the procurement of *mfkȝt*, the interpretation of this term as turquoise or malachite is still a matter of some debate (see Levene 1998). When H.G. Bachmann describes the Bir Nasib mining and smelting region, he stresses the fact that a number of copper-related materials were being exploited simultaneously: 'Bir Nasib, the largest smelting site in Sinai, is also a place of copper ore and turquoise mining . . . The small adits visible in the sandstone cliffs surrounding the smelting area . . . show green lumps consisting of malachite, paratacamite and quartz' (Bachmann, unpublished comment, quoted in Rothenberg 1987: 7).

Description

In Egyptian artefacts, malachite has occasionally been misidentified as green feldspar (see MICROCLINE) and *vice versa*, although the latter is clearly distinguished by its much higher Mohs hardness (6) and absence of effervescence in hydrochloric acid.

Uses

From the Badarian period onwards, it was primarily mined either as copper ore or in order to be ground up into powder for use as a green eye-paint. Malachite has survived in Predynastic graves not only as a pigment stain on cosmetic palettes and grinding stones but also occasionally in the form of quantities of the raw material held in small linen or leather bags (as well as the kohl itself stored in shells, reeds, leaves or jars), usually preserved among funerary equipment. The green malachite-based form of eye-paint (*wḏw*) seems to have been used only until the middle of the Old Kingdom, when it was replaced by the black galena-based form of kohl (*msdmt*; see Chapter 6, this volume, for discussion of galena mining; and see also Hassan and Hassan 1981 for an early source of galena). These ground pigments appear to have been mixed with water to form a paste and were probably applied with the fingers until the introduction of the 'kohl pencil' in the Middle Kingdom. Malachite was almost certainly also used, from at least the Fourth Dynasty onwards, as one of the essential ingredients in the production of the synthetic pigment 'Egyptian blue' (see Chapter 4, this volume). It was very occasionally used as a green pigment in its own right, although green frit seems usually to have been preferred for this purpose.

There are a number of instances of malachite beads, amulets and inlays in both the Predynastic and Pharaonic periods. There appear to be only two examples of the carving of malachite into vessels, one complete flask of unknown provenance dating to the period between th Naqada III phase and the Early Dynastic (BM EA36356 and the other a fragment from the tomb of the First Dynasty ruler Djer at Abydos (Oxford, Ashmolean 1896-1908 E.1592). There is some evidence for the trading o malachite with Crete, perhaps from the Middle Kingdom onwards (see Warren 1995: 5–10).

Examples

1. Several large, roughly worked beads from Girga, Predynastic period (Cairo JE 44488).
2. Diadem of gold, turquoise, garnet and malachite beads from the burial of a woman at Abydos, late Predynastic period, *c.* 3250 BC (overall length 31.2 cm; BM EA37532).
3. Small vessel dating between the Naqada III and Early Dynastic periods, *c.* 3150–2649 BC (height: 5.3 cm; BM EA36356).

Bibliography

Lucas (1962: 80–84, 204–5, 400–1); Ogden (1982: 101–2); Hassan and Hassan (1981: 77–82); Rothenberg (1987); Aston (1994: 71–2); Warren (1995: 5–10).

For colour photograph of a malachite vessel (BM 36356) see Aston (1994: pl. 16c).

Marble

Definition

'Marble' is a metamorphic rock consisting predominately of calcite or dolomite with subordinate amounts of any of a wide variety of other minerals. Depending on the mineralogy, the coloration can vary from pure white to any other colour or combination of colours. Textures are usually uniform and contorted internal laminations are common.

Egyptian sources

Large, workable marble deposits are known from only three localities in Egypt, all in the Eastern Desert: in Wadi Dib northwest of Hurghada, at Gebel Rokham near Wadi Mia, and in Wadi Haimur near Wadi Allaqi. In addition to these, small veins of marble occur in association with serpentinite at numerous sites in the Eastern Desert. Gebel Rokham provided the best quality marble and was closest to the Nile valley. Consequently, it alone appears to have been worked in ancient times (see map, Fig. 2.1). The ancient workings at Gebel Rokham have been destroyed by modern quarrying, but the original tailings still exist and have yielded potsherds of the New Kingdom and Roman period (Brown and Harrell 1995).

Description

The rock from Gebel Rokham is fine-grained marble consisting mainly of calcite with subordinate amounts of brucite and dolomite plus rare quartz. Most specimens exhibit distinctive thin, cross-cutting veins of two types: whiter, finer-grained, brucite-free calcite; and dark grey, graphite-bearing calcite. The carbon and oxygen isotopic ratios for the rock are +3.45 (d^{13}C) and −11.91 (d^{18}O), respectively (see Brown and Harrell 1995). In terms of its isotopic character and brucite content, this marble appears to be compositionally unique among the known white marbles quarried in ancient times in the Mediterranean region.

Uses

The only demonstrated uses of the Gebel Rokham marble are Eighteenth-Dynasty sculptures, including several statues of Thutmose III and a few other objects from the reigns of Akhenaten and Tutankhamun. White marble was used extensively for statuary during the Ptolemaic and Roman periods, and upon examination some of it may be found to come from Gebel Rokham. Most of this stone, however, was probably imported from sources in the eastern Mediterranean. A white marble was occasionally used for small vessels in the Early Dynastic period but its source is unknown.

Examples

1. Kneeling statuette of Thutmose III from Deir el-Medina in Thebes, Eighteenth Dynasty, *c.* 1479–25 BC (26.5 cm high; Cairo Museum, JE 43507A).
2. Bust of Thutmose III from Deir el-Bahari in Thebes, Eighteenth Dynasty, *c.* 1479–25 BC (face [height 18 cm]: Cairo JE90237, rest of statue [height 42.6 cm]: New York, MMA 07.230.3).
3. Marble vessel from the valley temple of Menkaura at Giza, Fourth Dynasty(?) (height 6.2 cm; Boston, MFA 11.1593; Aston 1994: 56).

Bibliography

Alford (1901: 14–15); Lucas (1962: 414–15); Ramez and Marie (1973); Lilyquist (1989); De Putter and Karlshausen (1992: 108–10); Klemm and Klemm (1993: 427–9); Aston (1994: 55–6); Brown and Harrell (1995).

For colour photograph of a polished slab see: Klemm and Klemm (1993: pl. 6.1).

Mica

Definition

The term mica is used to describe a group of potassium aluminosilicate minerals, usually with an admixture of iron and magnesium. The principal types of mica are dark brown or black biotite ($K[Mg,Fe]_3[OH,F]_2AlSi_3O_{10}$), colourless to pale yellow muscovite ($KAl_2[OH,F]_2AlSi_3O_{10}]$), coppery yellow to brown phlogopite ($KMg_3[OH, F]_2AlSi_3O_{10}]$) and pink to pale purple lepidolite ($KLi_2Al[F,OH]_2Si_4O_{10}$). They are all glistening in appearance and have excellent cleavage, usually splitting into very thin translucent sheets. Their Mohs hardness varies between 2 and 3. While biotite and muscovite are rock-forming minerals occurring in a wide variety of igneous and metamorphic rocks, phlogopite occurs mainly in metamorphic rocks, and lepidolite occurs only in igneous pegmatites. It is possible that the only form of mica used in ancient Egypt was muscovite.

Egyptian sources

Deposits of muscovite are recorded at Rod Um el-Farag in the Eastern Desert, although there is no evidence to indicate whether these were exploited in ancient times. Numerous outcrops of mica schist (a rock composed primarily of flaky grains of mica) have been identified in Eastern Desert, particularly in the Gebel Sikait region (see Hume 1934: 109–13 and Aston 1994: 61–2). A deep adit close to the Roman amethyst mines at Wadi el-Hudi, about thirty-five kilometres southeast of Aswan, was identified by Fakhry (1952: 14) as a 'mica mine', but there has not yet been any modern confirmation as to whether this is an ancient working, or even as to whether it is indeed a mica mine (see Shaw and Jameson 1993: 86).

Uses

From the Predynastic period onwards mica was used to a small extent for beads, pendants and mirrors. Most surviving examples of worked mica, however, derive from Upper Nubia during the Classic Kerma period, *c.* 1750–1500 BC, in the form of decorative plaques sewn onto leather caps. Lucas (1962: 263) notes that the collection of the Metropolitan Museum, New York, includes Middle Kingdom mica pendants and a New Kingdom necklace incorporating mica.

As far as mica schist is concerned, Aston (1994: 61) notes three instances of vessels made from this material (BM 58139, Cambridge, Fitzwilliam 94.1954 and New York, MMA 13.2816), all dating to the Predynastic or Early Dynastic periods.

Examples

1. Triangular vessel of mica schist, probably dating to the Predynastic or Early Dynastic periods (length 9 cm; BM EA58139).
2. Mica cap ornament carved in the form of four lion's heads, from Grave 1044, Tumulus KX at Kerma, *c.* 1750–1550 BC (height 5.6 cm; Leipzig, Karl-Marx Universität, Ägyptisches Museum 3792).
3. Mica cap ornaments (displayed on a restored cap) from Kerma, *c.* 1750–1550 BC (height of cap 13.3 cm; Boston MFA 20.1768).

Bibliography

Reisner (1923: 272–80); Fakhry (1952: 14); Hayes (1953: 20; 1959: 193); Lucas (1962: 262–3); Wenig (1978: 150–2); Shaw and Jameson (1993: 86).

For colour photograph of a mica schist vessel (BM 58139), see Aston (1994: pl. 13b).

Microcline (amazonite)

Definition

Feldspar is a mineral group which makes up 60 per cent of the earth's crust. The group consists of calcium, sodium or *potassium aluminosilicates, but there are two main types:* (1) sodium-potassium alkali (or potash) feldspars, mainly consisting of microcline and orthoclase ($KAlSi_3O_8$), and (2) sodium-calcium plagioclase feldspars. Besides the common pink to light gray alkali feldspars found in granite and other igneous rocks, there are two gemstone varieties: moonstone (an opalescent form of orthoclase which is transparent to translucent and yellowish-brown to bluish-white) and amazonite (or amazonstone, a form of microcline which is opaque and green to bluish green).

Egyptian sources

Amazonite is found mainly in the Eastern Desert in the area of Wadi Higelig and Gebel Migif, about forty kilometres to the west of Gebel Zubara (see Ball 1912: 272). It is also found in the Libyan Mountains north of Tibesti (Dalloni and Monod 1948: 133, 153–4), although there is no proof that the latter source was actually exploited by the ancient Egyptians. Hussein and El-Sharkawi (1990: 563–4) report that it occurs in pegmatite veins intruded into the gneisses of Gebel Migif and Wadi Gimal, and that it also occurs as a constituent of the metasomatically altered gneisses of Abu Rushaid.

Description

Amazonite was one of the Egyptians' six most precious stones, and inscriptions during the Pharaonic period often associate it with turquoise and lapis lazuli. The colour of amazonite derives from the presence of traces of lead and crystalline water. It has frequently been confused with other green stones such as turquoise or beryl.

Uses

It was carved into small beads from the Predynastic period onwards, with a particular peak of popularity in the jewellery of the Middle Kingdom. It was also used for amulets, inlay and small vessels in the New Kingdom.

Examples

1. Early First-Dynasty green amazonite vase, originally gilded on the neck, from Abydos, *c.* 2900 BC (height 7.3 cm; BM EA4711).
2. Small amazonite kohl-pot from the tomb of the 'three wives of Thutmose III' in Wadi Gabbanet el-Qirud, western Thebes, Eighteenth Dynasty, *c.* 1479–25 BC (New York MMA; see Winlock 1948: 51).
3. Unprovenanced amazonite amulet carved in the form of a seated anthropomorphic figure of Amun, dating to the Napatan period, *c.* 785–270 BC (height 8.4 cm; Munich, Staatliche Sammlung Ägyptischer Kunst ÄS6293).

Bibliography

Ball (1912: 272); Dalloni and Monod (1948: 133, 153–4); Lucas (1962: 393–4).

Obsidian

Definition

The term obsidian is used to describe a volcanic gl formed from magma which has cooled too rapidly minerals to crystallise. It is usually felsic in compositi and is commonly black in colour, although it may brown, red or colour-banded. It has a characteristic c choidal fracture and a glassy lustre, and while opaque in mass, it is translucent at the edges. Its Mohs hardness 5–5.5.

Sources

Lucas (1942, 1947) published the first substantial co parisons between the physical properties of obsidian jects from Egypt and samples from possible source lo tions. He concluded that the density and refractive ind of most Egyptian objects corresponded with sources Abyssinia (modern Ethiopia and Eritrea), but did not c relate with any of the Mediterranean, Armenian or A bian sources tested. Since the 1960s, modern analytic methods such as optical emission spectroscopy, neutr activation analysis, x-ray fluorescence and electron mic probe analysis have been employed to characterise obsi ian based on its major, minor and trace element conte Distribution patterns for obsidian from the Mediterrane and Near Eastern sources have been outlined (Zari 1989: 341), but the range of these objects does not appe to extend south of southern Israel or into the Sinai. Obsi ian sources in the Arabian peninsula and Eritrea are n so well documented, but Tykot (1996) reports that thr New Kingdom objects match the composition of a samp from Arafali on the Buri peninsula in Eritrea. Obsidia from sector TKY–5 in the Dhamar-Reda area in Yeme also has a high barium content, characteristic of the Egy tian samples, but other trace elements present in th Egyptian pieces correspond with the Arafali rather tha the Yemeni obsidian.

In an ongoing provenancing study of Egyptian obsidia Bavay *et al.* (2000) have used laser-ablation inductive coupled plasma mass spectrometry to analyse a vessel fra ment from the Early Dynastic royal cemetery at Abydo (Brussels, Musées Royaux d'Art et d'Histoire E4833a), a well as a number of artefacts from Ethiopia and Syria. Th results indicate that the northern part of the East Africa Rift Valley in Ethiopia was the most probable source for th Abydos vessel, given that two trace element ratios (Th/T and Th/U) were found to be very similar in the Egyptia and Ethiopian samples, and quite different from thos found in the Syrian artefacts. The same team is currentl analysing further Predynastic and Early Dynastic objects, a part of a more general study of trade patterns in the Earl Bronze Age (see Bavay 1997).

Thus recent analyses tend to corroborate Lucas' contention that most of the obsidian found in Egypt originated in Ethiopia. It is possible, however, that different results might be obtained if samples from Lower Egypt were analysed, since an Upper Egyptian site such as Abydos might have been more likely to obtain obsidian from an African source, whereas a Delta site might have been more accessible to Asiatic sources (Laurent Bavay pers. comm.). Furthermore, obsidian sources throughout the Red Sea region still need further investigation.

Description

Nearly all of the imported obsidian found in Egypt is of a pure jet-black variety. Lucas records one finger amulet of Twenty-sixth-Dynasty date, the dull grey appearance and physical properties of which correspond to obsidian from Melos, and indeed, the presence of some obsidian from Aegean sources would not be remarkable in Egypt during the Late Period.

Uses

Obsidian was imported into Egypt beginning in Naqada I, and occurs in the Predynastic period as flakes and blades (including sickle blades), beads, pendants and as one material of fish-tail knives (Zarins 1989: 361–5). Obsidian vessels of First-Dynasty date have been found in the large *mastaba*-tomb excavated by de Morgan (1897) at Naqada, and in several of the royal tombs at Abydos. A fragmentary obsidian dish in the shape of a hand was discovered in the tomb of Den, recently re-excavated by the German Archaeological Institute, Cairo.

There is a notable lack of evidence for obsidian from the Second to Fourth Dynasties, but it reappears as a material for the pupils of inlaid eyes beginning in the Fifth Dynasty (Saleh and Sourouzian 1987: no. 47). Further examples of obsidian used for the inlaid eyes of statues survive from the Sixth Dynasty, while obsidian eye inlays of Middle Kingdom and New Kingdom date commonly derive from coffins and masks, and this usage continued into the Roman period (Wainwright 1927: 88, 91).

Model vessels in 'opening of the mouth' sets were occasionally made of obsidian during the Sixth Dynasty, and a small number of cosmetic vessels of obsidian survive from the Middle Kingdom, Second Intermediate Period and New Kingdom (Aston 1994: 25, 140). Amulets and scarabs were also made of obsidian, beginning in the Middle Kingdom, and three obsidian sculptures of Middle Kingdom date and four of the New Kingdom are known (Wainwright 1927: 88, 91; Lacovara *et al.* 1996: 174).

Examples

1. Pupils of inlaid eyes in copper statues of Pepi I and his son(?), Sixth Dynasty, *c.* 2289–46 BC (overall height of Pepy I statue 1.77 m; Cairo JE33034; Quibell and Green 1902: pls. 50–4).
2. Obsidian and gold mirror handle of Sithathoriunet from her tomb at Lahun, inlaid with cornelian, faience and electrum, dating to the reigns of Senusret II–Amenemhat III, *c.* 1897–1797 BC (height of whole mirror 28 cm; Cairo CG52663; JE44920; Brunton 1920).
3. Five cosmetic vessels of Merit from her tomb at Dahshur, dating to the reigns of Senusret III–Amenemhat III, *c.* 1878–1797 BC (heights ranging from 45 to 70 cm; Cairo CG18772–6; de Morgan 1895: pls. 25.60–62).
4. Face, ear and fragments of foot and neck(?) of a life-size (presumably composite) statue of Amenhotep III from the Karnak cachette, *c.* 1391–53 BC (face, foot and neck: Cairo CG42101; ear: Boston MFA 04.1941; see Tykot 1996).

Bibliography

Wainwright (1927); Lucas (1942, 1947, 1962: 415–16); Zarins (1989); De Putter and Karlshausen (1992: 111–13); Aston (1994: 23–6); Lacovara *et al.* (1996); Tykot (1996); Bavay *et al.* (2000).

For colour photographs see Saleh and Sourouzian (1987: nos. 5:1, 113) and De Putter and Karlshausen (1992: pl. 40).

Olivine (peridot)

Definition

A silicate mineral, also known as chrysolite, which occurs in two compositional subvarieties: iron-rich fayalite ($FeSiO_4$) and magnesium-rich fosterite (Mg_2SiO_4). It has a Mohs hardness of 6.5–7. The transparent gem variety of olivine is known as peridot (perhaps from the Arabic *faridat*: 'gem'). Peridot (which may be either fayalite or fosterite, but not a combination of both) is coloured yellow-green, olive-green or greenish brown although its typical appearance is a warm yellowish green (caused by a relative dearth of iron). It almost always forms in mafic and ultramafic igneous rocks such as serpentinite.

Egyptian sources

Olivine occurs commonly as minute grains in basalt and as such is found at various locations in the Eastern and Western deserts. However, the only known Egyptian source for the larger crystals of peridot is the island of Zabargad (St John's Island) situated in the Red Sea, about eighty kilometres southeast of the Ptolemaic and Roman port of Berenike (Couyat 1908; Keller 1990: 119–27). The island consists mostly of mafic and ultramafic rocks, and it is in the latter that the peridot occurs. This island appears also to have been the principal source of peridot for the whole ancient Mediterranean region. In the Roman period, Scipio and Strabo knew peridot as 'topaz' (a term now used by geologists to refer to a different mineral).

Uses

From the Predynastic period onwards, olivine was used for jewellery (beads, pendants and amulets), but peridot does not appear to have been used until the Ptolemaic period, when it became a popular material for intaglios and cabochons. An Eighteenth-Dynasty scarab identified by Petrie (1917: 8) as peridot has not yet been subjected to modern analysis. Peridot has often been misidentified as green beryl (emerald).

Examples

1. Late Predynastic (Naqada II) necklace of olivine beads from Mostagedda (BM EA63100).
2. Late Predynastic (Naqada II) olivine pendant, forming part of an anklet from Matmar (BM EA63695).

Bibliography

Couyat (1908); Wainwright (1946); Lucas (1962: 390, 402); Ogden (1982: 102–4); Keller (1990: 119–27).

For colour photograph of fine cut peridot (as well as crystals and rough mass) from St John's Island, see Woodward and Harding (1987: 30).

Onyx *see* chalcedony

Peridot *see* olivine

Porphyry, volcanic: andesite, dacite, trachyandesite and others

Definition

'Porphyry' is a textural term applied to volcanic igneous rocks which consist of phaneritic crystals (phenocrysts) floating in an aphanitic groundmass. Volcanic porphyries occur in a wide variety of rock types. Those used in ancient Egypt are mainly dacite, trachyandesite and especially andesite. When the phenocrysts constitute over 20 volume per cent, the rock is described as a 'porphyry', and if the phenocrysts make up only 10–20 per cent, it is described as being 'porphyritic'. The name of the rock type must be used in conjunction with 'porphyry' or 'porphyritic' to indicate the composition of the rock.

Egyptian sources

Volcanic porphyries are widely distributed in the mountains of the Eastern Desert and are especially abundant in the region northwest of Hurghada. Only two ancient quarries are known and both date from the Roman period: Gebel Dokhan (Mons Porphyrites, see Fig. 2.20), and Wadi Umm Towat (see maps in Figs. 2.1a–b). The sources of other porphyries used for vessels in the Predynastic and Early Dynastic periods (see Fig. 2.21) are unknown.

1. Andesite-dacite porphyry from Gebel Dokhan (Mons Porphyrites)

Description

On the eastern flank of Gebel Dokhan, high on the hillslopes on the west and east sides of Wadi Abu Maamel, are six quarrying areas collectively called Mons Porphyrites by the Romans. From north to south, those on the west side are the northwest, west (or Lycabettus) and southwest (or Rammius) quarries (see Fig. 2.20); and those on the east side are the northeast, east and southeast (or Lepsius) quarries. These were all worked from the middle of the first to the late fourth century AD. The porphyry varies in composition from trachyandesite and trachydacite to mainly andesite and dacite. Three varieties were extracted and these are distinguished by their colour.

Figure 2.20 *Gebel Dokhan (Mons Porphyrites), Eastern Desert, with the southwest (left arrow) and west (right arrow) quarries from which the purplish-red 'imperial' andesite-dacite porphyry was extracted. Note the Roman causeway descending on the right from the west quarry.*

Variety 1: purplish-red porphyry

This rock has a purplish-red aphanitic groundmass of oligoclase-andesine and hornblende with minor biotite and accessory minerals (mainly magnetite). The phenocrysts are medium-grained oligoclase-andesine (up to 3 mm across) with colours of either pale pink to mainly white (northwest quarry) or all pink (west, southwest and southeast quarries). The groundmass is coloured by haematite

Figure 2.21 *Andesite porphyry vessel, late Predynastic or Early Dynastic period (BM EA35304).*

(red) and piemontite (pinkish-purple), and the latter mineral is also responsible for the pink colour of the phenocrysts. In part of the west quarry, a brecciated porphyry was extracted. Variety 1 is the so-called 'imperial porphyry' of ancient Rome and most of the rock quarried at Mons Porphyrites is of this variety. The Romans called it *lapis porphyrites* (purple stone) and it is from this term that the modern words 'porphyry' and 'porphyritic' derive.

Variety 2: greenish-black porphyry

This rock, which comes only from the east quarry and one of the excavations in the northwest quarry, has a greenish-black aphanitic groundmass, and pale green and white medium-grained phenocrysts (up to 5 mm across). It has the same mineralogy as Variety 1 except that it lacks haematite and piemontite but contains abundant chlorite and epidote. It is these latter two minerals that give the rock its green coloration.

Variety 3: black porphyry

This variety comes only from the northeast quarry and one of the excavations in the northwest quarry. It has a black aphanitic groundmass, pale green to mainly white medium-grained phenocrysts (up to 5 mm across), and the same mineralogy as Variety 2 except that chlorite and epidote are rare. The Romans apparently called it *lapis porphyrites nero*.

Uses

Buildings

All three varieties were quarried for export from Egypt by the Romans, who used them for pavement and wall tiles as well as, in the case of the imperial porphyry, small whole columns and drums for larger columns.

Sculptures

The Romans made extensive use of the imperial porphyry for sarcophagi, basins and statues, and this same variety was also occasionally used for small vessels during the Early Dynastic period, although no Early Dynastic workings have yet been identified in the Gebel Dokhan area. They may have been destroyed by Roman quarrying, or perhaps the rock was not quarried and the abundant boulders of imperial porphyry found in the nearby *wadis* were used instead. Alternatively, the material for the stone vessels may have been obtained from other localities in the northern part of the Eastern Desert where the same rock type can be found as, for example, in Wadi Umm Esh in the Esh-Mellaha range near Hurghada.

Examples (all Variety 1)

1. Fragmentary bowl with vertical fluting, from tomb Q80 at Ballas, Early Dynastic period (height 16.1 cm, diameter 23.7 cm; Petrie Museum UC5989).
2. Half of a vessel lid from the Step Pyramid at Saqqara, Early Dynastic period (Cairo JE69493).
3. Torso of a draped female figure from Italy, second century AD (BM GR1947.12–29.2).
4. Column fragment from Egypt, Roman period (length c. 3 m; BM GR1802.7–10.3).
5. Bust of a Roman emperor (possibly Maximinus) from Benha, c. AD 300 AD (height 23 cm; Cairo JE10176).
6. Headless colossal seated statue, possibly of Pantocrate, from Alexandria, Roman period (height 2.82 m; Alexandria 5934).

Bibliography

Hume (1934: 276–84); Andrew (1938); Meredith and Tregenza (1950); Lucas (1962: 417–18); Kraus *et al.* (1967: 157–99); Gnoli (1988: 122–3, 133–5, 138); Klein (1988: 55–88); Marchei *et al.* (1989: 272, 274, 278); De Putter and Karlshausen (1992: 119–21); Klemm and Klemm (1993: 387–95); Harrell (1995); Aston (1994: 21–3); Peacock and Maxfield (1994, 1995, 1996); Brown and Harrell (1995).

For colour photographs of polished slabs see: Variety 1 – Mielsch (1985: pl. 21–698, 702); Gnoli (1988: figs. 90–1); Marchei *et al.* (1989: fig. 116a); De Putter and Karlshausen (1992: pl. 54f–23); Dodge and Ward-Perkins (1992: a in pl. 1) and Klemm and Klemm (1993: pls. 14.1–15.1); Variety 2 – Mielsch (1985: no. 714 in pl. 21), Gnoli (1988: fig. 93); Marchei *et al.* (1989: fig. 120a); Klemm and Klemm (1993: pl. 15.3); and Variety 3 – Mielsch (1985: pl. 21–719); Gnoli (1988: fig. 92) and Marchei *et al.* (1989: fig. 114a).

2. Trachyandesite porphyry from Wadi Umm Towat

Description

In Wadi Umm Towat, on the southwestern flank of Gebel Dokhan, is a small Roman quarry of indeterminate age but probably dating from the first two centuries AD. The rock is a trachyandesite porphyry with moderate grey, medium- to coarse-grained andesine phenocrysts (most less than 1 cm across) and white quartz amygdules (up to 1.5 cm across). The black, aphanitic groundmass consists of andesine plus minor pyroxene and rare magnetite.

Uses

This rock was quarried for export from Egypt by the Romans but was little used. The few known examples include small columns and pavement tiles. No sculptures are known.

Bibliography

Scaife (1935); Gnoli (1988: 139); Marchei *et al.* (1989: 276); Brown and Harrell (1995).

For colour photographs of polished slabs see: Gnoli (1988: fig. 94); Marchei *et al.* (1989: fig. 118a).

3. Andesite porphyries from other sources

Description

A further four varieties of andesite porphyry with generally white phenocrysts and black groundmass appear among the stones used by the ancient Egyptians. The first variety is characterised by very large (up to 3 cm long) rectangular white feldspar phenocrysts, fairly sparsely scattered within the black matrix (Aston 1994: pl. 3a Type A; De Putter and Karlshausen 1992: pl. 46), while the second variety contains more numerous but much smaller (about 1 cm long) phenocrysts (Aston 1994: pl. 3b Type B). The third variety has elongated feldspar phenocrysts (about 1–2 cm long) commonly forming clumps of crystals. Some examples also contain numerous round green amygdules (Aston 1994: pl. 4a Type C; De Putter and Karlshausen 1992: pl. 54g–25). The fourth variety is densely packed with phenocrysts (most 0.5–2 cm long) having a greenish tint (De Putter and Karlshausen 1992: pls. 47, 54g–26). No quarries for the first three varieties have been located, but the rock almost certainly comes from the Eastern Desert, where similar porphyries are common. For example, Aston's Type C andesite porphyry exists on Gebel el-Hammaliya in the Esh-Mellaha range near Hurghada. There is no evidence of quarrying here, but boulders of porphyry are abundant in the ravines draining into Wadi Umm Dirra el-Qibli and these may perhaps have been used for the small number of objects which are known. The quarry for the fourth variety of porphyry has been discovered at Rod el-Gamra, near Gebel Urf Hamam, in the southern Eastern Desert (Harrell and Brown, 1999).

Uses

Aston's Type A porphyry is restricted to the period from Naqada III to the Second Dynasty, and was used for vessels, maceheads, animal figurines and weights. Vessels made from her Type B variety date from the middle of the Predynastic through the Early Dynastic period and possibly into the Old Kingdom. Aston's Type C porphyry is only known from the Predynastic period and the First Dynasty, when it was used for vessels and animal figures, while her Type D variety was used in the Late Period (e.g. two Thirtieth-Dynasty statues in the Louvre, see De Putter and Karlshausen 1992: 124, pl. 47).

Examples

1. Jar from tomb 1257 at Naqada, dating to the Naqada II period, *c.* 3300–3100 BC (height 13 cm; Ashmolean 1895.166), Type B porphyry.
2. Frog statuette dating from the late Predynastic period to the early First Dynasty, *c.* 3100–2900 BC (height 12.3 cm; BM EA66837), Type C porphyry.
3. Large shouldered jar dating to the Early Dynastic period, *c.* 3000–2649 BC (height 29.9 cm; BM EA35698), Type A porphyry.
4. Rectangular dish from the Step Pyramid galleries, Saqqara, dating to the Early Dynastic period, *c.* 3000–2649 BC (Cairo JE88382), Type A porphyry.
5. Dish from the Step Pyramid galleries, Saqqara, dating to the Early Dynastic period, *c.* 3000–2649 BC (Cairo JE88385), Type C porphyry.
6. Head of a man with shaved head, dating to the Thirtieth Dynasty, *c.* 380–43 BC (height 13.5 cm; Louvre E10973), Type D porphyry.

Bibliography

De Putter and Karlshausen (1992: 122–4); Aston (1994: 21–3).

Prase *see* quartz, 4

Quartz (amethyst, milky quartz, prase, rock crystal, citrine, rose quartz, smoky quartz)

Definition

Quartz (silicon dioxide, SiO_2) is one of the commonest minerals in the Earth's crust. It has a Mohs hardness of 7, making it one of the hardest materials worked by the ancient Egyptians. Pure quartz is either white, due to abundant minute water-filled vacuoles (i.e. milky quartz) or, when vacuole free, colourless (i.e. rock crystal and macrocrystalline aggregates lacking crystal form). Chemical impurities have produced a wide range of quartz gemstones, each with distinctive colours, patterns or optical effects, including amethyst, citrine, rose quartz and smoky quartz. The colours of these gems can sometimes fade over time.

'Massive' (i.e. high purity) deposits of quartz occur in the form of two different types of depost: (1) vein quartz, which is formed by the intrusion of a silica magma into a fracture (only in igneous and metamorphic rocks), and (2) cavity-filling quartz, which is formed by the precipitation of quartz inside an open cavity from silica-rich, usually hydrothermally charged, ground water (in any kind of rock). Rock crystal is the colourless form of cavity-filling quartz. Vein quartz is therefore the term used to describe any kind of quartz that occurs in an intrusive igneous vein; it can be colourless, milky white or pink in colour. When it occurs alone as a white rock (i.e. milky quartz), it is commonly described by geologists as 'hydrothermal quartz', which is a reference to the abundant water-filled vacuoles that produce the milky colour. Aston (1994: 65) notes that Egyptian artefacts made from milky quartz have often been identified incompletely as 'crystal' (e.g. Ashmolean 1896–1908 E.1144, 1185, 1245–6, 1311, 1677) or wrongly as 'quartzite' (e.g. BM EA64357; New York, MMA 66.99.2; Cambridge, Fitzwilliam 274.1954).

Bibliography

Frondel (1962).

1. Amethyst

Definition

A translucent violet-coloured, macrocrystalline form of quartz in which the colour is produced by the presence of trace amounts of ferric oxide. 'Amethystine quartz' is a compact formation of amethyst, usually streaked and banded with milky quartz.

Egyptian sources

Amethysts were being used in Egyptian jewellery (and amethystine quartz for small vessels) from the late Predynastic period onwards. The mines in the Stele Ridge area of the Gebel el-Asr gneiss quarries are a possible early source, although all of the known pottery from the quartz-mining part of the site dates to the Middle Kingdom or Roman period (see Engelbach 1933: 69 and Little 1933: 77 for discussion of amethystine quartz at Gebel el-Asr). Another early source, dating to at least the First Dynasty, is suggested by the results of a survey in the Wadi Abu Had, in the northern part of the Eastern Desert (Bomann 1995).

The Wadi el-Hudi region, covering an area of *c.* 300 square kilometres in the Eastern Desert, about thirty-five kilometres southeast of Aswan, was the primary location for amethyst mining in Egypt from the Eleventh Dynasty until the end of the Middle Kingdom, during which time the use of amethysts in jewellery reached a peak of popularity (see Fakhry 1952; Sadek 1980–5; Shaw and Jameson 1993; Shaw in press (a)). It has been exploited for its minerals (including barytes, gold, amethyst and possibly also mica) since at least the early second millennium BC, and modern miners and quarriers are still extracting haematite and building stone from the immediate area. The amethyst occurs in cavities in the granite.

The mines at Wadi el-Hudi were rediscovered by the geologist Labib Nassim in 1923 (Nassim 1925), but the first proper archaeological examination of the site did not take place until 1939, when it was visited by G.W. Murray and Ibrahim Abdel ʿAl of the Egyptian Topographical Survey (see Rowe 1939). Sites 5, 6 and 9, in the western part of the region, constitute an area of intense Middle Kingdom mining activity. Site 5 consists of a hilltop miners' settlement and an adjacent amethyst mine. The L-shaped amethyst mine at site 5 – perhaps better described as an open-cut quarry – is located at the southern end of the hilltop settlement. The deposits of amethyst appear to have been completely worked out in the Pharaonic period. Incorporated into the walls of the adjacent settlement are numerous rock-carvings and inscriptions, five of which are securely dated to the first two years of the reign of Nebtawyra Mentuhotep IV, the last ruler of the Eleventh Dynasty. The pottery, present in large quantities throughout the settlement, also dates mainly to the early Middle Kingdom. Site 9 is a large rectangular stone-built fort, probably dating to the Twelfth Dynasty. To the northeast of the fort are two amethyst mines, while to the northwest there is a short, well-preserved section of ancient road. Roughly midway between sites 5 and 9 is a conical hill, the summit of which is decorated with many inscriptions and rock-carvings, mainly dating to the Middle Kingdom (site 6). There is some evidence for the continued exploitation of amethyst at Wadi el-Hudi after the Middle Kingdom: site 12, for instance, is almost certainly an amethyst mine of the Roman period (Shaw and Jameson 1993: 86; Shaw in press (b)). During the late Middle Kingdom the principal Egyptian amethyst mines may possibly have been located at the northern end of the Gebel el-Asr gneiss quarries (the so-called 'Chephren diorite quarries'), about sixty-five kilometres northwest of Abu Simbel (see Engelbach 1938: 370; Murray 1939a: 105; Lucas 1962: 389; Shaw and Bloxam 1999; Shaw in press (a)).

In the New Kingdom, amethyst was less commonly used for personal adornment, and it is even possible that there was a temporary dearth of known sources. By the Roman period, however, they had apparently regained their popularity (or availability), and, apart from site 12 at Wadi el-Hudi, there are Roman amethyst quarries in the Safaga region near Gebel Abu Diyeiba (midway between the phosphate mines of Wasif and Umm Huetat), where the amethyst has formed in cavities in the red granite following the courses of quartz veins reportedly extending for hundreds of metres (Murray 1914: 179; Lucas 1962: 389). In modern Egypt the natural reserves of amethysts appear to have been virtually exhausted, and they now have to be imported from South America.

Description

It is difficult to determine the precise character of the amethyst mined at Wadi el-Hudi, since the stone is now completely worked out, but judging from the surviving Middle Kingdom jewellery incorporating amethyst beads, it was of a dark violet hue. The amethysts reported by Engelbach at the Gebel el-Asr gneiss quarries appear to be of a much paler colour, and according to Ogden (1982: 107), 'some Egyptian amethysts are so pale they could almost pass for rose quartz'.

Uses

Amethyst was primarily used as a gemstone, and is almost entirely restricted to items of jewellery dating either to the Middle Kingdom or the Roman period, although there are a few instances of its use for beads and small vessels between the late Predynastic period and the end of the Old Kingdom. It was, however, also occasionally used for small vessels (in the Predynastic and Early Dynastic periods) or small amulets (mainly in the Old Kingdom). There is a certain amount of evidence for the trading of amethyst with Crete from at least the Middle Kingdom onwards (perhaps in exchange for such products as animal horns, oils and lichen, see Warren 1995: 5–10).

Examples

1. Vessel from the Step Pyramid at Saqqara, dating to the Naqada III period or Early Dynastic period, *c.* 3150–2649 BC (height 9 cm; Cairo JE65416).
2. Gold, amethyst and turquoise bracelet from the tomb of King Djer at Abydos, First Dynasty, *c.* 3000–2770 BC (length 15 cm; Cairo JE52010).
3. Falcon amulet dating to the Old Kingdom, *c.* 2649–2152 BC (height 1 cm; BM EA57803).

4. Twelfth-Dynasty gold and amethyst girdle from the tomb of Sithathoriunet (in the vicinity of the pyramid of Senusret II at Lahun), dating to the reigns of Senusret II–Amenemhat III, *c.* 1897–1797 BC (length 82 cm; New York, MMA 16.1.16, Brunton 1920).

Bibliography

Murray (1914, 1939a); Nassim (1925); Engelbach (1938); Rowe (1939); Fakhry (1946, 1952); Frondel (1962: 171–81); Lucas (1962: 388–9); Sadek (1980–85); Shaw and Jameson (1993); Aston (1994: 66–7); Bomann (1995); Warren (1995: 5–10); Shaw in press (a), (b).

For colour photograph of the amethyst vessel Cairo JE65416 see Aston (1994: pl. 15).

2. Milky quartz

Definition

Cloudy white form of vein quartz, the milky hue of which is caused by abundant, disseminated, submicroscopic vacuoles or cavities filled with ion-charged water.

Egyptian sources

Milky quartz is abundant virtually everywhere that there are outcrops of igneous and metamorphic basement rocks in Egypt. It is also a common constituent of the modern *wadi* gravels between these outcrops and the Nile valley; the many ancient river deposits in the Nile valley contain large amounts of gravel including many milky quartz clasts. According to Ball (1907: 84–5) there are indications of ancient milky quartz workings to the north of Aswan.

Uses

From the Naqada III period until the end of the Early Dynastic period, milky quartz was frequently carved into pendants and funerary vessels, the latter particularly at Abydos and the Memphite necropolis. It was also used for the model vessels employed in the funerary ceremony of the 'opening of the mouth' in the Fourth to Sixth Dynasties, and became a popular material for inlay and beads in the Middle Kingdom. Many of the red inlays in the jewellery of Tutankhamun have been identified as milky quartz or rock crystal placed over a bed of red cement, probably in imitation of cornelian or red glass.

Examples

1. Late Predynastic or Early Dynastic statuette of a recumbent lion, perhaps from Gebelein; *c.* 3100–2900 BC (length 25 cm; New York, MMA 66.99.2).
2. Miniature vessel from tomb E21 at Abydos; Sixth Dynasty, *c.* 2250 BC (height 8.1 cm; Ashmolean 1910.488a).

Bibliography

Ball (1907: 84–5); Little (1933: 77); Frondel (1962: 189–92); Lucas (1962: 402–3); Aston (1994: 64–5).

For colour photograph of a milky quartz vessel, see Aston (1994: pl. 15a).

3. Rock crystal

Definition

Colourless, transparent form of quartz, which is sometimes described as 'quartz crystal', especially when it occurs in its distinctive six-sided, prismatic crystal form.

Egyptian sources

Rock crystal is reportedly found in the region of the Western Desert between the Fayum and Bahariya Oasis, as well as in the Sinai peninsula.

Uses

Used from the Predynastic period onwards for beads and small vessels. From the Old Kingdom onwards it was regularly used for the corneas of artificial eyes on statuary and coffins, as well as for the miniature vessels serving the 'opening of the mouth' ritual. In the New Kingdom it was frequently used for inlay (sometimes over red cement so as to imitate cornelian) and as a decorative component of prestige goods such as weaponry or funerary equipment. Lucas (1962: 403) argues that Tutankhamun's iron dagger, with its rock crystal pommel, may have been an import. On the other hand, there appears to be some evidence that rock crystal, like malachite and amethyst, was being exported to Crete as a raw material (see Warren 1995: 5–10).

Examples

1. Corneas in the inlaid eyes of a squatting scribe statue, Fourth Dynasty, *c.* 2575–2465 BC (Cairo CG36).
2. Amulet carved into the shape of a baboon, unprovenanced, Twelfth Dynasty, *c.* 1991–1783 BC (Fitzwilliam E.121.1939).

Bibliography

Frondel (1962: 192–4); Lucas (1962: 402–3); Aston (1994: 64–5); Warren (1995: 5–10).

4. Other types of quartz (rose, smoky, citrine, prase)

Definition

The pink (and occasionally slightly violet) colour of rose quartz is caused by the presence of manganese or titanium impurities. Some rose quartz contains many tiny rutile needles which produce a star-like effect, especially when the gem is cut as a cabochon (a round or oval stone with plain, curved surfaces). Smoky quartz is a brown or black form of vein quartz, the colour of which derives from the presence of aluminium impurities, while citrine is a yellow to yellowish-brown form of vein quartz, its colour deriving from iron impurities.

Prase is a leek-green, semi-translucent variety of quartz which derives its colour from the presence of vast numbers of minute fibres of green amphibole minerals such as hornblende or actinolite. Although technically it differs from chrysoprase (an apple-green form of chalcedony), in practice the two are easily confused.

Egyptian sources
No specific ancient source of rose quartz in Egypt has yet been discovered. Traces of smoky quartz have been found in a Roman gold mine at Romit in the Eastern Desert (Ball 1912: 353).

Uses
During the Early Dynastic period and the Old Kingdom, rose quartz was very occasionally used for funerary vessels. Prase was occasionally used for beads during the Pharaonic period.

Examples

1. Rose quartz round-bottomed dish from tomb 1207 at Armant, First Dynasty (SD80), *c.* 3000–2770 BC (Cairo; Mond and Myers 1937: pl. 17).
2. Rose quartz cylinder vessel from the valley temple of Menkaura at Giza, Fourth Dynasty, *c.* 2490–2472 BC (Cairo; Reisner 1931: 188, fig. 60.7).

Bibliography
Ball (1912: 353); Frondel (1962: 181–9, 219); Lucas (1962: 402); Aston (1994: 65–6).

Quartz diorite *see* diorite, quartz diorite and gabbro

Quartzite

Definition
Sedimentary quartzite is a sandstone in which the sand grains are so tightly cemented by quartz that the rock breaks across the grains rather than around them. This is also termed an 'orthoquartzite'. Some geologists prefer to call this rock 'siliceous sandstone' to distinguish it from metamorphic quartzite, although the quartzite used by the ancient Egyptians is entirely of the sedimentary variety. The term 'quartzose sandstone' is ambiguous and should be avoided as the quartzose could refer to either the quartz cement or grains.

Egyptian sources
Hard quartzites are widespread in the Eastern and Western Deserts and are also occasionally encountered in the Nile valley. In these places abundant quartz cementation has developed on exposed outcrops and in the shallow subsurface of otherwise friable sandstones of the Nubia Group and younger formations. There are only two known ancient quarries and these are located where silification has been unusually deep and pervasive: Gebel Ahmar near Cairo, and on and between Gebels Tingar and Gulab near Aswan (see maps in Figs. 2.1a and b). The rock at Gebel Ahmar belongs to the Gebel Ahmar Formation of Oligocene age and was worked from the Old Kingdom onwards. The quartzite near Aswan occurs in the upper part of the Timsah Formation and the lower part of the overlying Umm Barmil Formation (both units belong to the Nubia Group of late Cretaceous age). The quarry workings on Gebel Gulab date from the New Kingdom to the Roman period (see Fig. 2.6). Those on Gebel Tingar and elsewhere in the area may date, in part, from the same time but most of the visible workings are probably associated with the construction of the nearby St Simeon's monastery, dating to the seventh to tenth centuries AD.

Descriptions
The quartzites used in ancient Egypt vary from fine- to very coarse-grained, frequently exhibit cross-bedding, and commonly contain pebble-rich layers. In some cases the pebbles predominate over the sand grains and the rock is more correctly described as a 'siliceous conglomerate'. The predominant colour is brown but other colours are occasionally encountered including light grey to nearly white, and various shades of yellow, orange, red and purple. The different colours are caused by variable amounts of iron oxides (haematite and goethite) in the quartz cement. Manganese oxides are probably responsible for the purplish coloration in some samples.

The quartzites from the two widely separated quarries are usually indistinguishable megascopically but, in thin section, they differ markedly in the roundness of the sand grains. Those from Gebel Ahmar are predominately round to subround whereas those from Aswan are mostly angular to subangular in cross-section. This is the only consistent difference but the type of quartz cement will also be definitive for some samples. Quartz cement normally occurs as optically continuous overgrowths on quartz sand grains. This is the type of cement that occurs at Aswan and predominates at Gebel Ahmar, but at the latter quarry there also occurs a rare form of quartz cement that appears in the form of a finely polycrystalline mosaic resembling chert. It has also been suggested that the two quarries can be distinguished by the presence or absence of detrital anatase sand grains and chert pebbles with the former occurring only at Aswan and the latter occurring only at Gebel Ahmar. These distinctions appear to be valid but the two grain types are not always present. The chert pebbles are significant, however, in that they are the only difference between the quarry stones that can be recognised megascopically. The chert has a microcrystalline texture and greyish colour whereas most of the other pebbles (at both quarries) are coarsely crystalline, milky white quartz. Trace elements have also been proposed as discriminators and they have shown some promise. However, their reliability is questionable for small samples given the inherently variable composition of quartzites.

Uses
Quartzite was employed sparingly as a construction material from the Old Kingdom onwards. Its use was largely limited to doorway thresholds in temples (as in the mortuary temple of the Sixth-Dynasty King Teti at Saqqara) and wall-linings in burial chambers (as in the Twelfth-Dynasty pyramid of King Amenemhat III at Hawara). It was also

used extensively for statuary and sarcophagi from the Old Kingdom onwards. At the Gebel Gulab quarries there is an unfinished obelisk of Seti I still *in situ* (Habachi 1960: 224–31; 1977: 32–3, pl. 6). Quartzite was also the material used for the 'rubbers' with which Egyptian woodworkers finished and smoothed pieces of timber, a process which was depicted in some tomb-paintings and reliefs (e.g. Wild 1966: pl. CLXXIV; see Chapter 15).

Examples

1. Head of an old man, Twenty-fifth Dynasty, after 730 BC (height 23.5 cm; BM EA37883) [white rock].
2. Two colossal heads of Amenhotep III from his funerary temple in Thebes, Eighteenth Dynasty, *c.* 1391–53 BC (height *c.* 1.2 m; BM EA6–7) [pebbly, light grey and brown rock].
3. Standing figure of prince Khaemwaset, son of Rameses II, from Asyut, Nineteenth Dynasty, *c.* 1290–1224 BC (height 1.46 m; BM EA947) [pebbly, light grey and brown rock].
4. Statue of the god Thoth in the form of a baboon; Eighteenth Dynasty, *c.* 1390 BC (height 67 cm; BM EA38) [brown rock].
5. Stelophorous statue of Amenwahsu, Eighteenth or Nineteenth Dynasty, *c.* 1550–1196 BC (height 56 cm; BM EA480) [purplish red rock].

Bibliography

Shukri (1953, 1954); Habachi (1960); Lucas (1962: 62–3, 418–9); Bowman *et al.* (1984); Klemm *et al.* (1984); Niazi and Loukina (1987); Stross *et al.* (1988); De Putter and Karlshausen (1992: 95–9); Klemm and Klemm (1993: 283–303); Aston (1994: 33–5).

For colour photographs of cut slabs see: Klemm and Klemm (1993: pls. 8.1–9.6).

Rock crystal *see* quartz, 3

Sandstone

Definition

Sandstone is a sedimentary rock consisting predominately of sand-size grains (0.063–2 mm) of detrital (transported) rock and mineral fragments that are held together by quartz, calcite, iron oxide, clay or other cements.

Egyptian sources

Outcrops of sandstone are widespread in Egypt. They occur continuously in the Nile valley and on the adjacent desert plateaux from Esna southward into northern Sudan and are interrupted only at the Nile cataracts where more resistant igneous and metamorphic rocks crop out. A total of thirty-four ancient quarries are identified, together with their ages, in Table 2.1 and on the maps in Figures 2.1a–b (see Figs. 2.22–2.24 for photographs of specific quarries). This rock is commonly described as 'Nubian sandstone' because it belongs to the stratigraphic sequence known as the Nubia Group. The quarries may be tentatively assigned to the following geologic formations within this group: Duwi (1–4), Quseir (5–11 and possibly 33–34), Umm Barmil (12–16 and possibly 32), Timsah (17–18), Abu Aggag (19–23) and Sabaya (24–31). Except for the quarry near the Buhen ruins (28) and the workings at the higher elevations near Qertassi (20), all quarries south of Aswan are now under Lake Nasser. As this region received relatively little attention prior to flooding, it is likely that there are more quarries than those shown in Figure 2.1b. The same is true for quarries in the Western and Eastern Deserts. In the Nile valley north of Aswan, however, the list of quarries is probably reasonably complete.

Figure 2.22 Sandstone quarry on the east bank at Gebel el-Silsila.

Figure 2.23 Sandstone quarry at Nag el-Hoch.

Figure 2.24 Sandstone quarry at el-Mahamid.

Identifying the quarry of origin for sandstone objects is not possible at present. However, the formation and hence the general geographic area, can sometimes be established from the grain size and bedding characteristics. This determination can be made megascopically but large blocks are needed to recognise the bedding characteristics. For the quarries investigated north of Aswan, no systematic change in mineralogy has been noted either geographically or stratigraphically. It is possible that trace element analysis may permit more detailed provenance determinations but too little is yet known from quarry samples to evaluate this possibility. It seems unlikely, however, that this would be an effective approach when using small samples because of sandstone's great compositional variability on the scale of individual quarries.

Descriptions

Virtually nothing is known about the character of the sandstone south of Aswan. From Aswan northward, however, quarry samples indicate that the rock almost always contains at least 75 volume per cent quartz grains with most of the remaining percentage consisting of feldspar grains (mainly microcline). The sandstone thus varies from a sub-feldspathic arenite to a quartz arenite, with the former restricted to the finer-grained rocks. The sandstones are highly porous and only loosely cemented with quartz, iron oxides (goethite and minor haematite) and chlorite clay. All three cements are almost always present, and commonly kaolinite clay and rarely calcite also contribute. Because it is incompletely cemented, the sandstone is friable and thus relatively easy to quarry and carve. Its strength and durability is imparted by the sparse but omnipresent quartz cement, and iron oxides give the sandstone its typical brownish colour.

The sandstones encountered in ancient quarries and tombs come from the following six geologic formations (all date from the upper part of the Cretaceous Period; stages and alternative formation names are given in parentheses and brackets, respectively).

1. *Duwi Formation* [or 'phosphate formation'] (Late Campanian to Early Maastrichtian): almost nothing is known about this sandstone; it may be similar to the underlying Quseir Formation.
2. *Quseir Formation* [or 'variegated shale'] (Early to Late Campanian): very fine- to fine-grained, flat-bedded and ripple cross-laminated sandstone.
3. *Umm Barmil Formation* [or 'Taref sandstone'] (Santonian to Early Campanian): coarse-grained to mainly fine- to medium-grained, mostly tabular cross-bedded sandstone.
4. *Timsah Formation* (Coniacian to Santonian): very little is known about this sandstone; it appears to be relatively fine-grained and may be similar to the overlying Umm Barmil Formation.
5. *Abu Aggag Formation* (Turonian): fine- to very coarse-grained but mainly medium- to coarse-grained, mostly trough cross-bedded, kaolinitic sandstone with common, thin granule to pebble conglomerate interbeds.
6. *Sabaya Formation* (Albian to Early Cenomanian): relatively little is known about this sandstone; it may be fine- to coarse-grained and mostly trough cross-bedded with occasional conglomeritic interbeds.

Uses

The earliest known use of sandstone for building purposes was for pavement and wall-lining in the burial chamber of an Early Dynastic tomb at Hierakonpolis. It was not until the Eleventh Dynasty, however, that it was first used on a monumental scale in the mortuary temple of Nebhepetra Mentuhotep II at Deir el-Bahari in Thebes. Here a purplish sandstone was employed along with limestone. The source of this distinctively coloured sandstone, which was apparently not used elsewhere, may be Gebel el-Silsila West or Nag el-Hammam (nos. 8–9 in Table 2.1 and Fig. 2.1b). Sandstone was next used for portions of a few Twelfth-Dynasty temples, including that of Senusret I at Karnak and others nearby at Qift and Nag el-Madamud. It was not, however, until the Eighteenth Dynasty that this rock became the principal building material for temples in Thebes and other sites to the south. It was occasionally imported into the limestone region north of Thebes as, for example, when it was used for portions of the Hathor temple and associated buildings at Dendara, and for the temples of Seti I and Rameses II at Abydos.

The ascendancy of sandstone as the building material of choice coincided with the re-establishment of royal and religious authority at Thebes at the beginning of the New Kingdom, and the concomitant discovery that sandstone was superior to limestone in terms of the size and strength of the blocks that could be extracted from quarries. These attributes facilitated the construction of enormous temples with long architraves in the New Kingdom and later periods.

As a sculptural medium, sandstone was decidedly inferior to limestone, which was more durable and could be more intricately carved. Sandstone was, however, easily worked and readily available and thus widely used for reliefs and statuary outside the limestone region. Objects made from this rock were typically painted.

Examples

1. Osirid statue of King Amenhotep I from Deir el-Bahari, western Thebes, Eighteenth Dynasty, *c.* 1525–1504 BC (height 2.69 m; BM EA683).
2. Painted kneeling statue of the Theban general Intef, from his tomb chapel in the Assasif region of Thebes, Eleventh Dynasty, *c.* 2050 BC (height 58 cm; Cairo JE89858 and 91169).
3. Upper part of a colossal Osirid statue of King Akhenaten, from east Karnak, Eighteenth Dynasty, *c.* 1350 BC (height 1.37 m; Louvre E27112).

Bibliography

De Morgan *et al.* (1894); Weigall (1910); Lucas (1962: 55–7); Van Houten and Bhattacharyya (1979); Ward and McDonald (1979); Klitzsch (1988); Hermina *et al.* (1989); De Putter and Karlshausen (1992: 91–4); Klemm and Klemm (1993: 225–81).

For colour photographs of cut slabs see Klemm and Klemm (1993: pls. 7.1–7.6).

Sardonyx *see* chalcedony

Satin spar *see* alabaster

Schist *see* siltstone, greywacke and conglomerate

Serpentinite (serpentine)

Definition

Serpentine is a hydrated magnesium silicate of the composition $Mg_6Si_4O_{10}[OH]_8$ which is formed by the alteration of magnesium-rich silicates by hot water solutions. The three serpentine minerals – chrysotile, lizardite and antigorite – are differentiated by the degree of substitution of magnesium by iron. 'Serpentinite' rocks contain one or more of these minerals plus minor amounts of brucite, talc, tremolite, magnetite and/or dolomite.

Egyptian sources

Serpentinite is widely distributed in the Eastern Desert. Some of the larger and more accessible outcrops are in Wadi Hammamat and in the tributary wadis of Atalla and Umm Esh to the north. Only one ancient quarry is known and it is Roman in date (Brown and Harrell 1995). It is in an unnamed tributary of Wadi Umm Esh near its confluence with Wadi Atalla. A modern quarry has now destroyed the ancient workings but the remains of stone huts of the Roman period can still be seen. The sources of the two different varieties of serpentinite utilised in the Pharaonic period are not known, although it is possible that one of them (Variety 1 below) may have come from the Wadi Umm Esh area.

Description

Two general varieties of serpentinite were used in the Pharaonic period: Variety 1 is greyish to mostly greenish (often with a mottling of yellowish and darker shades) with black veins or patches; and Variety 2 is mostly black and speckled with grains of grey or brown. Both varieties may be hydrothermally altered peridotites. The blackish serpentinite (Variety 2), for example, has a matrix of antigorite showing mesh structure with granules of iron oxide outlining the boundaries of original olivine grains, and scattered pseudomorphs after pyroxene crystals. Variety 1, from the Wadi Umm Esh quarry, consists mainly of fine-grained antigorite with rare chrysotile and lizardite plus minor dolomite (in veins) and accessory minerals (magnetite, talc and tremolite). The black veins of magnetite are particularly prominent when the surface has been weathered to a greenish-white colour. A translucent subvariety of the greenish serpentinite was called 'green noble serpentine' by Petrie (1937: 2).

Uses

Translucent greenish serpentinite with black patches was used for small vessels and amulets in the Predynastic period and First Dynasty. Blackish serpentinite was a common material for statues and kohl vessels in the Middle Kingdom and Second Intermediate Period though rarely occurs outside this time. Greenish serpentinite with black veins was used for small vessels from the Predynastic period (Naqada II) to the Eighteenth Dynasty. It was also used for small funerary objects, such as heart scarabs and *shabti* figures, in the New Kingdom.

The Wadi Umm Esh serpentinite was quarried for export from Egypt by the Romans who used it for pavement tiles and sculptures – an especially fine example is the figure of a dog in the Palazzo dei Conservatori in Rome. The only known earlier example of its use is a column drum, still *in situ* at Bir Umm Fawakhir, at the eastern end of Wadi Hammamat, which is inscribed with the name of Ptolemy III Euergetes and comes from a temple dedicated to this king that once existed at the same locality.

Examples

1. Bird-shaped vessel from tomb 89 at Naqada, dating to the Naqada II period, *c.* 3500–3100 BC (height 5.5 cm; Oxford, Ashmolean 1895.217) [green with black veins].
2. Kohl jar from the mastaba of Sehetepibraankh at Lisht, Twelfth Dynasty, *c.* 1991–1783 BC (New York, MMA) [green with black veins].
3. Statuette of a girl holding a kohl jar, Twelfth Dynasty (BM EA2572) [granular black].
4. *Shabti* of Amenhotep II, Eighteenth Dynasty, *c.* 1427–1 BC (29 cm; BM EA35365) [green with black veins].

5. *Shabti* of Amenhotep III, Eighteenth Dynasty, *c.* 1391–53 BC (Louvre N 649) [green with black veins].

Bibliography

Akaad and Noweir (1972); Gnoli (1988: 159); Marchei *et al.* (1989: 291); De Putter and Karlshausen (1992: 136–9); Klemm and Klemm (1993: 376–8); Aston (1994: 56–9); Brown and Harrell (1995).

For colour photographs of two varieties of serpentine used in the Pharaonic period see Aston (1994: pl. 12), for the *shabti* (Louvre N 649) and a vessel of green serpentine with black veins see De Putter and Karlshausen (1992: pls. 51–2), and for polished slabs see Mielsch (1985: pl. 20–668), Gnoli (1988: fig. 115), Marchei *et al.* (1989: fig. 129a), De Putter and Karlshausen (1992: pl. 54h–30, 31, 32), and Klemm and Klemm (1993: pls. 13.1–13.2).

Siliceous sandstone *see* quartzite

Siltstone, greywacke and conglomerate

Definition

Siltstone, greywacke and conglomerate are types of sedimentary rock formed from fragments of pre-existing rocks. They are classified by the Udden-Wentworth scale (see Table 2.3) according to the size of their constituent grains. Greywacke is a poorly sorted variety of sandstone which contains a range of grain sizes including at least 10 per cent silt and clay matrix, and is characteristically dark-coloured, hard and dense.

Egyptian sources

The hard green siltstone, greywacke and conglomerate used by the ancient Egyptians belong to the Hammamat Series of late Precambrian age and are widely distributed in the northern and central parts of the Eastern Desert. Only one ancient quarry is known, located in the Wadi Hammamat, which was worked from the Predynastic through the Roman Period (see Fig. 2.25). Over 250 inscriptions and numerous quarry workings occur along a stretch of the wadi just over one kilometre in length, west of the confluence with Wadi Atalla. A Roman ramp runs up the south side of the wadi, while on the floor of the wadi on the north side are the ruins of a chapel of the Thirtieth Dynasty. The green conglomerate workings are in the western part of the quarry, but the most prominent of these, where there are many quarried blocks, dates from the present century. On some surviving blocks (partially broken-up, by twentieth-century quarry-workers), there are New Kingdom inscriptions, including two from the reign of Rameses IV (which is probably significant given that the conglomerate sarcophagus of Rameses VI originally belonged to Rameses IV; Harrell 1992b: 104).

Description

The Hammamat siltstone is composed of fairly well-sorted silt-size grains (primarily measuring 0.01–0.05 mm), while the greywacke consists mainly of fine to very fine sand grains (0.06–0.2 mm) with rare pebbles. The grains are mostly quartz with minor oligoclase-andesine plagioclase and felsic to intermediate volcanic rock fragments plus rare muscovite. These are tightly cemented by chlorite and sericite micas plus minor amounts of epidote and calcite. The chlorite-sericite matrix was formed from the original clay-rich matrix by compaction and recrystallization during long, deep burial. Some geologists consider that the heat and pressure which partially recrystallised the original clay to chlorite and epidote are sufficient for these to be called 'slightly metamorphosed'; they would therefore append the prefix 'meta-' to all varieties, i.e. metasiltstone, metagreywacke and metaconglomerate. The colour of the siltstone and greywacke ranges from dark grey to mainly greyish green; the texture is fine, hard and dense. The dark grey variety is restricted to the eastern part of the quarry.

Figure 2.25 Siltstone-greywacke quarry (arrow) in Wadi Hammamat, Eastern Desert.

Siltstone and greywacke may be distinguished by the visibly granular nature of the greywacke. In greywacke, the sand-size grains are visible to the naked eye and can be clearly seen with a hand lens, whereas siltstone has a fine uniform appearance, and individual grains are so small they cannot be distinguished without a microscope. The relative quantities of siltstone and greywacke utilised anciently are not yet known, and more accurate identifications are needed. Preliminary indications are that the siltstone comes mainly from the central part of the quarry, especially around the tributary wadi on the north side.

In a study of stone vessels, all five vessels of this stone which were examined in thin-section (from Giza, Saqqara, Tarkhan and Nag el-Deir) were found to be siltstone, as was a statue of Menkaura (Aston 1994: 29, 31, 32). On the other hand, a series of Fifth- and Sixth-Dynasty royal sarcophagi from Saqqara (Unas, Teti, Pepi I, Merenra), hitherto assumed to be of basalt, are actually made of greywacke (Wissa 1994: 387).

Siltstone and greywacke have sometimes been called 'slate', though the pronounced foliation (layering) and conspicuous flaking and splitting which characterise slate are absent from the Wadi Hammamat rocks. The so-called 'slate' palettes of the Predynastic period are actually of siltstone; the rock is identical to that used for stone vessels and statuary in the Pharaonic period (Klemm and Klemm 1993: 369).

'Schist' is another erroneous name which has previously been applied to the Hammamat rocks. Schist is a medium- to coarse-grained metamorphic rock with pronounced layering, completely unlike the fine-grained, homogeneous siltstone and greywacke of Wadi Hammamat. Dark grey siltstone and greywacke are occasionally confused with basalt – a crystalline, igneous rock formed directly from lava. Ironically, the English word 'basalt' actually derives from the ancient Egyptian word for siltstone-greywacke – *bḫn* – through Greek basan and Latin *basanites* (Harrell 1995: 30–3).

The conglomerate quarried in Wadi Hammamat has an overall greenish appearance but contains pebbles of a wide variety of colours, including white, pink, red, yellow, brown, green and grey. The pebbles are well-rounded, range in size up to 25 cm in diameter with most less than 4 cm, and consist mainly of volcanic rock fragments with lesser amounts of granite, chert, vein quartz, quartzite and other rock types. The rock has an unusual 'diamictic' texture where the pebbles are surrounded and supported by a matrix of coarse- to very coarse-grained sand compositionally similar to that in the greywacke. The conglomerate is tightly cemented with chlorite, sericite and epidote plus minor amounts of calcite and iron oxides.

The Romans had a very descriptive name for this conglomerate: *lapis hecatontalithos* ('stone of a hundred stones'). Italian stonemasons, who recycled stone that had been brought to Italy by the Romans, called this rock *breccia verde antico* or *breccia verde d'Egitto*, and this is the origin of the frequently encountered name 'green breccia'. However, in modern terminology, breccia is a rock composed of angular fragments, whereas in conglomerates such as this one the fragments are rounded.

Uses

In the Predynastic period siltstone was used for the so-called 'slate' palettes, and beginning in the Naqada II period also for stone vessels and other small items such as bracelets and spoons. During the Early Dynastic period siltstone was first employed for statuary, and siltstone vessels are particularly numerous. From the Old Kingdom onwards, siltstone and greywacke were employed for large objects such as statuary, stelae, sarcophagi and naoi, and this fine, hard stone was particularly favoured by the Egyptian élite in the Twenty-sixth and Thirtieth Dynasties.

Only a few examples of the use of green conglomerate are known from the Pharaonic period, including the inner sarcophagus of Rameses VI and the sarcophagus of Nectanebo II. The Romans quarried it extensively for export to
Italy; it was used for basins, small columns, pavement t
and rarely for statues.

Examples

1. Palette of the First-Dynasty king Narmer fr
   Hierakonpolis, *c.*3000 BC (height 64 cm; C
   JE32169) [siltstone].
2. Statue of the Second-Dynasty king Khasekhem
   from Hierakonpolis, *c.*2700 BC (height 56.5 cm; C
   JE32161) [siltstone].
3. Statue of Menkaura and Queen Khamerernebty fr
   Menkaura's pyramid complex at Giza, Fourth Dyna
   *c.*2490–72 BC (height 1.4 m; Boston MFA 11.1738) [
   stone].
4. Face from lid of inner sarcophagus of Rameses
   from his tomb in the Valley of Kings (KV9) (hei
   80 cm; BM EA140) [green conglomerate].
5. Slab inscribed with the Memphite Theology, datin
   the reign of the Twenty-fifth-Dynasty king Shaba
   from Memphis (the so-called 'Shabaka Stone'), *c.* 7
   698 BC (length 1.37 m; BM EA498) [conglomerate
6. Pair of obelisks of Nectanebo II *c.* 360–43 BC (heigh
   59 m and 2.42 m; BM EA523, 524) [siltstone].
7. Sarcophagus of Nectanebo II, *c.* 360–343 BC (len
   2.98 m; BM EA10) [green conglomerate].
8. Ptolemaic sarcophagus lid of troop comman
   Pedimahes, from Tell el-Muqdam (length 2.16 m; P
   adelphia PA, University Museum E16134) [greywac

Bibliography

Couyat and Montet (1912); Weigall (1913: 37–51); Lucas and R
(1938); Andrew (1939); Shiah (1942); Goyon (1957); De Putter
Karlshausen (1992: 59–60, 87–90); Harrell and Brown (19
1992b), Klemm and Klemm (1993: 355–76); Aston (1994: 28-
Wissa (1994); and Harrell (1995).

For colour photographs of polished slabs see De Putter
Karlshausen (1992: pls. 54d–16, 54e–19 greywacke; 54a–4 gr
conglomerate) and Klemm and Klemm (1993: pl. 12.1–2 g
wacke, 12.3 siltstone, 12.5–6 green conglomerate).

Slate *see* siltstone, greywacke and conglomerate

Sodalite *see* lapis lazuli

Steatite (soapstone)

Definition

Steatite is a rock composed primarily of the mineral tal
which the flakes of talc are oriented randomly, resultin
a massive, homogeneous texture. When the talc fla
are aligned in layers, the rock is called talc schist. T
is a hydrated magnesium silicate of the composit
$Mg_3Si_4O_{10}(OH)_2$ which is characterised by extreme softn
(it can be scratched by a fingernail) and a soapy feel (he
'soapstone', the alternative name for steatite).

yptian sources

eatite occurs widely in the central and southern parts of e Eastern Desert. Some of the largest exposures are im-ediately to the north and south of Wadi Barramiya, and in e area of Gebel Salatit north of Wadi Barramiya there are rge-scale modern quarrying operations. Near here, at ebel Rod el-Barram, there is a large, recently discovered, teatite quarry that dates from the Roman period (and ossibly earlier). The steatite from this quarry is a mottled grey and brown variety identical to that used for ancient vessels. Another newly discovered quarry is in Wadi Saqiyah in the central Eastern Desert , where a greenish talc schist was quarried by the Romans during the first two centuries AD.

Description

Steatite is generally grey, greenish grey or brown in colour, and ancient Egyptian vessels of steatite exhibit a mottled grey and brown appearance. The surface has a dull, waxy lustre, often with many scratches as a consequence of the extreme softness of the stone. A thin section of the Gebel Salatit steatite reveals lenticular masses of fine-grained (0.04–0.08 mm) talc flakes with a few large, patchy grains of magnetite and many fine, scattered shreds of haematite.

Uses

Lucas notes that steatite was used for beads as early as the Badarian period and also commonly for scarabs which were often glazed (1962: 421). Its use for statuary is not clear as it has sometimes been confused with serpentinite, however it was certainly used for cosmetic vessels in both the Middle and the New Kingdoms.

Examples

1. Kohl jar from tomb E3 at Abydos, Twelfth to Thirteenth Dynasties, *c.* 1991–1640 BC (height 2.6 cm; Ashmolean 1896–1908 E.2175).
2. Tubular kohl jar held by a monkey from tomb E10 at Abydos, dating to the Eighteenth Dynasty, *c.* 1550–1307 BC (height 4.7 cm; Ashmolean 1896–1908 E.2339).
3. Head from a statuette of Queen Tiy from the temple of Hathor at Serabit el-Khadim, Eighteenth Dynasty, *c.* 1391–53 BC (height 7.2 cm; Cairo JE38257; Petrie 1906: pl. 133).

Bibliography

Lucas (1962: 155–6, 220–1); De Putter and Karlshausen (1992: 140–3); Klemm and Klemm (1993: 378–9); Aston (1994: 59–60).

For colour photograph of the kohl jar (Ashmolean 1896–1908 E.2175) see Aston (1994: pl. 13a), and of the statuette of Queen Tiy (Cairo JE38257) see Saleh and Sourouzian (1987: no. 144).

Travertine ('Egyptian alabaster')

Definition

Travertine is a sedimentary rock and a variety of limestone consisting largely of calcite (calcium carbonate, $CaCO_3$) or aragonite (another form of calcium carbonate). The travertine used in ancient Egypt is frequently described as 'Egyptian alabaster' or simply 'alabaster'. This terminology, however, is incorrect, since true alabaster, as recognised by geologists, is composed of gypsum (see ALABASTER). As a compromise for those uncomfortable with the name travertine, the terms 'calcite' and 'calcite-alabaster' have been suggested, but they are not recommended here. The former is a mineral name (and hence inappropriate for a rock) and the latter is a hybrid name not recognised by geologists.

Egyptian sources

Small deposits of travertine occur sporadically in the Eocene limestones of the Nile valley and adjacent desert (mainly Eastern) plateaux between Esna and Cairo. A total of nine ancient quarries are known and these are shown, together with their ages, in Table 2.1 and on the map in Figure 2.1a. The most famous Egyptian travertine quarries were located eighteen kilometres to the southeast of Amarna in Middle Egypt. Texts from the Old Kingdom onwards refer to this site as Hatnub ('mansion of gold'). The inscriptions, graffiti and archaeological remains at Hatnub indicate that it was intermittently exploited by the Egyptians for a period of about 3,000 years, from at least as early as the reign of Khufu until the Roman period (see Fig. 2.26). The site of Wadi Gerrawi, near Helwan, was also an important travertine quarry, exploited primarily in the Old Kingdom (see Murray 1945–6; Dreyer and Jaritz 1983; and see Fig. 2.27).

Description

Egyptian travertine is a dense (non-porous) rock consisting entirely of calcite and is a variety known as 'calcareous sinter' (or 'calc-sinter'). A porous, spongy-looking variety called 'calcareous tufa' occurs outside Egypt (e.g. at Tivoli in Italy), and is the one more commonly associated with the name travertine. The Egyptian deposits formed in subsur-

Figure 2.26 The main travertine quarry at Hatnub, Eastern Desert.

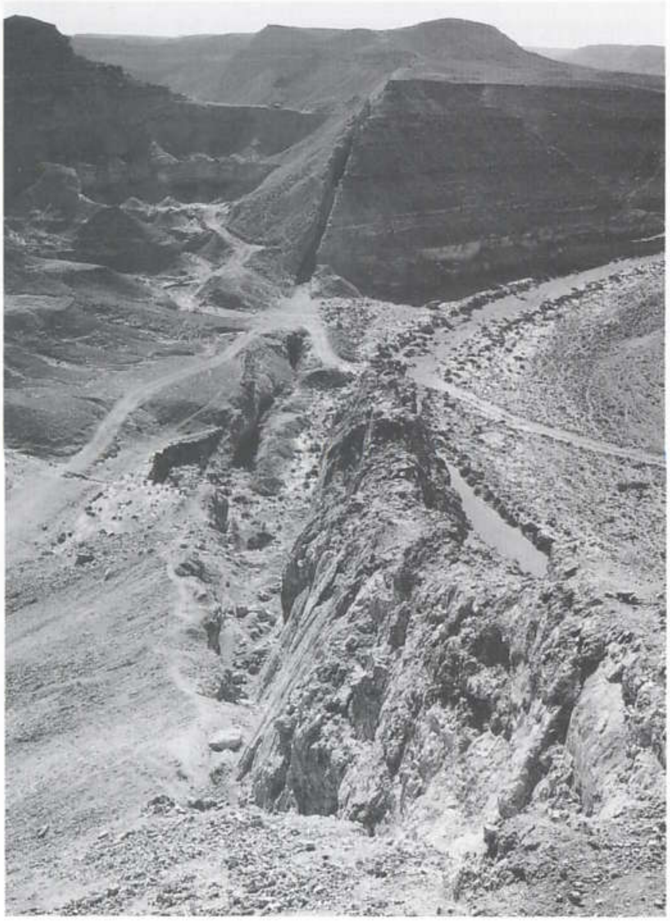


Figure 2.27 Travertine quarry in Wadi Gerrawi, Eastern Desert.

face caverns and fissures in the Eocene limestone bedrock, and consist of the same material from which cave stalagmites, stalactites and other flowstone spelothems are made. There is some evidence suggesting that hot springs may also have played a role in the formation of these deposits. The travertine occurs in three forms:

(1) an opaque, milky white calc-sinter that is fine-grained (crystals < 1 mm) with little or no layering;
(2) a translucent calc-sinter that is coarse-grained (crystals 1 mm to several centimetres across), fibrous, coloured in shades of pale brown or yellowish- to orangish-brown with faint to marked layering; and
(3) a strikingly banded calc-sinter that is an interlayering of the first two forms.

Only the last two types were commonly used in ancient Egypt. The brownish colouring fades to white after exposure to the sun, as in the case of the Muhammad Ali Mosque in Cairo's Citadel. This mosque was built between 1830 and 1848, using exterior and interior veneers of Type 3 travertine, and over the last 150 years the exterior has faded badly. This rock is called *alabastrites* by the Greeks and Romans, but the original meaning of the name was forgotten during the Middle Ages, when it was given its modern definition and applied to a variety of gypsum superficially resembling Egyptian travertine.

Uses

Travertine was widely used from Early Dynastic times onwards for pavements and wall-linings in temple passages and rooms. A particularly well-known example of a pavement is in the valley temple of the Fourth-Dynasty king Khafra at Giza. It was also used extensively for small New Kingdom shrines (such as those of Amenhotep I/Thutmose I and Thutmose III in the open-air museum at Karnak), and for small vessels from the late Predynastic to the Roman period. In addition it was commonly employed for other small objects such as canopic jars, statuettes, *shabtis*, offering tables, bowls and dishes. Because large blocks were difficult to obtain from quarries, travertine was only occasionally used for sarcophagi, large statues and *naoi*.

Examples

1. Statue of the Fourth-Dynasty king Khafra from Mitrahina, *c.* 2520–2494 BC (Cairo).
2. Sphinx of the Eighteenth-Dynasty king Amenhotep I, from Karnak, *c.* 1525–1504 BC (44 cm long; Cairo CG 42033).
3. Colossal pair-statue of the crocodile-god Sobek with the Eighteenth-Dynasty king Amenhotep III, from Dahamsha, *c.* 1391–53 BC (2.56 m high; Luxor J 155).
4. Statuette of Akhenaten from house N48.15 at Amarna, Eighteenth Dynasty, *c.* 1353–35 BC (height 12 cm; Berlin ÄM 21835).
5. Sarcophagus of King Seti I from the Valley of Kings (KV17), Nineteenth Dynasty, *c.* 1306–1290 BC (length 2.84 m; London, Sir John Soane's Museum).
6. Statue of King Seti I from the 'Karnak cachette', Thebes (height 2.38 m; Cairo CG 42139).
7. Bust from a statue of King Merenptah, Nineteenth Dynasty, *c.* 1224–14 BC (Louvre E25474).

Bibliography

Petrie (1894); Timme (1917); Lucas (1962: 59–61, 406–7); Akaad and Nagger (1964a, 1964b, 1965); el-Hinnawi and Loukina (1972); Dreyer and Jaritz (1983); Shaw (1986, 1987); Harrell (1990); De Putter and Karlshausen (1992: 43–6); Klemm and Klemm (1993: 199–223); Aston (1994: 42–7).

For colour photographs of polished slabs see: Mielsch (1985, pl. 1–1, 5, 8, 17); Gnoli (1988: figs. 224–5); Marchei *et al.* (1989: figs. 4a–b); De Putter and Karlshausen (1992: pl. 54a–1, 2) and Klemm and Klemm (1993: pls. 6.3–6.6).

Tuff and tuffaceous limestone

Definition

Tuff is a rock consisting of pyroclastic debris (ash and cinders) thrown into the air by a volcanic explosion and accumulating in air-fall or water-laid deposits. Although tuffs are usually considered to be volcanic igneous rocks, they are also equally volcanoclastic sedimentary rocks. A tuffaceous limestone is a sedimentary limestone which contains up to 50 per cent pyroclastic debris.

Egyptian sources

The green tuff and tuffaceous limestone utilised for stone vessels in the Early Dynastic period come from Gebel Manzal el-Seyl, in the upper reaches of Wadi Mellaha near Gebel Mellaha, in the Eastern Desert (see map in Fig. 2.1a and photograph in Fig. 2.28). This quarry site was discovered by an expedition led by Harrell in 1994 (Harrell *et al.*, forthcoming). About 200 small workings are scattered along a three-kilometre-long, ridge-like *gebel*. Within the workings and also in fifteen workshop areas among them are hundreds of roughed-out vessels along with the stone tools used to produce them. The tools are made from locally available dolerite and are mostly hand-held mauls (pounders), but some are notched to take a wooden handle. Alternating layers of tuff and tuffaceous limestone occur in the quarry and workings are present in layers of both rock types.

Description

The tuff at Gebel Manzal el-Seyl is a highly calcareous and chloritic andesite ash tuff. There are two gradational varieties: a dark green vitric tuff and a lighter olive-green vitric-crystal tuff. It is the chlorite that gives the tuffs their green colour, whereas an occasional bluish tint is probably due to the luminescent properties of the calcite. Both varieties consist of andesine plagioclase crystals, andesitic rock fragments (lithics), and rare quartz crystals in a groundmass of microcrystalline quartz and feldspar (originally glass shards, but now devitrified and partially replaced by calcite and chlorite). All of the mafic minerals and some of the plagioclase in the lithic fragments are also replaced by chlorite and calcite. In the dark green vitric tuff, glass shards predominate with fine-grained (less than one millimetre) plagioclase crystals making up less than 33 per cent of the rock. Although the original glass shards have devitrified to microcrystalline quartz and plagioclase, in many cases the outlines of the shards are still visible. Up to a few per cent of lithic fragments and quartz crystals are present. The light green vitric-crystal tuff differs in containing over 33 per cent plagioclase crystals. It has a grainy surface, due to the crystals, whereas the vitric tuff has a smooth surface. Less chlorite makes this rock lighter in colour, and conspicuous dark specks are commonly present. These specks are lithic grains and iron oxide ghosts of mafic minerals. Both tuffs are commonly banded, with laminations varying from less than one millimetre to a few tens of centimetres. However, many vessels were cut from the thicker layers and so show no banding.

Both tuffs are gradational with tuffaceous limestone, which consists predominately of sparry calcite with grains up to one millimetre across. The limestone also has minor amounts of plagioclase crystals and devitrified glass plus occasional quartz grains and andesite lithics. Secondary chlorite gives it a light green colour, which is commonly bluish or, when stained by iron oxides, brownish. The rock surface appears grainy due to the coarseness of the calcite, and it exhibits the same conspicuous dark specks as are seen in the vitric-crystal tuff. The tuffaceous limestone closely resembles the vitric-crystal tuff, and the two rocks are not easily distinguished megascopically. The tuffaceous limestone occurs in thick (up to several tens of centimetres), lamination-free layers and so vessels carved from it rarely show the kind of banding common in the tuff.

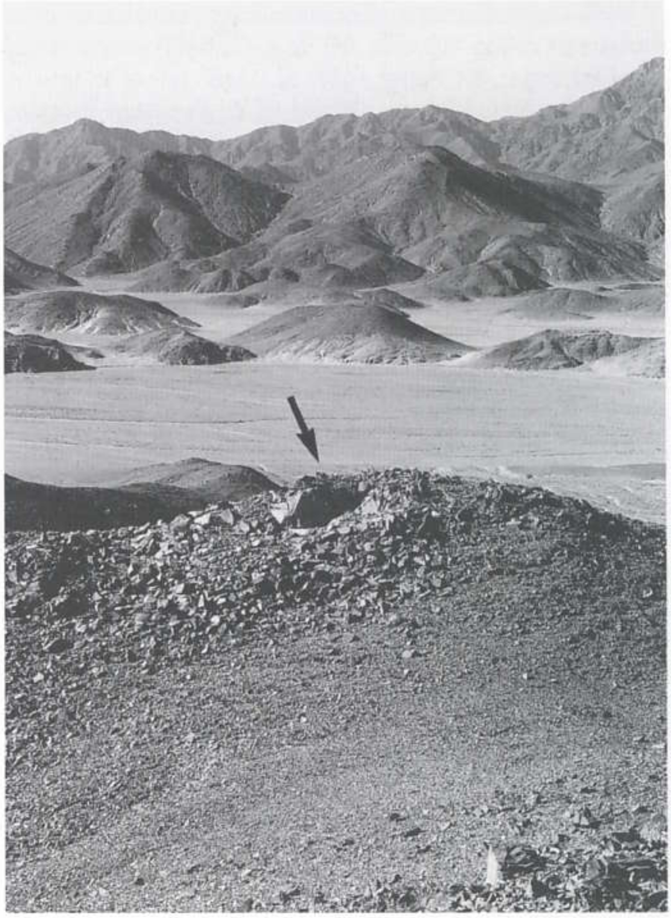


Figure 2.28 One (arrow) of numerous small quarries for calcareous tuff and tuffaceous limestone on Gebel Manzal el-Seyl, Eastern Desert.

Another variety of tuff utilised by the ancient Egyptians is yellowish brown in colour with purple bands. The source of this rock is unknown. In composition it is a lithic andesite tuff with scattered crystals of feldspar and bands rich in iron oxides. Examples of known provenance consist of fragments of three vessels from the First-Dynasty royal tombs at Abydos (Aston 1994: 27, colour photograph pl. 5b).

Tuff and tuffaceous limestone have sometimes been incorrectly called 'volcanic ash' (e.g. Caton-Thompson and Gardner 1934: 87; Petrie 1937: 2). 'Ash' refers to unconsolidated volcanic fragments and when these are compacted and/or cemented into rock the result is a tuff. The dark green tuff may be confused with the Wadi Hammamat siltstone as these rocks closely resemble each other megascopically. However, they are easily distinguished with the aid of dilute hydrochloric acid: only the tuff contains substantial calcite and so effervesces.

Uses

Tuff and tuffaceous limestone was used during the First and Second Dynasties for small vessels, including bowls of various types (Aston 1994: nos. 51, 59) and cylinders. Known examples of vessels come from tombs at Abydos, Nag el-Deir and Saqqara (Petrie 1901b: 43, Aston 1994: 27). The vessels in the Gebel Manzal el-Seyl quarry, though crudely shaped and not hollowed out, have the forms of bowls, dishes and cylinders. These rough pieces would have been carried to the Nile valley for final carving and polishing.

Examples

1. Unprovenanced beaker dating to the Naqada III or Early Dynastic period, *c.* 3150–2649 BC (height 12.6 cm; Cambridge, Fitzwilliam E.110.1994).
2. Dish from tomb 1513 at Nag el-Deir, Second Dynasty, *c.* 2770–2649 BC (Hearst Museum of Anthropology, University of California, Berkeley 6–132).
3. Cylinder vessel from the Step Pyramid at Saqqara, dating to the Early Dynastic period, *c.* 3000–2649 BC (height 16.5 cm; Cairo JE 65422).
4. Purple-striped tuff vessel from the tomb of King Qa'a (tomb Q), Umm el-Qa'ab, Abydos, First Dynasty, *c.* 2770 BC (height 13.6 cm; Ashmolean 1896–1908 E.3235).

Bibliography

Lucas (1962: 419–20); Aston (1994: 26–7); Harrell *et al.* (forthcoming).

For colour photographs of the dish from Nag el-Deir (Berkeley 6–132) and the vessel from Abydos (Ashmolean 18961908 E.3235) see Aston (1994: pls. 5b–c), and for the cylinder vessel (Cairo JE 65422) see Saleh and Sourouzian (1987: no. 20).

Turquoise

Definition

The chemical composition of turquoise is hydrated phosphate of copper and aluminium ($CuAl_6[PO_4]_4[OH]_8 \cdot 4H_2O$). Its colour is opaque blue-green or pale sky blue and its Mohs hardness is 5–6. It forms as veins and nodules usually in trachytic volcanic rocks in arid regions.

Egyptian sources

The two principal ancient Egyptian sources of turquoise are in the Sinai peninsula at Wadi Maghara from the Early Dynastic period to the Middle Kingdom and at Serabit el-Khadim from the Middle Kingdom until at least the Late Period (see also Beit-Arieh 1980 for evidence of prehistoric mining at this site).

The mines at Wadi Maghara, located in the southern Sinai, 225 kilometres southeast of Cairo, were particularly exploited during the Old and Middle Kingdoms. When Petrie examined the site in 1904–5 he found an Old Kingdom hilltop settlement on the opposite side of the wadi from the adits and rock-carvings, as well as two unfortified groups of stone huts on the floor of the wadi, the latter also dating to the Old Kingdom (Petrie and Currelly 1906; Chartier-Raymond 1988).

The mines at Serabit el-Khadim (Barrois 1932; Starr and Butin 1936; Giveon 1978; Bonnet *et al.* 1994; Chartier-Raymond *et al.* 1994; see Fig. 2.29), about eighteen kilometres to the north of Wadi Maghara, were also accompanied by rock-carved stelae, as well as an unusual associated temple complex dating to the Middle and New Kingdoms (*c.* 2040–1070 BC). In the temple precincts and the surrounding area, many rock-cut and free-standing stelae were dedicated by mining expeditions to the goddess Hathor in her aspect of *nbt mfk3t* ('lady of turquoise') and the god Soped 'guardian of the desert ways'. Among the results of Israeli work at Serabit el-Khadim and Wadi Maghara between 1967 and 1982 (Beit-Arieh 1977; Giveon 1972) was the discovery that one of the mines contained equipment concerned with the processing of copper. This find has added to the controversy regarding the ancient Egyptians' precise aims in the Sinai. Many of the inscriptions at Wadi Maghara and Serabit el-Khadim refer to the procurement of a substance called *mfk3t*, which was once translated as malachite and has more recently been taken to mean turquoise. It is possible that the main focus of Egyptian operations at these two sites was the obtaining of copper and malachite, with turquoise perhaps being only a convenient by-product of this mining (see Rothenberg 1987; Levene 1998). It is interesting to note in this context that the surviving examples of turquoise as a gemstone actually form quite a minor component in Egyptian jewellery, compared with the vast quantities implied by the numerous adits, shafts and stelae at Wadi Maghara and Serabit el-Khadim.

Description

Mined by the Egyptians from the late Predynastic period onwards, the greener variety of turquoise appears to have been highly prized by the ancient Egyptians, who preferred it to the more porous blue variety, which tends to fade when exposed to the sun or water.

Uses

Turquoise was used primarily for jewellery from the Predynastic to the Greco-Roman period. There is no evidence that powdered turquoise was used for a pigment (see Chapter 4, this volume), although Jack Ogden (pers. comm.

Figure 2.29 Turquoise mine at Serabit el-Khadim, Sinai, with a rock-cut stele of the Twelfth-Dynasty ruler Amenemhat III just above the entrance.

and Chapter 6, this volume) argues that it may have been used extensively in powdered form in the production of glazes.

Examples

1. Bracelet consisting of thirteen gold and fourteen turquoise *serekh*-plaques, each crowned by a falcon, from the First-Dynasty tomb of King Djer at Umm el-Qa'ab, Abydos, *c.* 3000 BC (overall length 15.6 cm; Cairo CG52010).
2. Gold pectoral of Sithathoriunet, from her tomb at Lahun, incorporating turquoise, lapis lazuli and cornelian inlay, Twelfth Dynasty, *c.* 1830 BC (height 4.5 cm; New York, MMA 16.1.3).
3. Gold arm band of Herihor set with an unusually large nugget of turquoise, Twentieth Dynasty, *c.* 1080 BC (diameter 9 cm; Hildesheim, Pelizaeus Museum, on loan from the Niedersächsische Sparkassenstiftung; Eggebrecht 1996: 76, fig. 71).
4. Gold human-headed *ba*-bird pendant inlaid with turquoise and lapis lazuli, of unknown provenance and dating to the Twenty-sixth Dynasty or later, after *c.* 600 BC (width 5 cm; BM EA3361).

Bibliography

Brugsch (1868); Weill (1908); Petrie and Currelly (1906); Barron (1907: 209–12); Thomas (1912); Barrois (1932); Starr and Butin (1936); Clère (1938); Gardiner and Peet (1952); Cerny (1955); Lucas (1962: 404–5); Rothenberg (1970; 1979: 13780); Giveon (1972, 1974, 1974–5, 1978, 1983); Beit-Arieh (1977, 1980); Chartier-Raymond (1988); Bonnet *et al.* (1994); Chartier-Raymond *et al.* (1994); Levene (1998).

Volcanic ash *see* tuff and tuffaceous limestone

Stone-working technology

A great deal of the impact of Egyptian civilization derives from the products of stone-working technology. On the largest scale there are the techniques of stone-dressing, masonry and civil engineering employed in the construction of such ceremonial buildings as *mastabas*, pyramids, temples and palaces. In addition, however, a substantial amount of skill and energy was expended on the carving of stone sculpture and such characteristically Egyptian artefacts as offering tables, sarcophagi and stone vessels. Finally there was a highly-developed area of technology devoted to the conversion of gemstones into items of jewellery. The section below provides brief summaries of the technologies associated with each of these types of stone product. Given that this is a wide area, we have concentrated both on the provision of bibliographical information and on the discussion of recent developments.

Masonry

As far as stone masonry is concerned, many volumes have been published describing the surviving remains of pharaonic temples and tombs, whether in the form of travellers' accounts, archaeological reports or architectural histories (Badawy 1954–68 and Smith 1958 being the first attempts to provide comprehensive historical surveys). Although there have been many meticulous studies of specific sites or buildings, only a few – notably Petrie's surveys of the pyramids at Giza and Meidum in 1883 and 1892 – have focused on the technological aspects of the structures. On the other hand, it is remarkable that, despite Petrie's concern with the minutiae of many aspects of craftwork and tools, his general works include no study of the structural engineering of the Pharaonic period.

This gap in the literature began to be filled in the 1920s with Reginald Engelbach's studies of obelisks (Engelbach 1922, 1923), Ludwig Borchardt's many detailed studies of pyramid complexes and sun temples (e.g. Borchardt 1926, 1928) and the first edition of Alfred Lucas' *Ancient Egyptian Materials and Industries* (Lucas 1926), which included a substantial section devoted to the scientific study of stone working. However, the first real turning point arrived in 1930 with the publication of *Ancient Egyptian Masonry*, in which Engelbach collaborated with Somers Clarke to produce a detailed technological study of Egyptian construction methods from quarry to building site (Clarke and Engelbach 1930).

The meticulous excavations of George Reisner at Giza and elsewhere soon afterwards bore fruit in the form of the publication of *The Development of the Egyptian Tomb down to the Accession of Cheops* (Reisner 1936), and Reisner's work at Giza was later supplemented by the architectural reconstruction of the Step Pyramid of Djoser at Saqqara by Jean-Philippe Lauer, whose *Observations sur les pyramides* (Lauer 1960) was also informed by a sense of the fundamental practicalities of ancient stone masonry. Both I.E.S. Edwards (1947, 5th edn. 1993) and Rainer Stadelmann (1985) produced general books on Egyptian pyramids which built on the observations of Borchardt, Reisner, Lauer and others, including substantial discussion of the technological problems encountered by Pharaonic builders. Christopher Eyre (1987) has provided a detailed study of the textual and visual evidence for the organisation of labour in the Old and New Kingdoms, which includes a great deal of data relating to quarrying and building (particularly covering such questions as the composition, management and remuneration of the workforce involved in procuring, transporting and working stone, as well as the timing of quarrying and construction projects).

Most recently, Dieter Arnold's *Building in Egypt: Pharaonic Stone Masonry*, published in 1991, is a wide-ranging study of the data, including meticulous discussion of the surviving evidence for quarrying and stone-working tools, and sophisticated, well-illustrated studies of the grooves and marks on stone blocks which can indicate many of the ways in which they were transported, manoeuvred into position and interlocked with the rest of the masonry. Like Clarke and Engelbach's *Ancient Egyptian Masonry*, it serves as an essential and welcome basis for all future study of Pharaonic stone masonry. Arnold's primary concern is with the technology rather than the materials; for a detailed discussion of the different types of stone utilised by the Egyptians in art and architecture, see De Putter and Karlshausen (1992).

An area of structural stone-working that has still received comparatively little treatment is the study of the procedures and techniques of rock-tomb architecture as opposed to free-standing buildings. The Eighteenth-Dynasty élite rock-cut funerary chapels at Amarna represent a useful opportunity to observe various stages in the process, since they were all abandoned before final use, many of them at a relatively early point in terms of ancient excavation and decoration. Owen and Kemp (1994) have made a preliminary study of the unfinished tombs at Amarna, noting that the characteristic procedure was to cut out the first part of the outer hall of the chapel at ceiling level, and then to cut downwards towards the intended floor-level, usually hollowing out first the transverse area at the front and then the aisle between the colonnades further in. The stone-workers then seem to have gradually hollowed out the rest of the tomb from the ceiling downwards, resulting in a stepped effect when the work was stopped prematurely. The blocked-out outlines of lintels and columns are often visible, the latter being cone-shaped initially in order to accommodate the eventual column-base, as well as leaving plenty of excess rock for the process of decorative cutting. Owen and Kemp (1994: 3) also make the point that all this initial work seems to have been executed with a 'metal bar chisel' (Pendlebury 1951: I, 72, II, pl. LXXIX.3.30), whereas the next stage – the dressing of the surfaces – was accomplished, probably by a different, more skilled set of workmen, using a chisel with a narrower blade, the marks from which are visible in the form of shallow chisel marks cut at a greater variety of angles than the rougher first-stage chiselling.

The related topic of the carving of monolithic columns, which was first scientifically addressed by Engelbach (1928), in the form of an experimental study of the method of production of a Fifth-Dynasty example from the pyramid complex of Sahura at Abusir, has more recently been examined by the Martin Isler (1992), following on from an earlier study of the production of obelisks (Isler 1987) and drawing on his personal experience as a stone sculptor. Like Owen and Kemp, he argues that columns were quarried in such a way that the major part of a column, obelisk or sculpture could be completed by a relatively unskilled stone-cutter, thus minimising the numbers of sculptors who would be required at any one time (Isler 1992: 54).

Vessels

Like the creation of stone masonry, the carving of stone vessels reached a comparatively early peak in ancient Egypt, and became firmly established as one of the most characteristic products of Egyptian craftsmen from the Predynastic period onwards. Indeed, the great antiquity of this area of technology appears to be confirmed by the fact that the Egyptian term for 'craftsman' (*ḥmwty*), written with a determinative sign in the form of a drill, was initially used only to refer to those workers who drilled out stone vessels.

Until the publication of Barbara Aston's *Ancient Egyptian Stone Vessels* in 1994, the only general publications on this topic were the catalogue of stone vessels in the Cairo Museum compiled by Friedrich von Bissing (1907) and a typological study of stone and metal vessels by Flinders Petrie (1937). A few other publications have appeared in recent years, but all these have concentrated on specific periods (e.g. el-Khouli 1978 on Early Dynastic vessels; Reisner 1931, 1932 and Bernard 1966–7 on Old Kingdom vessels; el-Khouli *et al.* 1994 on the vessels from the tomb of Tutankhamun; and Lilyquist 1996 on Second Intermediate Period and New Kingdom vessels). Aston's study of the materials and forms of ancient Egyptian stone vessels combines field survey and petrographic analysis to produce a thorough study of changing materials and forms.

The initial stages of vessel production clearly consisted of a process by which the fragment of stone was roughly shaped and smoothed with stone tools. No monograph has yet tackled the question of the means by which the interiors of stone vessels were hollowed out, although a number of insights have been provided by ethnoarchaeological and experimental studies (Hester and Heizer 1981; Stocks 1986a, 1986b, 1993). In 1972, Thomas Hester and Robert Heizer undertook an ethnographic and technological study of the modern 'alabaster' workshops at the Upper Egyptian village of Sheikh Abd el-Gurna on the west bank opposite Luxor, both in order to record a unique modern cottage industry and in an attempt to gain new insights into ancient techniques of vessel carving and drilling (Hester and Heizer 1981).

Denys Stocks has studied such pictorial evidence as Old and New Kingdom hieroglyphs representing boring tools (Stocks 1993: fig. 3) and depictions of the use of the so-called twist-reverse-twist drill (or TRTD) in various tombs, including that of Mereruka at Saqqara (Sixth-Dynasty; Duell 1938), that of Pepyankh at Meir (Twelfth-Dynasty), and those of Rekhmira at Thebes and Iby at Thebes (Eighteenth-Dynasty and Twenty-sixth-Dynasty; see Stocks 1986b: fig. 1). On the basis of such depictions, Stocks succeeded in creating modern replicas of the figure-of-eight stone borer and the TRTD, thus producing an experimental limestone vessel. With a height of 10.7 cm and a diameter of 10 cm, the vessel took 22 hours, 35 minutes to make (including the exterior shaping, interior tubular drilling and stone boring). Stocks points out that bow-driven tubes produce a tapering drill core, whereas the use of the TRTD results in a parallel-sided core, as in the case of an uncatalogued alabaster gypsum vase in the Petrie Museum. Although bow-driven tubes would have been five times faster than the TRTD, they would have provided insufficient leverage and control, and Stocks' experiments showed that the vessels could actually be broken by the additional mechanical stresses involved in using a bow.

The final stage of the ancient production process consisted of the smoothing and polishing of the vessel both inside and outside, which took place largely with the use of stones and quartz sand. The more delicate parts of the vessels, such as lugs, handles and lips, would have been worked with fine copper chisels.

Gemstones

From as early as the Neolithic period, the Egyptians were using gemstones for jewellery. By the Pharaonic period they were carving and piercing a wide variety of stones, including amethyst, cornelian, chrysoprase, garnet, haematite, milky quartz, sard, jasper, malachite, agate, mica, rock crystal, serpentinite, lapis lazuli, olivine, fluorspar, turquoise, microcline and beryl. The earliest beads were probably created with the use of flint or chert tools, but as early as the Naqada period copper drills were being used to perforate the stone, while copper wires were employed to cut small gems, sometimes leaving serrations that are still visible on the stone. Both the drills and wires achieved their effect by combination with quartz sand and emery abrasives. By the New Kingdom, jewel-makers were employing sophisticated bow-drilling equipment in order to drive the drills.

As with stone vessel production, the study of gemstone working has been significantly advanced by the experimental work of Denys Stocks (1986c, 1989). Six Theban tombs, dating to the Eighteenth and Nineteenth Dynasties, contain scenes showing the drilling of stone beads, including one instance of the drilling of three beads simultaneously (in the tomb of Rekhmira). Although no archaeological examples of such multiple drills have survived, Stocks used the information provided by the six tomb-scenes to construct a replica multiple drill and bow (hypothesising that the bow shaft was probably made from some kind of bamboo-like reed (e.g. *Arundo donax*). He notes not only that the bows depicted in the tomb of Rekhmira were longer than those represented in other tombs (at about 120 cm in length) but also that the operators of the drills had their fingers entwined in the bow-strings at the far end. His experimental work shows that this technique was essential for multiple drilling.

Sculpture

In a culture characterised by the anonymity of the artist and craftworker, it is no doubt significant that those who sculpted statues were not only frequently described by their peronal names in the captions accompanying funerary scenes of sculptors' workshops, but were also sometimes shown in contexts other than the working environment (e.g. eating, carrying offerings, or accompanying the deceased on hunting trips), and were evidently taken on as individual employees, rather than simply being part of the permanent workforce of the deceased. Rosemarie Drenkhahn (1995) therefore argues that sculptors (and also the painters who decorated statues) were higher in status than other craftsmen, and would have been much more closely involved with their employer:

> The carving of a statue created a close and personal relationship between the patron commissioning the work and the sculptor, for the statue was an embodiment of the patron that was placed in his tomb and as such formed an essential precondition for his continued existence in the next world. (Drenkhahn 1995: 339)

Because of Egyptian artistic conventions, ancient depictions of sculptors' workshops (e.g. those in the Eighteenth-Dynasty Theban tomb-chapel of Rekhmira, see Fig. 2.30) tend to show the statues in their finished state, even when they are clearly at comparatively early stages in the process. However, a great deal of information on the various stages of statue-carving has survived in the form of unfinished sculptures of many periods (e.g. the Twenty-sixth-Dynasty semi-worked limestone statue of a standing man in the Institute of Arts, Detroit, and a number of unfinished statues of the Third-Dynasty king Djoser from his Step Pyramid complex at Saqqara, now in the Egyptian Mu-

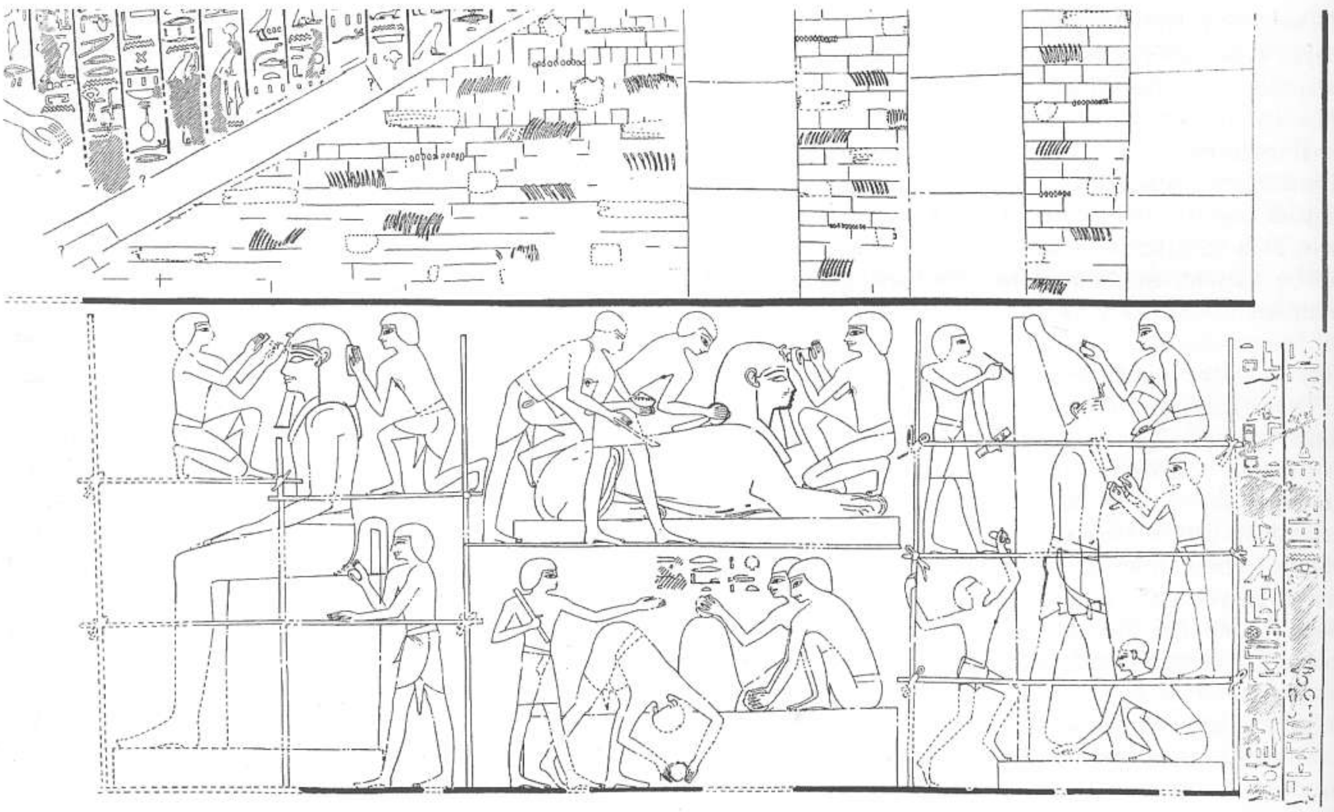


Figure 2.30 Scene from the tomb of Rekhmira at Thebes (TT100), showing sculptors polishing and inscribing colossal statues of Thutmose III.

seum, Cairo), and excavations of settlement sites have revealed the contents of several sculptor's workshops at the Eighteenth-Dynasty city of Amarna. The finds from the studio of Thutmose at Amarna (Roeder 1941; Krauss 1983) show that sculptors may have copied plaster 'masks' and busts in order to standardise the facial portraiture of statues of members of the élite. Such workshops also contain various parts of composite statues, such as separately carved limbs, torsos, heads and headgear, carved from several different types of stone.

These archaeological remains show that the basic sculpting process was to rough out a cube of rock, which then had preliminary drawings executed on all sides, thus providing guidelines for the sculptors (which, in the case of colossal statues, comprised large teams of workers perched on scaffolding) as they worked inwards simultaneously from each side. In the Pharaonic period, they primarily used stone tools for the initial roughing out, but then gradually employed finer copper or bronze tools, until the final minute details were incised with pointed chisels and/or drills. As with the stone vessels, the statues were eventually polished with rubbing stones and quartz sand, although the final production stage was the application of coloured pigments.

Summary of methods of scientific analysis

Introduction

Rock and mineral deposits are usually heterogeneous on the scale of outcrops and quarries, and sometimes can even be quite variable on the scale of individual artefacts. Any petrological analysis of archaeological stone must therefore incorporate a sampling plan that takes this heterogeneity into account. Obtaining a statistically representative sample is easy for outcrops and quarries but not for artefacts which would be damaged by such sampling. Thus samples of artefacts tend to be very few (often only one), very small (less than one gram) and taken from only certain areas (hidden or broken sides), and consequently may not be representative of the object as a whole. Any conclusions based on the analytical results must be qualified accordingly. If, however, a megascopic examination of an artefact reveals it to be compositionally uniform and, in the case of rocks, fine-grained, then a single small sample will probably suffice.

Once a sample of archaeological stone is collected, two questions need to be answered: what is it, and where does it come from? Approaches to answers for these questions are discussed in the next two sections. With the exception of megascopic analyses, the analytical methods described below can be performed by commercial laboratories and, for a of chemistry departments.

Identifications

Megascopic analyses

Many rocks and minerals can be identified, at least preliminarily, by a megascopic examination. Good general reference books with excellent colour photographs of typical specimens are Mottana *et al.* (1978), Pellant (1992), and Hall (1994). Less well illustrated but more authoritative reference books are Klein and Hurlbut (1993) for minerals, and Raymond (1995) and Blatt and Tracy (1996) for rocks. Brown and Harrell (1991) provide a good summary of rock classifications suitable for megascopic work.

Equipment and supplies needed include: a hand lens (preferably with 5 × to 10 × magnification and large diameter lens, at least 20 mm, for a wide, bright field of view); a toothbrush with stiff bristles for cleaning surfaces; a small magnet; dilute (5%) hydrochloric acid for testing carbonate content; a small plate of unglazed porcelain for testing streak colour; and, for testing the Mohs scratch hardness, a steel pocket knife or dental pick, a copper or bronze coin, and a small plate of glass. Even better are commercially available sets of metal-tipped scribers representing all the Mohs hardnesses from 2 to 9. Portable hydrometers, used to determine specific gravity (i.e. density) are also commercially available and easy to operate. Minerals can be identified from their unique set of physiochemical properties, including some combination of the following: external crystal form, colour, lustre, streak, cleavage or fracture, scratch hardness, magnetism, specific gravity, reaction to acid, and others. Rocks are classified on the basis of their composition (varieties and relative abundances of minerals present) and texture (grain size, grain articulation – crystalline or clastic, and structures such as foliation for metamorphic rocks).

Thin-section petrography

This is the best method for identifying minerals in rocks, determining their volumetric percentages, and describing their textures. The descriptions of rocks in this chapter are based primarily on thin-section petrography.

A thin-section is a thirty micron-thick slice of rock mounted on a glass slide. These can be prepared from rock chips of any size or shape, but the chip must be at least five millimetres thick to accommodate standard equipment. Thin-sections are examined using a 'polarising transmitted-light (i.e. petrographic) microscope'. Good reference books on thin section petrography are: Ehlers (1987), Nesse (1991), Mackenzie and Guilford (1980) and MacKenzie and Adams (1994) for minerals; Williams *et al.* (1982), MacKenzie *et al.* (1982) and Yardley *et al.* (1990) for igneous and metamorphic rocks; and Scholle (1978, 1979), Adams *et al.* (1984) and Carozzi (1993) for sedimentary rocks.

There is an enormous variety of analytical methods that can potentially be applied to rocks and minerals. Those described below are only the ones most commonly used in petrological studies. Informative summaries of these methods, with bibliographies, are given in Tucker (1988: 191–354) and Lewis and McConchie (1994: 144–81).

X-ray powder diffraction (XRD)

Sub-gram size, powdered rock or mineral samples are irradiated with x-rays in a 'x-ray powder diffractometer'. Diffraction of x-rays by atoms in the crystal structures of the minerals present permits their identification as well as a semi-quantitative determination of their relative abundances. After thin-section petrography, this is the best method for identifying minerals, except in the case of clay minerals, where XRD is superior to thin-sectioning. Examples of the use of XRD on Egyptian rocks all involve limestone and include Bradley and Middleton (1988), Middleton and Bradley (1989), Campbell and Folk (1991), Harrell and Penrod (1993) and Ingram *et al.* (1993).

X-ray fluorescence spectrometry (XRF)

Five or fewer grams of a powdered rock sample are irradiated with x-rays in an 'x-ray fluorescence spectrometer'. Analysis of wavelengths and intensities of the secondary x-rays emitted by the sample permits identification of the elements present and a fully quantitative determination of their relative amounts. The results are normally presented as weight percents of the oxides for the elements (e.g., calcium and iron would be reported as CaO and FeO, respectively). The method works best for major and minor elements (those present in amounts exceeding 0.001 weight percent or 10 ppm) with atomic numbers larger than about eight. XRF is an essential method for analysing volcanic igneous rocks where the groundmass is usually too fine-grained for thin-section petrography. Thin sections are still needed, however, to identify the phenocrysts and other coarser phases in these rocks. XRF is also a popular method for all other rock types when an inexpensive whole-rock chemical analysis is needed. Examples of the use of XRF include Klemm and Klemm (1981: fig. 9), Harrell (1992) and Harrell and Penrod (1993) for limestone; el-Hinnawi and Loukina (1972) for travertine; Klemm *et al.* (1984) for quartzite; and Klemm and Klemm (1993; partial data only) and Brown and Harrell (1995) for a wide variety of igneous and metamorphic rocks.

Scanning electron microscopy (SEM)

Gold- or carbon-coated pieces of rock or mineral are illuminated with an electron beam in a 'scanning electron microscope' to reveal details of grain morphologies and textures too small to be seen in thin sections. Magnifications of at least 30,000 × are possible and range up to

100,000 × or higher depending on the instrument. These magnifications are not only far higher than those attainable with petrographic microscopes (normally at most 500 × to 750 ×, depending on the lenses used), but, unlike thin sections, SEM provides three-dimensional images of surfaces and these are especially useful for investigating textures and grain morphologies. More useful, however, are the semi-quantitative elemental analyses obtainable from a microscope equipped with an 'energy dispersive x-ray analysis system' (EDS). EDS is very similar to x-ray fluorescence spectrometry but has the advantage of being able to irradiate an area on a sample specimen as small as one micron across. Although the resulting elemental analysis is only semi-quantitative, it can still be useful for identifying the mineralogy of a specific grain. This may be needed, for example, when a rare or unfamiliar mineral cannot be identified in thin section. The thin section itself can then be examined with SEM.

Another instrument sometimes attached to the microscope is the 'wavelength dispersive spectrometer' (WDS). This is essentially an x-ray fluorescence spectrometer but differs from the XRF instrumentation in that excitation of secondary x-rays from elements is caused by an electron beam rather than primary x-rays. Unlike the EDS, WDS provides fully quantitative elemental analyses. Examples of the use of SEM-EDS all involve limestones and include Bradley and Middleton (1988), Middleton and Bradley (1989), Harrell and Penrod (1993), Ingram *et al.* (1993) and Klemm and Klemm (1993: 34–44).

The 'electron microprobe' (or 'probe') is a more specialised and efficient combination of a scanning electron microscope and multiple wavelength dispersive spectrometers. It is the instrument of choice for performing fully quantitative elemental analyses of micron-size areas on rock and mineral specimens. 'Electron microprobe analysis' (EMPA) has been applied to tonalite gneiss by Peacock *et al.* (1994).

Instrumental neutron activation analysis (INAA)

Whereas the scanning electron microscope and electron microprobe provide elemental analyses of parts of a single grain, 'instrumental neutron activation analysis' provides the same information for whole-rock samples. It is especially good for carbonate rocks like marble, limestone and travertine. For these and other rock types, the elements most commonly analysed by this method are those with atomic numbers 57 and above. Depending on the elements sought and the detection limits desired, one to thirty grams of powdered rock are needed. The sample is placed within a nuclear reactor or synchroton and irradiated with neutrons. The resulting radioactivity generated by the sample is analysed by a gamma-ray spectrometer to determine the amounts (in parts per million) and types of elements present. INAA is especially good for trace element analyses but the large sample sizes required often makes it inappropriate for artefacts. Examples of the use of INAA include: Meyers and van Zelst (1977) for limestone; and Heizer *et al.* (1973), Bowman *et al.* (1984) and Stross *et al.* (1988) for quartzite.

Atomic absorption spectrophotometry (AAS)

This method is a popular alternative to INAA for quantitative whole-rock elemental analyses. It has the advantages of providing lower detection limits, requiring only 0.1 gram samples, and detecting more (over fifty) elements. Samples are dissolved in acid and the solution aspirated into a flame in the 'atomic absorption spectrophotometer'. The wavelengths and amounts of incident light absorbed by the heated atoms indicate the concentrations (in parts per million) and types of elements present. A closely related method, 'flame photometry', determines elemental composition from the wavelengths and intensities of light emitted by the heated atoms. This latter method is normally used only to analyse Li, Na, Ca, K, Sr and Rb. Examples of the use of AAS include Oddy *et al.* (1976), and Campbell and Folk (1991) for limestone; Klemm *et al.* (1984) for quartzite; and Klemm and Klemm (1993; partial data only) for virtually all rock types.

Inductively-coupled plasma spectrometry (ICP)

The atomic absorption spectrophotometer is now being replaced by the 'inductively-coupled plasma spectrometer' which can analyse more elements simultaneously, and more rapidly with lower detection limits. AAS, however, is still superior for detection of Na and K. An acidised sample solution is combined with argon gas in radio-frequency coils to form a high-temperature plasma. The atomised and ionised sample is then analysed by either of two procedures. ICP-optical (or atomic) emission spectrometry (ICP-AES or ICP-OES) is similar to flame photometry in that the wavelengths and intensities of light energy emitted by the excited atoms in the plasma are used to identify the elements present. In ICP-mass spectrometry (ICP-MS), in contrast, the elements in the plasma are identified by a mass spectrometer. An example of the use of ICP-AES is Ingram *et al.* (1993) for limestone.

Stable isotope fractionation

Isotopes of oxygen (16 and 18), carbon (12 and 13) and sulphur (32 and 34) are now widely used to characterise carbonate rocks such as limestone, travertine and especially marble. The relative amounts (fractionation) of the isotopic pairs are determined in sub-gram, powdered samples using a 'mass spectrometer'. The analyses are time-consuming and labour-intensive, and so there are relatively few laboratories offering this service. Examples of the use of this method all involve marble and include Brown and Harrell (1995) and Harrell (1996).

Thermogravimetric analysis (TGA)

Limestone and rock gypsum contain minerals that, when heated, evolve gases such as water vapour, carbon dioxide and sulphur dioxide. This characteristic is useful for distinguishing among varieties of these rocks. In TGA, a subgram, powdered sample is gradually heated within a 'thermogravimeter', which records the progressive reduction in weight due to loss of volatile components with increasing temperature. 'Differential thermal analysis' (DTA) is a closely related method that measures, with increasing temperature, changes in the heat content of a sample due to any of a variety of possible reactions. An example of the use of TGA on limestone is Harrell and Penrod (1993).

Provenance studies

Provenance studies seek to discover the ancient quarry supplying a rock or mineral, or, at the very least, a localised geographic area (or areas) where outcrops of the same material can be found. In order for this to be possible, a comprehensive, detailed geologic database must exist where all rock formations and mineral deposits in an area have been described and mapped, and all ancient quarries have been located and petrologically characterised. In the case of Egypt, such a database is still incomplete. However, good descriptions of the geology of Egypt are given in Said (1990), and an excellent series of geologic maps covering the country have been published by Klitzsch *et al.* (1986–7), with explanations provided by Hermina *et al.* (1989). For maps and reports on specific areas within Egypt, the publications of the Egyptian Geological Survey and Mining Authority should be consulted.

All the major and most of the minor quarries of ancient Egypt have been located (Harrell *et al.* 1996); these are listed in Tables 2.1 and 2.2 and their locations are shown on the maps in Figures 2.1a and b and 2.2. Petrological descriptions of the rocks from these quarries are given in relatively few sources: Akaad and Naggar (1964a, 1964b, 1965); Klemm (1986); Klemm and Klemm (1979, 1981 and 1993); Klemm *et al.* (1984); Harrell (1992, forthcoming (a) and (b)); Brown and Harrell (1995); Harrell and Bown (1995); Harrell and Brown (1994); and Harrell *et al.* (forthcoming).

There have been relatively few attempts at provenancing ancient Egyptian materials based on petrological analyses. Aston (1994) analysed, by thin-section petrography, all the different rock types used for stone vessels from the late Predynastic period through the Old Kingdom. She also collected some quarry samples, and based on these and the geological literature was able to determine the provenance of many of the materials. Meyers and van Zelst (1977) investigated the trace element content (by INAA) of limestone artefacts from numerous sites along the Nile River, but did not sample limestone outcrops or quarries. On the basis of the trace element 'signatures', they were able to distinguish between artefacts coming from the areas near Thebes and north of Thebes. Middleton and Bradley (1989) also analysed limestone artefacts from many sites between Thebes and Giza, and included samples from two ancient quarries. By using a combination of thin-section petrography, SEM-EDS and XRD, they were able to distinguish among limestone objects originating from the Thebes-Abydos, Deir el-Bersha and Cairo areas.

The most contentious investigation of provenance involved analyses of quartzite by Heizer *et al.* (1973), Bowman *et al.* (1984) and Stross *et al.* (1988) using thin-section petrography and INAA, and by Klemm *et al.* (1984) using thin-section petrography, XRF and AAS. Samples from the Colossi of Memnon in western Thebes and other quartzite artefacts were collected by these investigators and compared with samples from the only known ancient quarries for this rock type at Gebel Ahmar near Cairo and the Gebels Tingar-Gulab area near Aswan (see section on quartzite above for additional discussion). McGill and Kowalski (1977) re-analysed the INAA data of Heizer *et al.* (1973) using a variety of multivariate statistical methods.

The study of the provenance of the tonalite gneiss quarried during the Roman period at Mons Claudianus, involving the analysis of numerous samples of similar-looking rocks from sites throughout the Roman empire, was undertaken by David Peacock *et al.* (1994), using megascopic and chemical identification. They employed XRF to compare variations in Y and Zr, and EPMA to compare variations in the Mg and Fe content of the amphiboles, and the Ti and Al content of biotites. They were able to distinguish clearly between three principal ancient sources: (1) Mons Claudianus, (2) the Kozak Dag area of Turkey, and (3) the Cavoli region of Elba, thus demonstrating that the tonalite gneiss (or 'granito del foro') from Mons Claudianus was used in a much smaller number of sites than previously thought (various monuments in Rome, Diocletian's Mausoleum in Split, and possibly Hagia Sophia in Istanbul). Peacock *et al.* (1994: 229) thus conclude that 'the distribution and restricted use contrasts markedly with that of other great decorative stones such as the granite from Aswan . . . all of which suggests that Mons Claudianus may have been a rather special stone, perhaps restricted to the emperor himself'.

There have been few provenance studies of Egyptian gemstones, although some recent analysis has been undertaken on samples of beryl from the Sikait-Zubara region in the Eastern Desert. Grubessi *et al.* (1989, 1990) used XRD and infrared spectroscopy to characterise the emeralds from Gebel Zubara, comparing them with others from mines in Brazil, Austria, Columbia and the Urals.

References

Adams, A.E., MacKenzie, W.S. and Guilford, C. 1984. *Atlas of Sedimentary Rocks under the Microscope*. New York: John Wiley.

Ahmed, S.M. 1993. Collapse and solution red breccia of the Issawia Sharq locality, Nile valley, Upper Egypt. *Egyptian Journal of Geology*, 37/2: 187–202.

Akaad, M.K. and Naggar, M.H. 1964a. Petrography of the Egyptian alabaster of Wadi Al Assyuti. *Bulletin of the Faculty of Science, Alexandria University*, 6: 157–73.

1964b. The deposit of Egyptian alabaster at Wadi El Assyuti. *BSGE*, 36: 29–39.

1965. Geology of the Wadi Sannur alabaster and the general geological history of the Egyptian alabaster deposits. *Bulletin de l'Institut du Desert de l'Egypte*, 13/2: 35–63.

Akaad, M.K. and Noweir, A.M. 1972. Some aspects of the serpentinites and their associated derivatives along Qift-Quseir Road, Eastern Desert. *AGSE*, 2: 251–70.

Alford, C.J. 1901. Gold mining in Egypt. *Transactions of the Institute of Mining and Metallurgy* (London), 10: 2–28.

Altenmüller, H. and Moussa, A.M. 1981. Die Inschriften der Taharkastele von der Dahschurstrasse. *SAK*, 9: 57–84.

Andrew, G. 1938. On imperial porphyry. *BIE*, 20: 63–81.

1939. The greywackes of the Eastern Desert of Egypt, Part I. *BIE*, 21: 153–90.

Andrews, C.A. 1981. *Catalogue of Egyptian Antiquities in the British Museum VI: Jewellery I: From the Earliest Times to the Seventeenth Dynasty*. London: BMP.

1990. *Ancient Egyptian Jewellery*. London: BMP.

Arnold, D. 1987. *Der Pyramidenbezirk des Königs Amenemhet III. in Dahschur* I. Mainz: von Zabern.

1991. *Building in Egypt: Pharaonic Stone Masonry*. New York and Oxford: OUP.

Arnold, F. 1990. *South Cemeteries of Lisht II: The Control Notes and Team Marks*. New York: MMA.

Aston, B.G. 1994, *Ancient Egyptian Stone Vessels: Materials and Forms*. Studien zur Archäologie und Geschichte Altägyptens 5. Heidelberg: Heidelberger Orientverlag.

Attia, M.I. 1955. *Topography, Geology and Iron-ore Deposits of the District East of Aswan*. Cairo: GSE.

Aufrère, S. 1991. *L'univers minéral dans la pensée égyptienne* (2 vols.). Cairo: IFAO.

Badawy, A. 1954–68. *A History of Egyptian Architecture*, 3 vols. Cairo: Urwand (vol. 1); Berkeley and Los Angeles, CA: University of California Press (vols. 2–3).

Ball, J. 1907. *A Description of the First or Aswan Cataract of the Nile*. Cairo: GSE.

1912. *Geography and Geology of South-eastern Egypt*. Cairo: GSE.

Barrois, A. 1932. The Serabit expedition of 1930. *Harvard Theological Review*, 25: 101–21

Barron, T. 1907. *Topography and Geology of the Peninsula of Sinai: Western Portion*. Cairo: GSE.

Barron, T. and Hume, W.F. 1902. *Topography and Geology of the Eastern Desert of Egypt: Central Portion*. Cairo: GSE.

Baumgartel, E.J. 1960. *The Cultures of Prehistoric Egypt* II. London: OUP.

Bavay, L. 1997. Matière première et commerce à longue distance: le lapis-lazuli et l'Egypte prédynastique. *Archéo-Nil*, 7: 65–79.

Bavay, L., De Putter, T., Adams, B., Navez, J. and André, L. 2000. The origin of obsidian in Predynastic and Early Dynastic Upper Egypt. *MDAIK*, 56.

Beit-Arieh, I. 1977. South Sinai: The Early Bronze Age. Doctoral dissertation. Tel Aviv University, Israel.

1980. A Chalcolithic site near Serabit el-Khadim. *Tel Aviv*, 7: 45–64.

Bernard, M. 1966–7. Les Vases en pierre de l'ancien empire (Ve et VIe dynasties). Unpublished dissertation. Université catholique de Louvain, Faculté de philosophie et lettres, Institut supérieur d'archéologie et d'histoire de l'art.

Bissing, F.W. von 1907. *Steingefäße*. CGC 18065–18793. Vienna: Adolf Holzhausen.

Blatt, H. and Tracy, R.J. 1996. *Petrology: Igneous, Sedimentary, and Metamorphic* (2nd edn.). New York: W. H. Freeman.

Blom-Böer, I. 1994. Zusammensetzung altägyptischer Farbpigmente und ihre Herkunftslagerstätten in Zeit und Raum. *OMRO*, 74: 55–107.

Bomann, A. 1995. Eastern Desert [part of 'Digging Diary' section]. *EA*, 6: 30.

Bonnet, C., Le Saout, F. and Valbelle, D. 1994. Le temple de la déesse Hathor, maîtresse de la turquoise, à Sérabit el-Khadim. *CRIPEL*, 16: 15–30.

Borchardt, L. 1926. *Längen und Richtungen der vier Grundkanten der grossen Pyramide bei Gise*. Cairo: Beiträge zur ägyptischen Bauforschung und Altertumskunde.

1928. *Die Entstehung der Pyramide an der Baugeschichte der Pyramide bei Mejdum nachgewiesen*. Berlin: J. Springer.

Boukhary, M.A. and Malik, W.M.A. 1983. Revision of the stratigraphy of the Eocene deposits of Egypt. *Neues Jahrbuch für Geologie und Palaeontologie Monatshefte*, 6: 321–37.

Bourriau, J. 1988. *Pharaohs and Mortals: Egyptian Art in the Middle Kingdom*. Cambridge: CUP.

Bowman, H., Stross, F.H., Asaro, F., Hay, R.L., Heizer, R.F. and Michel, H.V. 1984. The northern colossus of Memnon. *Archaeometry*, 26/2: 218–29.

Bradley, S.M. and Middleton, A.P. 1988. A study of the deterioration of Egyptian limestone sculpture. *Journal of the American Institute for Conservation*, 27: 64–86.

Brown, V.M. and Harrell, J.A. 1991. Megascopic classification of rocks. *Journal of Geological Education*, 39: 379–87.

1995. Topographical and petrological survey of ancient Roman quarries in the Eastern Desert of Egypt. In *The Study of Marble and Other Stones Used in Antiquity – ASMOSIA III, Athens: Transactions of the Third International Symposium of the Association for the Study of Marble and Other Stones in Antiquity* (eds. Y. Maniatis, N. Herz and Y. Bassiakis). London: Archetype, pp. 221–34.

1998. Aswan granite and granodiorite. *GM*, 164: 33–9.

Bruce, J. 1805. *Travels to Discover the Source of the Nile*, 2 vols., 2nd edn. London: G.C.J. and J. Robinson/Constable.

Brugsch, H. 1868. *Wanderung nach den Türkis-Minen und der Sinaï Halbinsel*. Leipzig: J.C. Hinrichs.

Brunton, G. 1920. *Lahun I*. London: Quaritch.

1930. *Qau and Badari III*. London: Quaritch.

1948. *Matmar*. London: BMP.

Cailliaud, F. 1821–62. *Voyage à l'Oasis de Thèbes et dans les déserts situés à l'orient et à l'occident de la Thébaide, fait pendant les années 1815–1818*. 2 vols. Paris: Imprimerie Royale.

Campbell, D.H. and Folk, R.L. 1991. The ancient Egyptian pyramids – concrete or rock? *Concrete International*, 13/8: 28, 30–9.

Carnarvon and Carter, H. 1912. *Five Years' Exploration at Thebes: A Record of Work Done 1907–1911.* London: OUP.

Carozzi, A.V. 1993. *Sedimentary Petrography.* Englewood Cliffs: Prentice Hall.

Castel, G. and Soukiassian, G. 1985. Dépôt de stèles dans le sanctuaire de nouvel empire au Gebel el-Zeit. *BIFAO*, 85: 285–93.

1989. *Gebel el-Zeit I: Les mines de galène (Egypte, IIe Millénaire av. J.C.).* Cairo: IFAO.

Caton-Thompson, G. and Gardner, E.W. 1934. *The Desert Fayum*, 2 vols. London: Royal Anthropological Institute of Great Britain and Ireland.

Cerny, J. 1955. *Inscriptions of Sinai* II, 2nd edn. London: OUP.

Chartier-Raymond, M. 1988. Notes sur Maghara (Sinaï). *CRIPEL*, 10: 13–22.

Chartier-Raymond, M. Gratien, B., Traunecker, C. and Vinçon, J.-M. 1994. Les sites miniers pharaoniques du Sud-Sinaï: quelques notes et observations de terrain. *CRIPEL*,16: 31–80.

Clarke, S. and Engelbach, R. 1930. *Ancient Egyptian Masonry: The Building Craft.* London: Humphrey Milford and OUP.

Clère, J.J. 1938. Sur un nom du Wadi Maghara (Sinaï). *JEA*, 24: 125–6.

Couyat, J. and Montet, P. 1912. *Les Inscriptions hiéroglyphiques et hiératiques du Ouadi Hammamat.* Cairo: IFAO, pp. 1–141.

Dalloni M. and Monod, T. 1948. *Mission scientifique du Fezzan VI.* Algiers: Institut de Recherches Sahariennes de l'Université d'Alger.

Debono, F. 1971. Ateliers et carrières pharaoniques: (a) ateliers pour la fabrication d'outils de silex pharaoniques. In *Graffiti de la Montagne Thébaine I/2: La Vallée de l'Ouest* (ed. J. Černy). Cairo: Centre de la documentation et d'études sur l'ancienne Egypte, pp. 43–4.

1982. Rapport préliminaire sur les résultats de l'étude des objets de la fouille des installations du Moyen Empire et Hyksos à l'est du la sacré de Karnak. In *Cahiers de Karnak VII (1978–1981).* Paris: Editions Recherche sur les Civilisations, pp. 377–83.

De Putter, T. and Karlshausen, C. 1992. *Les Pierres utilisées dans la sculpture et l'architecture de l'Egypte pharaonique: guide pratique illustré.* Brussels: Connaissance de l'Egypte Ancienne.

Desroches-Noblecourt, C. and Vercoutter, J. 1981. *Un Siècle de fouilles françaises en Egypte 1880–1980.* Cairo: IFAO and Louvre.

Dietrich, R.V. and Skinner, B.J. 1979. *Rocks and Rock Minerals.* New York: John Wiley and Sons.

Dodge, H. and Ward-Perkins, B. (eds.), 1992. *Marble in Antiquity: Collected Papers of J. B. Ward-Perkins.* Archaeological Monographs of the British School at Rome No. 6. London: British School at Rome.

Dott, R.H. 1964. Wacke, greywacke and matrix: what approach to immature sandstone classification? *Journal of Sedimentary Petrology*, 34: 625–32.

Drenkhahn, R. 1995. Artisans and artists in Pharaonic Egypt. In *Civilizations of the Ancient Near East* I (ed. J. Sasson). New York: Charles Scribner's Sons and Simon and Schuster Macmillan, pp. 331–43.

Dreyer, G. and Jaritz, H. 1983. Die Arbeiterunterkünfte am Sadd el-Kafara. In *Der Sadd el-Kafara: die älteste Talsperre der Welt.* Braunschweig: Leichtweiss-Institut für Wasserbau der Technischen Universität.

Duell, P. 1938. *The Mastaba of Mereruka.* 2 vols. Chicago: OIP.

Dunham, D. 1947. Four Kushite colossi in the Sudan. *JEA*, 33: 63–5.

Dunham, R.J. 1962. Classification of carbonate rocks according to depositional texture. In *Classification of Carbonate Rocks: A Symposium* (ed. W.E. Ham). Tulsa: American Association of Petroleum Geologists, Memoir 1, pp. 108–21.

Edwards, I.E.S. 1993. *The Pyramids of Egypt.* 5th edn. Harmondsworth: Penguin.

Eggebrecht, A. (ed.) 1996. *Pelizaeus Museum Hildesheim: The Egyptian Collection.* Mainz: von Zabern.

Ehlers, E.G. 1987. *Optical Mineralogy* (2 vols.). London: Blackwell Scientific.

Emery, W.B. 1938a. *The Tomb of Hemaka.* Cairo: SAE.

1938b. *The Royal Tombs of Ballana and Qustul.* 2 vols. Cairo: Government Press.

Engelbach, R. 1922. *The Aswan Obelisk.* Cairo: Department of Antiquities.

1923. *The Problem of the Obelisks: from a Study of the Unfinished Obelisk at Aswan.* New York: George H. Doran.

1928. An experiment on the accuracy of shaping a monolithic column of circular cross section of the Vth dynasty from Abusir. *ASAE*, 28: 144–52.

1931. Notes of inspection. *ASAE*, 31: 126–7, 132–7, pl. I.

1933. The quarries of the western Nubian Desert: a preliminary report. *ASAE*, 33: 65–74.

1938. The quarries of the western Nubian Desert and the ancient road to Tushka. *ASAE*, 38: 369–90.

Erman, A. 1885. *Ägypten und Ägyptisches Leben im Altertum.* 2 vols. Tübingen: H. Laupp'schen.

Eyre, C.J. 1987. Work and organization of work in the Old Kingdom and New Kingdom. In *Labor in the Ancient Near East* (ed. M.A. Powell). New Haven: American Oriental Society, pp. 5–48, 167–222.

Fakhry, A. 1946. A report of the inspectorate of Upper Egypt. *ASAE*, 46: 51–4.

1952. *The Inscriptions of the Amethyst Quarries at Wadi el-Hudi.* Cairo: Government Press.

Fischer, H.G. 1991. Sur les routes de l'ancien empire. *CRIPEL*, 13: 59–64.

Folk, R.L. 1962. Spectral subdivision of limestone types. In *Classification of Carbonate Rocks: A Symposium* (ed. W.E. Ham). Tulsa: American Association of Petroleum Geologists, Memoir 1, pp. 62–84.

Frankfort, H. 1939. *Cylinder Seals: A Documentary Essay on the Art and Religion of the Ancient Near East.* London: Macmillan.

French, C.A.I. 1984. Geomorphology and prehistory at Amarna. In *Amarna Reports* I (ed. B.J. Kemp). London: EES, pp. 202–11.

Frondel, C. 1962. *The System of Mineralogy III: Silica Minerals* (7th edn.). New York: John Wiley and Sons.

Galetti, G., L. Lazzarini and Maggetti, M. 1992. A first characterization of the most important granites used in antiquity. In *Ancient Stones: Quarrying, Trade and Provenance* (eds. M.

Waelkens, N. Herz and L. Moens). Leuven: Katholieke Universiteit Leuven, Acta Archaeologica Lovaniensia Monographiae 4, pp. 167–73.

Gardiner, A.H. 1941. Ramesside texts relating to the taxation and transportation of corn. *JEA*, 27: 19–73.

Gardiner, A.H. and Peet, T.E. 1952. *Inscriptions of Sinai* I (2nd edn.). London: OUP.

Garland, H. and Bannister, C.O. 1927. *Ancient Egyptian Metallurgy*. London: Griffin.

Garstang, J. 1907. Excavations at Hierakonpolis, at Esna and in Nubia. *ASAE*, 8: 135.

Gindy, A.R. 1956. The igneous and metamorphic rocks of the Aswan area, Egypt: their description, origin and age relations. *BIE*, 37/2:83–131.

Ginter, B., Kozlowski, J. and Drobniewicz, B. 1979. *Silexindustrien von el Tarif*. Mainz: von Zabern.

Giveon, R. 1972. Le temple d'Hathor à Serabit el-Khadem. *Archéologia*, 44: 64–9.

1974. Investigations in the Egyptian mining centers in Sinai. *Tel Aviv*, 1: 100–8.

1974–5. Egyptian objects from Sinaï in the Australian Museum. *Australian Journal of Biblical Archaeology*, 2/3: 29–47.

1978. *The Stones of Sinaï Speak*. Tokyo: Gakuseisha.

1983. Two officials of the Old Kingdom at Maghara (southern Sinaï). *Tel Aviv*, 10: 49–51.

Gnoli, R. 1988. *Marmora Romana*. Rome: Edizioni dell'Elefante.

Goedicke, H. 1962. Psammetik I. und die Libyer. *MDAIK*, 18: 26–49.

Goyon, G. 1957. *Nouvelles inscriptions rupestres du Wadi Hammamat*. Paris: Librarie d'Amerique et d'Orient Adrien-Maisonneuve.

Griffith, F.Ll. 1896. *Beni Hasan* III. London: ERA.

Griswold, W.A. 1992. Imports and social status: the role of long-distance trade in Predynastic Egypt state formation. Doctoral dissertation. Ann Arbor: UMI.

Grubessi, O., Aurisicchio, C. and Castiglioni, A. 1989. Lo smeraldo delle miniere dei faroni. *La Gemmologia*, 14: 7–21.

1990. The pharaohs' forgotten emerald mines. *Journal of Gemmology*, 22/3: 164–77.

Gundlach, R. 1980. Lapislazuli. *LÄ*, III: 937–8.

Habachi, L. 1960. Notes on the unfinished obelisk of Aswan and another smaller one in Gharb Aswan. In *Drevni i Egipet* (ed. V.V. Struve). Moscow: Institut Vostokovedeni i a, Akademi i a Nauk USSR, pp. 216–35.

1977. *The Obelisks of Egypt*. New York: Charles Scribner.

Habachi, L. and Biers, J. 1969. An agate bowl from Egypt. *Annual of the Museum of Art and Archaeology: University of Missouri, Columbia*, 3: 29–34.

Hall, C. 1994. *Eyewitness Handbook: Gemstones*. London: Dorling Kindersley.

Harden, D.B. 1954. Vasa Murrina again. *Journal of Roman Studies*, 44: 53.

Harrell, J.A. 1990, Misuse of the term 'alabaster' in Egyptology. *GM*, 119: 37–42.

1992. Ancient Egyptian limestone quarries: a petrological survey. *Archaeometry*, 34: 195–212.

1995. Ancient Egyptian origins of some common rock names. *Journal of Geological Education*, 43: 30–4.

1996. Geology. In *BERENIKE 1995: Preliminary Report on the 1995 Excavations at Berenike (Egyptian Red Sea Coast) and the Survey of the Eastern Desert* (eds. S.E. Sidebotham and W.Z. Wendrich). Leiden: Centre for Non-Western Studies, Leiden University, pp. 99–126.

forthcoming (a). Geology. In *The Survey of Gebel el-Haridi I* (ed. C.J. Kirby). London: EES.

forthcoming (b). The Tumbos quarry at the Third Nile Cataract, northern Sudan. *Meroitica*.

Harrell, J.A. and Bown, T.M. 1995. An Old Kingdom basalt quarry at Widan el-Faras and the quarry road to Lake Moeris in the Fayum, Egypt. *JARCE*, 32: 71–91.

Harrell, J.A. and Brown, V.M. 1992a. The world's oldest surviving geological map: the 1150 BC Turin papyrus from Egypt. *Journal of Geology*, 100: 3–18.

1992b. The oldest surviving topographical map from ancient Egypt (Turin Papyri 1879, 1899 and 1969). *JARCE*, 29: 81–105.

1994. Chephren's quarry in the Nubian Desert of Egypt. *Nubica*, 3/1: 43–57.

1999. A Late-Period quarry for naoi in the Eastern Desert. *EA*, 14: 18–20.

Harrell, J.A., Brown, V.M. and Lazzarini, L. in press. Two newly discovered Roman quarries in the Eastern Desert of Egypt. In *Actes D'ASMOSIA IV: Transactions of the Fourth International Symposium of the Association for the Study of Marble and Other Stones in Antiquity*. Bordeaux: Centre de Recherche en Physique Appliqué de l'Archéologie, Université de Bordeaux.

Harrell, J.A., Brown, V.M. and Masoud, M.S. 1996. Survey of ancient Egyptian quarries. *Egyptian Geological Survey and Mining Authority Paper 72*.

forthcoming. Early Dynastic quarry for stone vessels at Gebel Manzal el-Seyl, Eastern Desert. *JEA*.

Harrell, J.A. and Penrod, B.E. 1993. The great pyramid debate: evidence from the Lauer sample. *Journal of Geological Education*, 41: 358–63.

Hassan, A.A. and Hassan, F.A. 1981. Source of galena in predynastic Egypt at Naqada. *Archaeometry* , 23: 77–82.

Hawass, Z. and Verner, M. 1996. Newly discovered blocks from the causeway of Sahure. *MDAIK*, 52: 177–86.

Hayes, W.C. 1953. *The Scepter of Egypt* I. New York: MMA.

1959. *The Scepter of Egypt* II. New York: MMA.

Heikal, M.A., Hassan, M.A. and El-Sheshtawi, Y. 1983. The Cenozoic basalt of Gebel Qatrani, Western Desert, Egypt as an example of continental tholeiitic basalt. *AGSE*, 13: 193–209.

Heizer, R.F., Stross, F., Hester, T.R., Albee, A., Perlman, I., Asaro, F. and Bowman, H. 1973. The colossi of Memnon revisited. *Science*, 182: 1219–25.

Hermina, M., Klitzsch, E. and List, F.K. 1989. *Stratigraphic Lexicon and Explanatory Notes to The Geological Map of Egypt*. Cairo: Cononco Inc. and Egyptian General Petroleum Corp.

Herrmann, G. 1968. Lapis lazuli: the early phases of its trade. *Iraq*, 30: 21–57.

Herrmann, G. and Moorey, P.R.S. 1983. Lapis lazuli. *Reallexikon der Assyriologie und Vorderasiatischen Archäologie*, VI: 488–92.

Hester, T.R. and Heizer, R.F. 1981. *Making Stone Vases: Ethnoarchaeological Studies at an Alabaster Workshop in Upper Egypt*. Monographic Journals of the Near East. Malibu CA: Undena Publications.

el-Hinnawi, E.E. and Maksoud, M.A. 1968. Petrography of Cenozoic volcanic rocks of Egypt. *Geologische Rundschau*, 57: 879–90.

1972. Geochemistry of Egyptian Cenozoic basaltic rocks. *Chemie der Erde*, 31: 93–112.

el-Hinnawi, E.E. and Loukina, S.M. 1972. A contribution to the geochemistry of Egyptian alabaster. *Tschermaks Mineralogische und Petrographische Mitteilungen (Vienna)*, 17: 215–21.

Hoffmeier, J.K. 1993. The use of basalt in floors of Old Kingdom pyramid temples. *JARCE*, 30: 117–23.

Hume, W.F. 1934. *Geology of Egypt II: The Fundamental Precambrian Rocks of Egypt and the Sudan, 1: The Late Plutonic and Minor Intrusive Rocks*. Cairo: GSE.

1937. *Geology of Egypt II: The Fundamental Precambrian Rocks of Egypt and the Sudan, 3: The Minerals of Economic Value*. Cairo: GSE.

Hussein, A.A.A. and El-Sharkawi, M.A. 1990. Mineral deposits. In *The Geology of Egypt* (ed. R. Said). Rotterdam: A.A. Balkema, pp. 511–66.

Ibrahim, M.M. 1943. The petrified forest, part I. *BIE*, 25: 159–82.

1949. Ornamental stones in Egypt. *Transactions of the Mining and Petroleum Association of Egypt*, 4/1: 9–20.

1953. The petrified forest, part II. *BIE*, 34: 317–28.

al-Idrisi, M.M. 1836–40. La *géographie d'Edrisi*, trans. P.-A. Jaubert, Paris: Imprimerie Royale [facsimile edition published in 1975 by Philo Press Amsterdam].

Ingram, K.D., Daugherty, K.E. and Marshall, J.L. 1993. The pyramids – cement or stone? *JAS*, 20: 681–7.

Isler, M. 1987. The curious Luxor obelisks. *JEA*, 73: 137–47.

1992. The technique of monolithic carving. *MDAIK*, 48: 45–55.

Jeffreys, D.G. and Giddy, L. 1993. The people of Memphis. *EA*, 3: 18–20.

Jones, H.L. (ed. and transl.) 1917–32. *The Geography of Strabo*. 8 vols. London: Heinemann.

Junker, H. 1919. *Bericht über die Grabungen . . . auf den Friedhöfen von El-Kubanieh-Sud*. Vienna: Akademie der Wissenschaften in Wien.

Keldani, E.H. 1939. *Bibliography of Geology and Related Sciences Concerning Egypt up to The End of 1939*. Cairo: Survey and Mines Department.

Keller, P.C. 1990. *Gemstones and their Origins*. New York: Van Nostrand-Reinhold.

Kemp, B.J. 1989. *Ancient Egypt: Anatomy of a Civilization*. London: Routledge.

Kessler, D. 1981. *Historische Topographie der Region zwischen Mallawi und Samalut*. Wiesbaden: Dr Ludwig Reichert Verlag.

el-Khouli, A. 1978. *Egyptian Stone Vessels: Predynastic Period to Dynasty III: Typology and Analysis*, 3 vols. Mainz: von Zabern.

el-Khouli, A.A.R., Holthoer, R., Hope, C.A. and Kaper, O.E. 1993. *Stone Vessels, Pottery and Sealings from the Tomb of Tut'ankhamun*. Oxford: Griffith Institute.

Kitchen, K.A. 1991. Building the Ramesseum. *CRIPEL*, 13: 85–93.

Klein, M.J. 1988. *Untersuchungen zu den kaiserlichen steinbrüchen an Mons Porphyrites und Mons Claudianus in der östichen Wüste Ägyptens*. Bonn: Rudolf Habett GMBH no. 26.

Klein, C. and Hurlbut, jr., C.S. 1993. *Manual of Mineralogy*. New York: John Wiley.

Klemm, R. 1986. Steine und steinbrüche der Ägypter. *Geowissenschaften in Unserer Zeit*, 4/1: 11–8.

1988. Vom Steinbruch zum Tempel: Beobachtungen zur Baustruktur einiger Felstempel der 18. und 19. Dynastie im ägyptischen Mütterland. ZÄS, 115: 41–51.

Klemm, R. and Klemm, D.D. 1979. Herkunftsbestimmung altägyptischen Steinmaterials. *SAK*, 7: 103–40.

1981. *Die Steine der Pharaonen*. Munich: Staatliche Sammlung Ägyptischer Kunst.

1993. *Steine und Steinbrüche im Alten-Ägypten*. Berlin: Springer-Verlag.

Klemm, D.D. Klemm, R. and Steclaci, L. 1984. Die pharaonischen Steinbrüche des silifizierten Sandsteins in Ägypten und die Herkunft der Memnon-Kolosse. *MDAIK*, 40: 207–20.

Klitzsch, E., List, F. K. and Pöhlmann (eds.), 1986–7. Geological Map of Egypt (20 sheets, 1 : 500,000). Cairo: Conoco Inc. and Egyptian General Petroleum Corp.

Kozloff A. and Bryan, B. 1992 *Egypt's Dazzling Sun: Amenhotep III and his World*, (exhibition catalogue). Bloomington: Cleveland Museum of Art and Indiana University Press.

Kraus, T. and Röder, J. 1962a. Voruntersuchungen am Mons Claudianus im März 1961. *Archäologischer Anzeiger (Berlin)*, 1962: 693–745.

1962b. Mons Claudianus: bericht über eine erste erkundungsfahrt im März 1961. *MDAIK*, 18: 80–120.

Kraus, T., Röder, J. and Müller-Wiener, W. 1967. Mons Claudianus-Mons Porphyrites bericht über zweite forschungsreise 1964. *MDAIK*, 22: 108–205.

Krauss, R. 1983. Der Bildhauer Thutmose in Amarna. *Jahrbuch preussischer Kulturbesitz*, 20: 119–32.

Kulke, H. 1976. Die lapislazuli-lagerstätte Sare Sang (Badakshan): Geologie, Entstehung, Kulturgeschichte und Bergbau. *Afghanistan Journal*, 3/2: 1–16.

Lacovara, P., Reeves, C.N. and Johnson, W.R. 1996. A composite-statue element in the Museum of Fine Arts, Boston. *RdE*, 47: 173–6.

Lauer, J.-P. 1960. *Observations sur les pyramides*. Cairo: IFAO.

Lauer, J.-P. and Debono, F. 1950. Techniques du façonnage des croissants de silex utilisés dans l'enceinte de Zoser à Saqqarah. *ASAE*, 50: 1–18.

Lazzarini, L. 1987. I graniti dei monumenti Italiani ed i loro problemi di deteriomento. *Materiali Lapidei, Bollettino d'Arte* 41: 157–72.

Legrain, G. 1906. *Statues et statuettes des rois et des particuliers* I. Cairo: Egyptian Museum, Catalogue Generale.

Lehner, M. 1985. The development of the Giza necropolis: the Khufu project. *MDAIK*, 41: 109–44.

Lepsius, K.R. 1849–59. *Denkmäler aus Ägypten und Äthiopien*. 6 parts in 12 vols. Leipzig: J.C. Hinrichs.

Levene, D. 1998. Expedition to Atika. In *Proceedings of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artefacts, Cairo, 10–12 April, 1995*. (ed. F. A. Esmael) Cairo: SCA, pp. 365–78.

Lewis, D.W. and McConchie, D. 1994. *Analytical Sedimentology*. New York: Chapman and Hall.

Lichtheim, M. 1973. *Ancient Egyptian Literature I: The Old and Middle Kingdoms*. Berkeley: University of California Press.

Lilyquist, C. 1989. The marble statue of Tuthmosis III from Deir el Bahari. *GM*, 109: 39–40.

1996. *Egyptian Stone Vessels: Khian through Tuthmosis IV*. New York: MMA.

Little, O.H. 1933. Preliminary report on some geological specimens from the Chephren diorite quarries, Western Desert. *ASAE*, 33: 75–80.

Loewental, A.I. and Harden, D.B. 1949. Vasa Murrina. *Journal of Roman Studies*, 39: 31–6.

Lucas, A. 1926. *Ancient Egyptian Materials and Industries*. 1st edn. London: Longman, Green and Co.

1934. *Ancient Egyptian Materials and Industries*. 2nd edn. London: Edward Arnold.

1933. Appendix 2: The chemistry of the tomb. In *The Tomb of Tut-ankh-amen III* (H. Carter). London: Cassell and Co., pp. 170–83.

1942. Obsidian. *ASAE*, 41: 271–5.

1947. Obsidian. *ASAE*, 47: 113–23.

1962. *Ancient Egyptian Materials and Industries*. 4th edn., rev. J.R. Harris. London: Edward Arnold.

Lucas, A. and Rowe, A. 1938. The ancient Egyptian bekhen-stone. *ASAE*, 38: 127–56.

MacAlister, D.A. 1900. The emerald mines of northern Etbai. *Geographical Journal, London*, 16: 537–49.

MacKenzie, W.S. and Adams, A.E. 1994. *A Color Atlas of Rocks and Minerals in Thin Section*. New York: John Wiley.

MacKenzie, W.S., Donaldson, C.H. and Guilford, C. 1982. *Atlas of Igneous Rocks and Their Textures*. New York: John Wiley.

MacKenzie, W.S. and Guilford, C. 1980. *Atlas of Rock-forming Minerals in Thin Section*. New York: John Wiley.

Macy Roth, A. 1992. The *pšs-kf* and the 'opening of the mouth' ceremony: a ritual of birth and rebirth. *JEA*, 78: 113–47.

Majidzadeh, Y. 1982. Lapis lazuli and the Great Khorasan road. *Paléorient*, 8/1: 59–69.

Mansour, H.H., Philobbos, E.R., Khalifa, H. and Galal, S. 1983. Contribution to the stratigraphy and micropaleontology of the Middle and Upper Eocene exposures southeast of Cairo, Egypt. *Bulletin of the Faculty of Science, Assiut University*, 12/2: 153–72.

Marchei, M.C., Sironi, A. and Gnoli, R. 1989. Repertorio. In *Marmi Antichi* (ed. G. Borghini). Rome: Leonardo-De Luca Editori, pp. 131–302.

Matthiae, G.S. 1992. Una testimonianza dei rapporti protohistorici tr Egitto e Asia anteriore da Abusir el-Meleq. *Contributi e materiali di archaeologia orientale*, 4: 1–9.

Maxwell-Hyslop, K.R. 1995. A note on the Anatolian connections of the Tôd Treasure. *Anatolian Studies*, 45: 243–50.

McGill, J.R. and Kowalski, B.R. 1977. Recognizing patterns in trace elements. *Applied Spectroscopy*, 31/2: 87–95.

Meneisy, M.Y., Ragab, A.I. and Taher, R.M. 1979. Contributions to the petrography, petrochemistry and classification of Aswan granitic rocks, Egypt. *Chemie der Erde*, 38/2: 121–35.

Meredith, D. 1952. The Roman remains in the Eastern Desert of Egypt, I. *JEA*, 38: 94–111.

Meredith, D. and Tregenza, L.A. 1949. Notes on Roman roads and stations in the Eastern Desert. *Bulletin of the Faculty of Arts, Fouad I (now Cairo) University*, 11/1: 97–126.

1950. Mons Porphyrites: the north-west village and quarries. *Bulletin of the Faculty of Arts, Fouad I (now Cairo) University*,12/1: 131–47.

Meyer, C. 1992. The Bir Umm Fawakhir project, 1992: a gold mining camp in the Eastern Desert. *Chicago House Bulletin*, 3/2:1–4.

Meyers, P. and van Zelst, L. 1977. Neutron activation analysis of limestone objects in a pilot study. *Radiochimica Acta*, 24: 197–204.

Middleton, A. and Bradley, S.M. 1989. Provenancing of Egyptian limestone sculpture. *Journal of Archeological Science*, 16: 475–88.

Mielsch, H. 1985. *Buntmarmore aus Rom in Antikenmuseum Berlin*. Berlin: Staatliche Museum Preussischer Kulturbesitz.

Miller, R. 1983. Lithic technology in East Karnak, Egypt. *JSSEA*, 13: 228–36.

1987. Flaked stone from the Workmen's Village. In *Amarna Reports* IV (ed. B.J. Kemp). London: EES, pp. 144–53.

Mond, R. and Myers, O. 1937. *Cemeteries of Armant*, 2 vols. London: EEF.

Moorey, P.R.S. 1983. *Ancient Egypt*, 2nd edn. Oxford: Ashmolean Museum Publications.

1994. *Ancient Mesopotamian Materials and Industries*. Oxford: OUP.

Moran, W.L. 1992. *The Amarna letters*. London: Johns Hopkins University Press.

de Morgan, J. 1895. *Fouilles à Dahchour 1894*. Vienna: Adolphe Holzhausen.

1897. *Recherches sur les origines de l'Egypte* II. Paris: Leroux.

de Morgan, J., Bouriant, U., Legrain, G., Jéquier, G. and Barsanti, A., 1894. *Catalogue des monuments et inscriptions de l'Egypte antique, I: De la frontière de Nubie à Kom Ombos*. Vienna: Adolphe Holzhausen.

Mottana, A., Crespi, R. and Liborio, G. 1978. *Simon and Schuster's guide to rocks and minerals*. New York: Simon and Schuster.

Moussa, A.M. 1981. A stela of Taharqa from the desert road at Dahshur. *MDAIK*, 37: 331–17.

Murray, G.W. 1914. Notes on Bir Kareim and amethysts. *CSJ*, 8: 179.

1925. The Roman roads and stations in the eastern desert of Egypt. *JEA*, 11: 138–50.

1939a. The road to Chephren's quarries. *Geographical Journal*, 94, 97–114.

1939b. An Archaic hut in Wadi Umm Sidrah. *JEA*, 25: 38–9.

1945–6. A note on the Sadd el-Kafara: the ancient dam in the Wadi Garawi; and a diorite quarry of the Roman period in Wadi Barud (Eastern Desert). *BIE*, 28: 33–46.

Nassim, L. 1925. Minerals of economic interest in the deserts of Egypt. In *Congrès international de géographie, le Caire, April 1925*, III, p. 167.

Nesse, W.D. 1991. *Introduction to Optical Mineralogy*, 2nd edn. New York: OUP.

Newberry, P.E. 1893. *Beni Hasan* I. London: ERA.

1894. *El-Bersheh I: The Tomb of Tehuti-hetep*. London: ERA.

Niazi, E.A. and Loukina, S. 1987. Effects of Tertiary volcanic activity on some continental sediments in Egypt. In *Current Research in African Earth Sciences* (ed. G. Matheis and H. Schandelmeier). Rotterdam: A.A. Balkema, pp. 329–32.

Nibbi, A. 1976. *Ḥsbd* from the Sinai. *GM*, 19: 45–7.

Nour, M.Z., Osman, M.S., Iskander, Z. and Moustafa, A.Y. 1960. *The Cheops Boats* I. Cairo: General Organisation for Government Printing Offices.

Oddy, W.A., Hughes, M.J. and Baker, S. 1976. The washing of limestone sculptures from Egypt and the Middle East. *Lithclastia*, 2: 3–10.

Ogden, J. 1982. *Jewellery of the Ancient World*. London: Trefoil.

Owen, G. and B. Kemp, 1994. Craftsmen's work patterns in unfinished tombs at Amarna. *CAJ*, 4/1: 121–9.

Payne, J.C. 1968. Lapis lazuli in early Egypt. *Iraq*, 30: 58–61.

Peacock, D.S. 1988. The Roman quarries of Mons Claudianus, Egypt: an interim report. In *Classical Marble Geochemistry, Technology, Trade: Proceedings of The NATO Advanced Workshop on Marble in Ancient Greece and Rome* (eds. N. Herz and M. Waelkens). Boston: Kluwer Academic Publishers, pp. 97–101.

1992. *Rome in the Desert: A Symbol of Power*. Inaugural lecture delivered at the University of Southampton, UK, December 3, 1992, Southampton: University Printing Service.

Peacock, D. and Maxfield, V. (eds.), 1994. *The Roman Imperial Porphyry Quarries: Gebel Dokhan, Egypt. Interim Report 1994*. Southampton and Exeter: Universities of Southampton and Exeter.

1995. *The Roman Imperial Porphyry Quarries: Gebel Dokhan, Egypt. Interim Report 1995*. Southampton and Exeter: Universities of Southampton and Exeter.

1996. *The Roman Imperial Porphyry Quarries: Gebel Dokhan, Egypt. Interim Report 1996*. Southampton and Exeter: Universities of Southampton and Exeter.

Peacock, D.S., Williams-Thorpe, O. Thorpe, R.S. and Tindle, A.G. 1994. Mons Claudianus and the problem of the 'granito del foro': a geological and geochemical approach. *Antiquity*, 68: 209–30.

Pellant, C. 1992. *Eyewitness Handbooks: Rocks and Minerals*. London: Dorling Kindersley.

Pendlebury, J.D.S. 1951. *City of Akhenaten* III, 2 vols. London: EES.

Petrie, W.M.F. 1888. *A Season in Egypt*. London: EEF.

1890. *Kahun, Gurob and Hawara*. London: EEF.

1894. *Tell el Amarna*. London: BSAE/Methuen and Co.

1901a. *Diospolis Parva: The Cemeteries of Abadiyeh and Hu, 1898–9*. London: BSAE.

1901b. *The Royal Tombs of the Earliest Dynasties* II. London: EEF.

1917. *Scarabs and Cylinders with Names*. London: Quaritch.

1920. *Prehistoric Egypt*. London: Quaritch.

1937. *The Funeral Furniture of Egypt/Stone and Metal Vases*. London: BSAE and Quaritch.

Petrie, W.M.F. and Currelly, C.T. 1906. *Researches in Sinai*. London: John Murray.

Petrie, W.M.F., Wainwright, G.A. and MacKay, E. 1912. *The Labyrinth, Gerzeh and Mazghuneh*. London: Quaritch.

Pettijohn, F.J. Potter, E. and Siever, R. 1972. *Sand and Sandstone*. New York: Springer-Verlag.

Pliny see Rackham 1968.

Porada, E. 1980. A lapis lazuli figurine from Hierakonpolis. *Iranica Antiqua*: 175–80.

1982. Remarks of the Tôd Treasure in Egypt. In *Societies and Languages of the Ancient Near East: Studies Presented in Honour of I.M. Diakonoff* (eds. M.A. Dandamayef, J.N. Postgate and I.M. Diakonoff). Warminster: Aris and Phillips, pp. 285–303.

Porter, B. and Moss, R. 1974–81. *Topographical Bibliography of Ancient Egyptian Hieroglyphic Texts, Reliefs and Paintings* III, 2nd edn., rev. J. Malek. Oxford:Griffith Institute.

Quibell, J. and Petrie, W.M.F. 1900. *Hierakonpolis* I. London: ERA.

Quibell, J. and Green, F.W. 1902. *Hierakonpolis* II. London: ERA.

Quirke, S. 1990. *The Administration of Egypt in the Late Middle Kingdom: The Hieratic Documents*. New Malden: SIA Publishing.

Rackham, H. (transl. and ed.) 1968. *Pliny (the Elder): Natural History*, 2nd edn. Loeb Classical Library. Cambridge MA: Harvard University Press.

Ragab, A.I., Meneisy, M.Y. and Taher, R.M. 1978. Contributions to the petrogenesis and age of Aswan granite rocks, Egypt. *Neues Jahrbuch für Mineralogie Abhandlungen*, 133/1: 71–87.

Ramez, M.R.H. and Marie, A.A. 1973. The geology and petrography of the basement rocks at Gebel El Rukham area, Eastern Desert. *Journal of Egyptian Geology*, 17/2: 147–62.

Raymond, L.A. 1995. *The Study of Igneous, Metamorphic and Sedimentary Rocks*. Boston: Wm. C. Brown.

Reisner, G.A. 1923. *Excavations at Kerma I–V*, 2 vols. Cambridge MA: Harvard University Press.

1931. *Mycerinus, the Temples of the Third Pyramid at Giza*. Cambridge MA: Harvard University Press.

1932. *A Provincial Cemetery of the Pyramid Age: Naga-ed-Dêr, III*. Oxford: OUP.

1936. *The Development of the Egyptian Tomb down to the Accession of Cheops*. Cambridge MA: Harvard University Press.

Roeder, G. 1941. Lebensgrosse Tonmodelle aus einer altägyptischen Bildhauerwerkstatt. *Jahrbuch der preussischen Kunstsammlungen*, 62: 145–70.

Röder, J. 1965. Zur Steinbrüchgeschichte des Rosengranits von Assuan. *Archäologischer Anzeiger*, 467–552.

Rothenberg, B. 1970. Archaeological survey of south Sinai. *Palestine Exploration Quarterly* 102: 4–29.

(ed.) 1979. *Sinai: Pharaohs, Miners, Pilgrims and Soldiers*. Berne: Kümmerly and Frey.

1987. Pharaonic copper mines in south Sinai. *Newsletter of the Institute of Archaeo-Metallurgical Studies*, 10/11: 3–7.

Rowe, A.E. 1938. Provisional notes on the Old Kingdom inscriptions from the diorite quarries. *ASAE*, 38: 391–6.

1939. Three new stelae from the south-eastern desert. *ASAE*, 39: 187–91.

Sadek, A.I. 1980–85. *The Amethyst Mining Inscriptions of Wadi el-Hudi*, 2 vols. Warminster: Aris and Phillips.

Said, R. (ed.) 1990. *The Geology of Egypt*. Rotterdam: A. A. Balkema Publishers.

Saleh, M. and Sourouzian, H. 1987. *The Egyptian Museum, Cairo: Official Catalogue*. Mainz: von Zabern.

Sax, M. and Middleton, A.P. 1992. A system of nomenclature for quartz and its application to the material of cylinder seals. *Archaeometry*, 34/1: 11–20.

Scaife, C.H.O. 1935. Two inscriptions at Mons Porphyrites (Gebel Dokhan), also a description, with plans, of the stations between Kainopolis and Myos Hormos together with some other ruins in the neighborhood of Gebel Dokhan. *Bulletin of the Faculty of Arts, Fouad I (now Cairo) University*, 3/2: 58–104.

Schäfer, H. 1910. *Königliche Museen zu Berlin I: Ägyptische Goldschmiedearbeiten*. Berlin: Königliche Museen zu Berlin.

Scharff, A. 1926. *Das Vorgeschichtliche Gräberfeld von Abusir el-Meleq*. Leipzig: J.C. Hinrichs.

Schneider, O. and Azruni, A. 1892. Der Ägyptische Smaragd nebst einer vergleichenden mineralogischen Untersuchung der Smaragd von Alexandrien, vom Gebel Sabara und vom Ural. *Zeitschrift für Ethnologie*, 24: 41–100.

Scholle, P.A. 1978. *A Color Illustrated Guide to Carbonate Rock Constituents, Textures, Cements, and Porosities*. Tulsa: American Association of Petroleum Geologists, Memoir 27.

1979. *A Color Illustrated Guide to Constituents, Textures, Cements, and Porosities of Sandstones and Associated Rocks*. Tulsa: American Association of Petroleum Geologists, Memoir 28.

Sethe, K. 1903. *Urkunden des Alten Reichs* I. Leipzig: J.C. Hinrichs.

Seton-Karr, W.H. 1898. Discovery of the lost flint mines of Egypt. *Journal of the Royal Anthropological Institute*, 27: 90–2.

1905. How the tomb galleries at Thebes were cut and the limestone quarried at the prehistoric flint-mines of the Eastern Desert. *ASAE*, 6: 176–87.

Seward, A.C. 1935. *Leaves of dicotyledons from the Nubian sandstone of Egypt*. Cairo: GSE.

Seyfried, K.J. 1981. *Beiträge zu den Expeditionen des Mittleren Reiches in die Ostwüste*. Hildesheim: Hildesheimer ägyptologische Beiträge.

Shaw, I. 1986. A survey at Hatnub. In *Amarna Reports* III (ed. B.J. Kemp). London: EES, pp. 189–212.

1987. The 1986 survey of Hatnub. In *Amarna Reports* IV (ed. B.J. Kemp). London: EES, pp. 160–7.

1994. Pharaonic quarrying and mining: settlement and procurement in Egypt's marginal regions. *Antiquity*, 68: 108–19.

1998. Exploiting the desert frontier: the logistics and politics of ancient Egyptian mining expeditions. In *Social Approaches to an Industrial Past: The Archaeology and Anthropology of Mining* (ed. B. Knapp) London: Routledge.

in press (a). The evidence for amethyst mining in Nubia and Egypt. In *Proceedings of the International Symposium: Recent Research into the Stone Age of Northeastern Africa* (eds. L. Krzyzaniak *et al.*) Poznan.

in press (b). Gold and amethyst mining at the Lower Nubian site of Wadi el-Hudi in the Roman period. In *The Second International Conference on Ancient Mining and Metallurgy and Conservation of Metals* (eds. F.A. Esmael *et al.*). Cairo: SCA.

forthcoming. The roads of Pharaonic Egypt.

Shaw, I. and Bloxam, E. 1999. Survey and excavation at the ancient pharaonic gneiss quarrying site of Gebel el-Asr, Lower Nubia. *Sudan and Nubia: Bulletin of the Sudan Archaeological Research Society*, 3.

Shaw, I. and Jameson, R. 1993. Amethyst mining in the Eastern Desert: a preliminary survey at Wadi el-Hudi. *JEA*, 79: 81–97.

Shaw, I., Jameson R. and Bunbury, J. 1999. Emerald mining in Roman and Byzantine Egypt. *Journal of Roman Archaeology*, 12.

el-Shazly, E.M. 1954. *Rocks of Aswan*. Cairo: GSE.

Shiah, N. 1942. Some remarks on the bekhen stone. *ASAE*, 41: 199–205.

Shukri, N.M. 1944. On the 'living' petrified forest. *BIE*, 26: 71–5.

1953. The geology of the desert east of Cairo. *Bulletin de l'Institut du Desert d'Egypte (Cairo)*, 3/2: 89–105.

1954. On cylindrical structures and coloration of Gebel Ahmar near Cairo, Egypt. *Bulletin of the Faculty of Science, Cairo University*, 32: 1–23.

Sidebotham, S.E. 1996. Newly discovered sites in the Eastern Desert. *JEA* 82: 181–92.

Sidebotham, S.E., Zitterkopf, R.E. and Riley, J.A. 1991. Survey of the Abu Sha'ar–Nile road. *AJA*, 95: 571–622.

Simpson, W.K. 1963. *Heka-nefer and the Dynastic Material from Toshka and Arminna*. New Haven CT and Philadelphia PA: Peabody Museum of Natural History of Yale University and University Museum of the University of Pennsylvania.

Smith, W.C. 1965. The distribution of jade axes in Europe (with a supplement to the catalogue of those of the British Isles). *Proceedings of the Prehistoric Society*, 31: 2533.

Smith, W.S. 1958. *The Art and Architecture of Ancient Egypt*. 1st edn. Harmondsworth: Penguin [2nd edn., rev. W.K. Simpson 1980].

Soliman, M.M. 1980. Geochemistry of some granodiorites, granites, pegmatites and associated gneisses from Aswan, Egypt. *AGSE*, 10: 611–26.

Spurrell, F.C.J. 1891. The stone implements of Kahun. In *Illahun, Kahun and Gurob: 1889–90* (ed. W.M.F. Petrie). London: EES, pp. 51–6.

1894. Flint tools from Tell el Amarna. In *Tell el Amarna* (W.M.F. Petrie). London: EES, pp. 37–8.

1895. Notes on Egyptian colours. *Archaeological Journal*, 52: 222–39.

Stadelmann, R. 1985. *Die ägyptischen Pyramiden*. Mainz am Rhein: von Zabern.

Starr, R.F.S. and Butin, R.F. 1936. Excavations and protosinaitic inscriptions at Serabit el-Khadim. *Studies and Documents*, 6: 15–20.

Stocks, D. 1986a. Experimental archaeology I: sticks and stones of Egyptian technology. *Popular Archaeology*, April 1986: 24–9.

1986b. Egyptian technology II: stone vessel manufacture. *Popular Archaeology*, May 1986: 14–18.

1986c. Egyptian technology III: bead production in ancient Egypt. *Popular Archaeology*, June 1986: 2–7.

1989. Ancient factory mass-production techniques: indications of large-scale stone bead manufacture during the Egyptian New Kingdom period. *Antiquity*, 63: 526–31.

1993. Making stone vessels in ancient Mesopotamia and Egypt. *Antiquity*, 67: 596–603.

Strabo see Jones 1917–32.

Streckeisen, A.L. 1973. Plutonic rocks: classification and nomenclature recommended by the IUGS subcommission on the systematics of igneous rocks. *Geotimes*, 8/10: 26–30.

1979. Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melitic rocks: recommendations and suggestions of the IUGS subcommission on the systematics of igneous rocks. *Geology*, 7: 331–5.

Stross, F.H., Hay, R.L., Asaro, F., Bowman, H.R. and Michel, H.V. 1988. Sources of quartzite in Egyptian sculpture. *Archaeometry*, 30: 109–19.

Terrace, E.L.B. 1966. 'Blue marble' plastic vessels and other figures. *JARCE*, 5: 57–63.

Thomas, E.S. 1909. The mineral industry of Egypt: emeralds. *CSJ*, 3: 267–72.

1912. The mineral industry of Egypt: turquoise. *CSJ*, 6: 56–90.

Timme, P. 1917. *Tell el-Amarna vor der Deutschen ausgrabung in Jahre 1911*. Leipzig: Wissenschaftliche Veröffentlichung der Deutschen Orient-Gesellschaft 31.

Tregenza, L.A. 1950. A Latin inscription from Wadi Semna. *Bulletin of the Faculty of Arts, Fouad I (Cairo) University*, 12/2: 85–9.

1951. The curator inscription and other recently found fragments from Wadi Semna. *Bulletin of the Faculty of Arts, Fouad I (Cairo) University*, 13/2: 39–52.

1955. *The Red Sea Mountains of Egypt*. London: OUP.

1958. *Egyptian Years*. London: OUP.

Tucker, M. (ed.), 1988. *Techniques in Sedimentology*. London: Blackwell Scientific.

Tykot, R.H. 1996. The geological source of an obsidian ear (04.9941) from the Museum of Fine Arts Boston. *RdE*, 47: 177–9.

Vachala, B. and Sroboda, J. 1989. Die Steinmesser aus Abusir. *ZÄS*, 116: 174–81.

Van Houten, F.B. and Bhattacharyya, D. 1979. Late Cretaceous Nubia formation at Aswan, Southeastern Desert, Egypt. *AGSE*, 9: 408–19.

Van Walsem, R. 1978–9. The *pšs-kf*; an investigation of an ancient Egyptian funerary instrument. *OMRO*, 59: 193–249.

Vercoutter, J. 1992. *L'Egypte et la vallée du Nil I: Des origines à la fin de l'Ancien Empire*. Paris: Nouvelle Clio.

Vermeersch, P.M., Paulissen, E., Gijselings, G., Otte, M., Thoma, A., Van Peer, P., Lauwers, R., Drappier, D. and Charlier, C. 1984. 33,000–year-old chert mining site and related Homo in the Egyptian Nile valley. *Nature*, 309: 342–4.

Vermeersch, P.M., Paulissen, E. and Van Peer, P. 1990. Palaeolithic chert exploitation in the limestone stretch of the Egyptian Nile valley. *The African Archaeological Review*, 8: 77–102.

Wainwright, G.A. 1927. Obsidian. *Ancient Egypt*, 13: 77–93.

1946. Zeberged – the shipwrecked sailors island. *JEA*, 32: 31–8.

Ward, W.C. and McDonald, K.C. 1979. Nubia Formation of central Eastern Desert, Egypt : major subdivisions and depositional setting. *American Association of Petroleum Geologists Bulletin*, 63: 975–83.

Warren, P.M. 1995. Minoan Crete and Pharaonic Egypt. In *Egypt, the Aegean and the Levant: Interconnections in the Second Millennium BC* (eds. W.V. Davies and L. Schofield). London: BMP, pp. 1–18.

Weigall, A.E.P. 1910. *A Guide to the Antiquities of Upper Egypt, from Abydos to the Sudan Frontier*. New York: Macmillan.

1913. *Travels in the Upper Egyptian Deserts*. London: W. Blackwood and Sons.

Weill, R. 1908. *La presqu'île du Sinaï*. Paris: H. Champion.

Weisgerber, G. 1982. Altägyptischer Hornsteinbergbau im Wadi el-Sheikh. *Der Anschnitt*, 34: 186–210.

Weisgerber, G., Slotta, R. and Weiner, J. (eds.), 1980. *5000 Jahre Feuersteinbergbau - die Suche nach dem Stahl der Steinzeit*. Bochum: Deutsches Bergbau-Museum.

Wendorf, F. and Schild, R. 1975. The Paleolithic of the lower Nile valley. In *Problems in Prehistory: North Africa and the Levant* (eds. F. Wendorf and A.E. Marks). Dallas: Southern Methodist University Press, pp. 127–69.

Wenig, S. (ed.), 1978. *Africa in Antiquity: The Arts of Ancient Nubia and the Sudan II: The Catalogue*. New York: Brooklyn Museum.

Wild, H. 1966. *Le tombeau de Ti*, fasc. III. Cairo: IFAO.

Wilkinson, J.G. 1878. *The Manners and Customs of the Ancient Egyptians*. vols. I–III (ed. and revised by S. Birch). London: John Murray.

Williams, H., Turner F.J. and Gilbert, C.M. 1982. *Petrography: An Introduction to the Study of Rocks in Thin Sections*. San Francisco CA: W.H. Freeman.

Winlock, H. 1948. *The Treasure of the Three Egyptian Princesses*. New York: MMA.

Wissa, M. 1994. Le sarcophage de Merenrê et l'expedition à Ibhat (I). In *Hommages à Jean Leclant* I (eds. C. Berger, G. Clerc and N. Grimal). Cairo: IFAO, pp. 379–87.

Woodward, C. and Harding, R. 1987. *Gemstones*. London: Natural History Museum Publications.

Wyart, J. *et al*. 1981. Lapis lazuli from Sar-e-Sang, Badakshan, Afghanistan. *Gems and Gemmology*: 184–90.

Yardley, B.W.D., MacKenzie, W.S. and Guilford, C. 1990. *Atlas of Metamorphic Rocks and Their Textures*. New York: John Wiley.

Yoyotte, J. (ed.), 1987. *Tanis, l'or des pharaons*. Paris: Association française d'action artistique.

Zarins, J. 1989. Ancient Egypt and the Red Sea trade: the case for obsidian in the predynastic and archaic periods. In *Essays in Ancient Civilization Presented to Helen J. Kantor* (ed. A. Leonard jr. and B. Beyer). Chicago: OIP, pp. 339–68.

Zuber, A. 1956. Techniques du travail des pierres dures dans l'ancienne Egypte. *Techniques et Civilisations*, 29/5: 161–78; 30/5: 196–215.

3. Soil (including mud-brick architecture)

BARRY KEMP

Introduction

Soil has been one of the most widely used building materials since the Neolithic, particularly in arid and semi-arid parts of the world. Commonly termed adobe, it still has considerable potential. Almost any kind of soil can be used (although some modification is often necessary to add strength), it is relatively easy to work with, and its plasticity and chemical stability give it great versatility. It can be moulded by hand or within rigid moulds into building blocks (bricks), can be rammed between formwork to create walls directly, and is equally suited for plastering to produce smooth or moulded finishes. Its vulnerability to erosion and damage do, however, create a constant need for maintenance in the form of replastering and actual repair.

Architectural applications do not exhaust the industrial uses to which soil was put in ancient Egypt. It was, of course, a prime ingredient of pottery, and in the study of composition and methods of handling there is a degree of overlap with pottery research. It was used in certain small applications which also relate more closely to pottery-making in the degree of manipulation of the clay that was involved. These include the administrative practice of sealing, and the making of small mud objects, such as figurines and beads. This section is, however, limited to soil architecture. Most of the evidence that can be cited in this context is archaeological, but it is important to note that a vocabulary of words exists in Egyptian texts which probably or certainly deal with soil architecture (Badawy 1957; Simpson 1963: 56–8, 72–80; Spencer 1979a: 3–4). Uncertainties in translation, however, make it hard to use these sources constructively.

The mud-brick ruins which have been most accessible to archaeologists have principally been constructions on new sites, frequently in the desert and including the brickwork of tombs. This gives a very distorted frame of reference. Most building in brick at any period was done on sites, often long-occupied, which were situated on the floodplain. Moreover, brick architecture in ancient Egypt included huge palace complexes which are still very poorly documented. Even when fragments are excavated they are normally no more than foundations. We must make allo
ance for such buildings originally having risen to consid
able heights and possessing elaborately constructed
teriors which utilised a level of building skills n
meagrely represented by what has survived. A mode
account of soil architecture in ancient Egypt is almo
bound not to do it justice.

History of soil architecture in Egypt

Soil was used for building in Egypt before the making
mud bricks was developed (Lacovara 1984). Although
precursor to brick, these simpler uses are bound to ha
continued into historic periods. Thus the practice of setti
criss-crossed twigs in the tops of walls seen in some Ne
Kingdom representations of houses is clearly related
wattle-and-daub technique (Davies 1929), which was pe
haps the building medium originally in empty foundatio
trenches of the New Kingdom or later at western Thebe
(Hölscher 1939: 71–2). We find its beginnings at a numbe
of Predynastic sites, at its simplest in the lining of fire-pi
and in the coating of the basketry and matting that wa
employed to line grain silos or to cover circular hut-bo
toms. Examples are known from settlements where n
more substantial use of soil has been detected, suggestin
that, locally, this technology might have preceded a full an
independent structural use of soil. The sites in questio
include the middle levels at Merimda and Wadi Hof (el
Omari) (Hayes 1965: 104–15, 117; Debono and Mortense
1990: 17–20). The remains of clay coating to interwove
branches was reported at Maadi (Rizkana and Seeher 1989
40; Rizkana 1996: 178), although at the same site mud
bricks had also been used (see p. 79).

At Hemmamiya North Spur, nine hut circles and a
straight wall 8.2 metres long had been built from a mixture of mud and limestone fragments during a period
defined initially by sequence-dates 35–45 and now known
to have commenced during the transition from Badarian
to Amratian. A radiocarbon date for a layer of fill in one of
them (re-examined in 1989) is 3830–3625 BC (Brunton

and Caton-Thompson 1928: 82–8; Holmes and Friedman 1994: 118–24, 134–5). The imprint of stalks, pressed vertically against the mud on the outside of the huts whilst still moist, showed that reeds had been used to give added height, whilst wooden posts had been set at thirty-centimetre intervals along one face of the straight wall. The shallowly sunken hut floors had been made of beaten mud. A slightly more advanced technique was employed for similar hut circles at Merimda (Junker 1930: 45–7; 1932: 44–6; Hayes 1965: 105–6; cf. Badawi 1978: 48–9). Whilst some had been built from superimposed rings of Nile mud, others had used rough blocks of the same material containing a binder of chopped straw. Mud had also been used to plaster the interiors and floors of the huts. These huts belong to the latest phase of Merimda (late fifth millennium BC).

Evidence for the moulding of bricks in small numbers for limited use appears quite early on settlement sites in Upper Egypt, sometimes accompanied by evidence that buildings (often rectangular in plan) were still primarily made with reed walls supported by posts and sometimes plastered with mud (wattle-and-daub). Sites 29 and 29A on the desert at Hierakonpolis illustrate this situation well and belong to the Gerzean and possibly Amratian periods (Holmes 1992; Hoffman 1980). Also at Hierakonpolis (site 24) and at several other Gerzean settlements which lack evidence for brick houses, long narrow bar-like bricks were used to support clay vessels built into brick-lined tunnels which were then fired, probably in the process of brewing beer (Peet and Loat 1913: Chapter I, pl. I; Peet 1914: 7–9, pl. I.8; Geller 1992: 21–3). The survival of a wattle-and-daub tradition long after brick-making developed leaves ambiguous the original material of the fired-clay model of a rectangular house found in a tomb at el-Amra of the Gerzean period (Randall-Maciver and Mace 1902: 42, pl. X.1,2; Baumgartel 1960: 132–3, pl. XII.3).

True mud-brick buildings of the Predynastic period still remain few. Petrie excavated the corner of a walled mud-brick settlement in the 'South Town' at Naqada which subsequent fieldwork has indicated belonged most probably to the late Gerzean period (Petrie and Quibell 1896: 54, pl. LXXXV; for dating, see Baumgartel 1970: 6, pl. LXXII; Hassan and Matson 1989: 312). Bricks were also used to line the burial chambers of élite tombs at Naqada (cemetery T) and Hierakonpolis (tomb 100, the Decorated Tomb) at a time which must fall within the Gerzean period (*c.* 3400 BC), and on the Umm el-Qa'ab (cemetery U) at Abydos in the period preceding the First Dynasty (Dreyer *et al.* 1996), but no evidence of superstructure has been found. We can also infer the use of mud brick in the construction of buttressed enclosures depicted in the art of the late Predynastic period (Spencer 1979a: 5).

In northern Egypt the advent of mud-brick architecture is one of the principal signs of major culture change shortly before the First Dynasty. It appears with apparent suddenness in excavated sequences at a number of sites in the Nile Delta, including Buto (von der Way 1992, 1993). Brick fragments from here have been compared with a remarkable use of long mud slabs to revet the wall of an underground chamber at Maadi (Rizkana and Seeher 1989: 54–5, pl. XV.1–2). They measured 50–65 × 9–10 cm along their sides, were probably about 10–15 cm thick, and had been laid in mud mortar. It was not recorded whether straw temper had been used, but this was certainly a feature of a few fragments of bricks found loose in other parts of the settlement. From earlier strata at Buto (Naqada IIb at the latest) come several cylinders or 'nails' of baked clay closely similar to objects which were used as a form of mosaic decoration in brick temple walls in the Uruk culture of Mesopotamia. There is the inevitable suggestion that, in another part of the site, a brick building of Mesopotamian style had been constructed.

In general it would seem that brick came into limited use in the Nile Valley and probably Delta from at least the beginning of the Gerzean period, and probably before, but also that wattle-and-daub remained the preferred medium for most buildings until close to the beginning of the First Dynasty, when all-brick towns began to appear throughout the country.

The hardening of soil through heating must have been a very ancient observation. The use of bricks and clay bars in late Predynastic brewing kilns such as at Abydos, the results of major conflagrations in some of the large First-Dynasty tombs which were subsequently repaired (Emery 1961: 180), and of several major burnings of town walls and houses, visible now on archaeological sites (e.g. Tell Edfu, Elephantine, Abydos and especially Kom Ombo), would have been especially dramatic evidence of the effects of burning on brickwork. The widespread preference for unfired soil architecture was thus through choice rather than ignorance. This is borne out by occasional exceptions, such as the fired clay tiles used in streets in Middle Kingdom fortresses in Nubia (Reisner *et al.* 1967: 118–19, pl. XLIXB; Emery *et al.* 1979: 8, 15–16, 35, fig. 19, pl. 92B). From the New Kingdom onwards these exceptions become a little more frequent: specially shaped bricks for friezes on tomb façades (Borchardt *et al.* 1934; Spencer 1979a: 140–1, pl. 37); the lining of burial chambers at Tell Nabasha (Petrie 1888: 18–19; Spencer 1979a: 44); and on to a little catalogue of examples from the Twenty-first Dynasty to the Hellenistic period (Spencer 1979a: 141; Petrie 1906: 49). One factor inhibiting the use of fired brick has presumably been the added cost of the fuel needed for the firing, as well as the need for a more suitable (and expensive) mortar, which, in the Hellenistic period, was lime.

The composition of mud bricks

Although 'mud-brick' is the term most often used in Egyptology, 'adobe' has a more widespread currency. The ancient Egypt word for mud brick, *djebet*, passed, via the Coptic ⲧⲱⲃⲉ into Arabic as طوب *tub(a)* and thence probably into Spanish to give the word adobe (Wiesmann 1914; Černý 1976: 181; Vycichl 1983: 210–11; Mond and Myers 1934: 48, n. 2; Simpson 1963: 76, n. 16).

The study of adobe architecture has wide geographical range and its literature extends to manuals of use for constructing sophisticated modern buildings in dry environments, especially in the USA (McHenry 1976, 1984). Modern views stress the simplicity of the techniques.

> Adobe building bricks are a very simple material. They are simple to make, and by following a few rules can be laid by anyone with a strong back, using a reasonable amount of care. A great deal of misinformation, myth, and old wives tales has been circulated about this great building material. (McHenry 1976: 50)

Suitable soils are widespread. They should contain four elements:

> coarse sand or aggregate, fine sand, silt, and clay. Any one may be totally absent and the soil may still make satisfactory bricks . . . The aggregate (sand) provides strength, the fine sand is a filler to lock the grains of aggregate, and the silt and clay (generally identified by particle size rather than chemical analysis) acts as a binder and plastic medium to glue the other ingredients together. Soil structures with a high percentage of aggregate (sand) may be strong when dry, but are more vulnerable to erosion from rain. Soil structures high in clay may be much more resistant to water and erosion, but less strong. (McHenry 1984: 48) (Also Brown and Clifton 1978; Hughes 1988.)

This is a valuable perspective from which to view the practice of ancient Egyptian builders, who seem not to have worked to a standard formula. It should be noted, however, that the characteristics of soils differ to the point that expert opinion derived from the study of one region (and much of the technical study of soil architecture has been done in the Americas) is not necessarily transferable to other regions. Local studies are essential, and so far few have been done in Egypt. Moreover, physical composition is not the only variable. 'Soluble salts are a major component of most soils and are as important as clay minerals for cementing the silt- and sand-sized particles' (Hughes, pers. comm.). They, too, vary from one region to another. Many of those who work the land develop an intuitive sense of soil character and whether a particular one is suited to brick-making and, if so, how it might be modified. Anecdotal evidence and personal observation suggest that in modern Egypt the generally preferred material, which produces the hardest bricks, is cultivated topsoil (*khart*) which will have seen a thorough mixing of particle sizes through regular turning by the farmer and will have been enriched with deliberately added organic material. Other soils can, however, also be made usable.

The most significant departures from the norm in ancient Egypt occurred on a minority of sites which were constructed in the desert and where local soils differed markedly from those available in the floodplain. In turning to nearby materials, as they often seem to have done, the ancient builders produced bricks with a different appearance from those normally employed, but it is probably a mistake to consider such bricks as necessarily inferior for the job that they were intended to do. They were simply different.

> Many naturally occurring soils will require some modification, more often to deal with the presence of too much clay, rather than the lack of it. The soil abundant in clay may be modified by the addition of sand, coarser aggregates, or vegetal matter such as straw, hay, or manure. It is perhaps unrealistic to try to establish rigid proportions in view of the nature of the material sources and the lack of difference in the performance of the finished product. (McHenry 1984: 50)

In order to judge the extent to which the soil of ancient Egyptian bricks was modified, particle analysis is required not only of samples of ancient bricks but also of local soils to provide a basis for comparison. A set of analyses by French at East Karnak (1981) and at Amarna (1984) has attempted to do just this (compare a similar study at Lachish in Palestine, Goldberg 1979). The contrasting characteristics of the two sites make these studies particularly valuable: East Karnak is part of a *tell* of long occupation located near the river and sufficiently far from the desert to imply an alluvial origin for the mud of its bricks. Amarna, by contrast, was situated on the desert edge, and the ancient brick-makers had available to them a much wider variety of soils. Figure 3.1 is a summary of the results.

The samples were first crumbled. Once any gravel fraction and other large inclusions had been removed by passing the resulting soil through a two-millimetre mesh sieve they were separated by means of the hydrometer method of particle size analysis into three basic components: fine to very fine sand (2–4 Ø), medium silt (5–7 Ø) and clay. At Amarna, the natural sediments from the river bank displayed a wide variety of mix when taken from different beds: pale brown sand, brown silt and dark brown silty clay loam, the products of a combination of seasonal changes in the amount of sediment carried by the Nile and the changing velocity of river flow. The most appropriate comparison at Karnak was with agricultural soil used for the manufacture of modern local bricks, a brown silt loam, probably alluvial, containing pottery fragments. In three out of these four samples medium silt was the dominant material.

At Karnak, a sample of eight bricks, ranging in date from the early second millennium BC to the late centuries BC/early centuries AD, together with a modern local brick, gave particle-analysis results showing very small to zero amounts of clay, and a silt proportion that varied between 28 per cent and 52 per cent. There is a difference in the silt–sand ratio – a reduction in silt – between the bricks and the single sample of natural alluvium from which they are made. Unless the brick-makers were, on other occasions, choosing soils of 60–70 per cent sandiness, they presum-

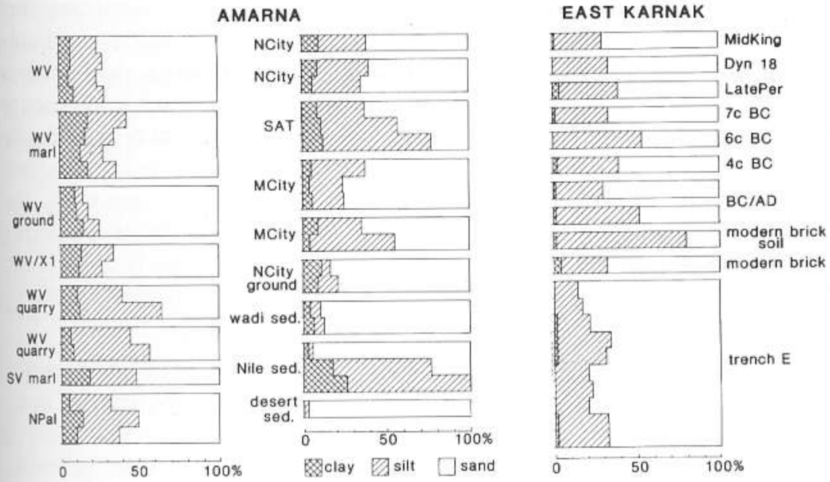


Figure 3.1 The relative proportions of clay, silt, and sand in samples of brick and soil from Amarna and East Karnak (after French 1981, 1984). Each small vertical division represents a single sample. WV = Workmen's Village; SV = Stone Village; NPal = North Palace; NCity = North City; MCity = Main City; SAT = Small Aten Temple. The bottom three sets of samples in the middle column are derived from natural sediments from the floor of a desert wadi, *the river bank, and the desert. The samples from WV ground, NCity ground, and trench E derive from archaeological deposits between or beyond walls.*

ably added sand to the mix (French's own explanation that the silt is puddled out during manufacture is hard to envisage on the scale required). Except for the two latest (which had been partially fired to an orange-brown colour, 7.5 YR 5/4 on the Munsell scale), all of the ancient bricks and the modern brick and sample of alluvium were a similar greyish-brown in colour (10YR 4/2–3 or 5/2–3). A further comparison comes from samples taken at intervals down stratigraphic trenches in the settlement strata (represented by Trench E) which in large part must be derived from the decay of mud brick structures. The generally larger proportions of sand presumably represent the combined effects of the wind in depositing sand and removing the finer silts.

At Amarna all of the bricks sampled were of the same period (*c.* 1350 BC), but came from widely dispersed parts of the site. The most valuable reference set derived from the Workmen's Village, where bricks could be divided into two broad groups on the basis of colour. One, from the village enclosure wall and of the common greyish-brown colour, was deemed to have been made from mud from the alluvial plain; the other group, of varying shades of orange and grey and often quite pebbly, was almost certainly made from marl locally dug from quarries adjacent to the village. Neither group had been given a straw temper. They differ principally from the Karnak bricks in the higher proportion of clay (6–10 per cent) at the expense of silt (17.5–20 per cent), but still were generally sandier than two of the three samples from the local alluvial beds from the banks of the Nile. Again we should accept intervention by the brickmakers. In the case of the marl bricks, comparison with source material can be made more confidently than is usually possible because the quarries which provided it are identifiable. A set of marl bricks, despite their distinctive appearance, broke down into proportions of clay and silt (13.75–18.75 per cent and 15–25 per cent) which were higher than the alluvial bricks but not substantially so. The natural samples from the quarries (6.25–12.5 per cent clay and 28.75–52.5 per cent silt) are again somewhat siltier than the bricks derived from them but the contrast is less marked. At a separate but similarly located site (the Stone Village) the analysis of a single marl brick gave a result closer to that from the Workmen's Village quarries. Samples from an ancient ground surface show, as with its equivalent (Trench E) at Karnak, an increase in sand.

Within the main parts of the city, which were much closer to the course of the river, the composition of bricks varies considerably. From the quantities of grit and pebbles and from the pale greyish colour which can so commonly be seen in the bricks it is likely that local desert materials were a common and deliberately added part of the mud mix (gravel was not present in the samples analysed). The analyses done were confined to fourteen samples of bricks which, from their superficial appearance, seemed to be alluvial. They showed the same persistence of clay (3.75–13.75 per cent) but a general tendency to greater siltiness (18.75–65 per cent) than the alluvial bricks from the Workmen's Village. Quite striking is the variation in the silt/sand ratio of three bricks from different parts of the Small Aten Temple, the third sample being almost identical in composition to one of the natural deposits from the river bank. One ancient ground deposit from the North City showed the increase in sand.

Several lessons can be drawn from these analyses. One is the regular appearance of a mix in which sand was generally in the region of 60–70 per cent implying that the brickmakers had a preferred mix, detectable by the feel of handfuls of the mud, to be achieved either by selection of soils or by the addition of sand. The East Karnak–Amarna comparison also shows that the near absence of clay did not hinder brick-making. A third lesson is that, whilst gross colour differences in bricks (sometimes expressed simply by terms such as 'marl', 'sandy') can be a general guide to the origin of their soils, it actually tells one little about their particle composition, which tends to be the same. Colour differences are more the product of chemical weathering. Thus the distinctive reddish-yellow colour (7.5YR 6/8) of the desert marl at Amarna is due to a high oxidized iron content.

A further lesson is perhaps that particle-size analysis of a few sample bricks on their own is likely to have very limited value. Bricks are the products of geological deposits modified by human intervention. To go beyond repeating what is probably a fairly common basic makeup, brick analyses need to be part of an integrated study of soils within the general locality. If this is the case, analyses which aim to identify sources of raw material can be undertaken which will take one further than the quantification of basic components. The heavy mineral species that are present might indicate, if they can be identified, the source of the sediment, whilst the shape of the quartz particles might distinguish abrasion by fluvial and/or aeolian transportation (French 1981: 277).

The source of the soil used in making bricks is connected to the question of where they were made and who made them. Some soil is invariably required at a building site for mortar and plaster, and one way of proceeding is to make the bricks also at the site, assuming that there is sufficient empty space to create a temporary brickyard. A common occasion for building must have been replacement of houses and other constructions within existing towns. A proportion of whole bricks could have been rescued for re-use from the demolition of the old structures, but the principal demolition product is likely to have been rubble which would then have been available for breaking down into the raw material for new bricks and mortar. The likelihood of recycling is an important factor in any study of the composition of bricks on other than virgin sites.

Soil particle analysis of this kind describes the gross material of the bricks. Extraneous material, added either deliberately or accidentally, can often be observed in ancient bricks, and can include ash, sherds, fragments from stone-working, and even the occasional bead or other small artefact. Reisner comments from personal observation:

> The only material which is now deliberately added to the mud is dust and broken straw, by preference the sweepings of the threshing-floor; but even street-sweepings, which usually contain a certain amount of wind blown straw, are used by poor people. (Reisner 1931: 72)

The value of added temper is that it redirects the stresses that arise as the bricks shrink as they dry. This reduces shrinkage and provides a reinforcing structure which limits cracking.

Particular interest attaches to the addition of vegetal matter, especially chopped straw and chaff (ancient Egyptian *dḥ3*, Arabic *tibn*). To judge from the impressions of *tibn* left in ancient bricks this was a widespread form of added temper and represents a practice that has survived to modern times. It was evidently a preferred temper. One New-Kingdom model letter contains a complaint about local unavailability of straw for the making of bricks (Caminos 1954: 188; cf. Simpson 1963: 75). The Old-Testament story of the failure of straw deliveries to the Israelite brick-makers whilst resident in Egypt (Exodus 5:1–19; Nims 1950; Kitchen 1966: 156) has given added significance to the practice (although, since other forms of temper can be just as good, the story reflects ancient prejudice). Indeed, despite much expert comment to the contrary, the omission of straw is still sometimes seen as producing bricks of lesser quality, even on desert sites (e.g. Meidum, Borkowski and Majcherek 1991: 27; cf. Nims 1950: 26). A robust comment is provided by McHenry:

> Straw is sometimes suggested as a necessary ingredient. It is not! Most adobes made with reasonable adobe soil don't need it. If the organic content is too high, or the clay content too low, it may be necessary to add straw for strength, and for speed in drying. (McHenry 1976: 51)

This is borne out by Clarke and Engelbach:

> With a good sand and alluvium he [the brick-maker] can make tolerably hard bricks, and dispense with the chaff which, in the southern parts of Egypt, is expensive . . . if there is no *tibn* the bricks are made without it, but sand is often added with good effect. (Clarke and Engelbach 1930: 208, n. 2 and 209)

In modern Egypt *tibn* is widely available only for a time following the harvest. For it to have been available round the year in ancient times it would have been necessary to maintain stocks. The city of Amarna, it should be noted, was largely built of bricks without straw, the normal temper having been coarse sand with some gravel. The possibility of insect infestation of the organic content of bricks has not (to my knowledge) been investigated for Egypt, although on desert sites it can lead to its total loss from termites.

The generally simple approach to the distribution of loads by ancient Egyptian builders meant that compressive strength was the prime physical requirement of mud bricks, which have normally weak tensile strength (large bricks often break in two if carried carelessly). Even so, one set of tests of compressive strength of Fourth-Dynasty mud bricks with chaff temper, and of mud and sand mortar, concluded that the results 'belong to the lowest-known compressive strength values for materials used in architectural monuments' (Borkowski and Majcherek 1991: 29). Making walls thick obviously compensates, but, apart from this, it is also clear from particular examples that walls of, say thirty centimetres in thickness, were capable of reaching heights of between three and four metres and of supporting the added weight of two roofs (Kemp 1995: 147–9). Moreover, modern mud bricks made with similar mixes of materials emerge as perfectly adequate in this respect (Fathy 1969: 241–2, 287–8). It is important to realise that the characteristics of ancient mud bricks are likely to have altered over time, so that one is making judgements which, whilst important in assessing present conservation needs on a mud-brick building, need not have been relevant at the time when the bricks were made and used. Thus a binder of *tibn* (or any organic material) can be lost to insect infestation; on the other hand, long exposure to low levels of humidity, which are likely to be present even on open desert sites, probably leads to the concentration of soluble salts (principally calcium carbonate) in exposed brickwork, especially towards the surface of bricks, and hence to an increase in hardness.

The making of mud bricks

Evidence from ancient Egypt that relates to brick-making, other than the bricks themselves, is not extensive. It is rarely illustrated in tomb scenes. The principal example is in the mid-Eighteenth-Dynasty tomb of Rekhmira (TT100; Davies 1935: pls. XVI, XVII, XXIII; Davies 1943: 54–5, pls. LVIII, LIX, LX; Mekhitarian 1954: 48; Lhote 1954: pls. 97–9, 101; Arnold 1991:97, fig. 3.52). There is also a questionable Twelfth-Dynasty example at Deir el-Bersha (Newberry [1895]: pls. XXIV, XXV; Klebs 1922: 118). The Rekhmira artist changed his colour convention from pinky-grey for bricks as they were being made, to pink and white once they were dry and in the hands of the builder, an attempt to convey the substantial change that does take place during drying. The scene helps to define the meaning of the key word used for making or 'striking' a brick, *sḫt* (Badawy 1957: 63–4; Simpson 1963: 77–8; Spencer 1979a: 3–4). Brick-making was also an occasional subject for the wooden tomb models of the early Middle Kingdom (e.g. Breasted 1948: 52, pl. 46C, from Deir el-Bersha; Garstang 1907: 131, fig. 129, from Beni Hasan; Nims 1950: fig. 2). A small number of actual ancient brick moulds, all made of wood, are known (Petrie 1890: 26, pl. IX.23; 1917: 42 pl. XLVII.55; David 1986: pl. 18; Clarke and Engelbach 1930: fig. 263e), some of them models from temple foundation deposits (Weinstein 1973: 98–9, 232, 296, 419). The remains have also been recorded of at least one place where bricks had been made in ancient times (Vercoutter 1970: 214–16). This very limited documentation shows a way of working that seems to be identical to that of traditional brick-making in modern Egypt which has often been described (e.g. Clarke and Engelbach 1930: 208–9; Reisner 1931: 72–3; Petrie 1938: 4; Nims 1950: 26–7; Spencer 1979a: 3).

One estimate of daily output by a pair of early modern brick-makers and a mud mixer is from 4,000 to 6,000 (Reisner 1931: 72–3; comparable to Nims 1950: 27). Since modern bricks are small this is likely to be a considerable over-estimate if applied to the numbers produced in Pharaonic times; on the other hand, if output is measured in terms of volume, the ancient rate of production is likely to have been higher, since the larger moulds would have meant a more efficient use of the brick-maker's labour.

A question that is bound to arise in the case of a society which, like that of ancient Egypt, was much given to large-scale public works and to the administration of labour and commodities, is the existence of administered brickyards, either permanent or set up for large-scale projects. Estimates of 24.5 million bricks originally in the pyramid of Senusret III at Dahshur and 4.6 million for Buhen fortress give an idea of the size of demand that could arise (de Morgan 1895: 47, n. 3; Emery *et al.* 1979, 40), and a few texts record the exact number of bricks used on a project (e.g. Reisner 1923: 511). The written evidence is, however, ambiguous. A Middle Kingdom administrative papyrus from Kahun concerned with large numbers of bricks could as easily be dealing with brick-laying as brick-making or delivery (Griffith 1898: 59 pl. XXIII.24–40; Simpson 1960). A section of Papyrus Reisner I (of the reign of Senusret I) from Naga el-Deir also covers several operations involving the structural use of soil, including the making of mud bricks, each operation being the subject of precise calculation (Simpson 1963: 56–8, 72–80), but imprecisions in our understanding of the technical vocabulary again hinder understanding.

Being in charge of brick-making did not earn a specific official title. It is possible, particularly in view of the fact that brick-making in traditional societies is a very widespread skill, that it was normally treated as a form of peasant labouring, and the necessary output was obtained through whatever means of coercion was practised at a given time. In the Rekhmira brick-making scene (Davies 1943: 54–5) the labour used is explicitly identified as being foreign captives, their output intended for storerooms for the temple of Amun at Thebes. Given the nature of the administered sector of the ancient Egyptian economy, which was able to transport materials over long distances to meet the needs of individual schemes, the existence of administered brickyards raises the possibility that sometimes bricks or, at least, some of the raw materials, were brought in from a distance, and thus that their composition owes nothing to local sediments.

Perhaps the clearest evidence for administered supervision is the practice of impressing bricks with an official stamp (Fig. 3.4a), which is known from the beginning of the Eighteenth Dynasty to as late as the Thirtieth (Spencer 1979a: 144–6), the Eighteenth Dynasty providing the broadest spread of examples. If at a brickyard the person wielding the stamp from time to time walked down an aisle between fields of recently made bricks and impressed a stamp every few paces, the relatively small number of stamped bricks that would result, and their irregular distribution in loads which might be made up by workmen carrying them away in a different order from that in which they were visited by the stamp-wielder, could well produce the haphazard way in which they appear in constructions. Just as interesting are buildings in which they were not used, the Great Palace, Kom el-Nana, the North Palace and the Great Wall around the North Riverside Palace at Amarna being conspicuous examples. Should we deduce that not all brickyards possessed stamps, and see this as evidence that the sources of supply available to the king did not all have the same status?

A possible precursor to the use of stamps was the tracing of a simple design on to the top of a brick by means of a finger. Examples have been found on the bricks used in Middle Kingdom pyramids (de Morgan 1895: 49, fig. 110; Arnold 1979: 7, pls. 2–3; 1987: 82, Abb. 40). Finger-markings occur on bricks at Amarna, often a single diagonal line (visible in Nicholson 1989: 67, fig. 3.3; 68, fig. 3.4).

Bricks as artefacts

In rare instances individual bricks served a special need. They were used as markers in the course of laying out structures (e.g. parts of the Small Aten Temple at Amarna; the alignment of the boat slipway at Mirgissa, Fig. 3.8a); they had a restricted use in ritual contexts: bricks in early Middle Kingdom temple foundation deposits sometimes contained inscribed plaques (Weinstein 1973: xvii, 'Mud bricks'; Arnold 1979: 50), and in New Kingdom tombs 'magical' bricks were inscribed with short texts of protection which actually specify 'bricks of unbaked clay' (Thomas 1964).

When in their normal use as a building material bricks, as artefacts, are open to systematic recording by the archaeologist. Spencer (1979a: 1) has put forward a set of standard headings under which brick details should be routinely recorded:

1. The composition of the bricks, and whether burnt or unburnt.
2. The dimensions of the bricks.
3. The bonding, preferably described by means of a Corpus of bonds.
4. The distribution of any reed-matting or timber tie-beams in the brickwork.
5. The nature of the mortar.
6. Details of any plaster.
7. Whether stamped bricks occur.
8. Any special usages, or bricks of special form.

We will consider brick sizes first, since measuring ancient bricks is perhaps the most obvious thing to do with them. The first aim of brick measurement is to identify the output of individual factories or brick-making teams, initially for the purpose of internal comparisons. These usually relate to a site's chronology. Although the potential is also perhaps there for a study of how many sources of supply there might have been for a given building project, the variables are probably uncontrollable. Moreover, brick measurement itself is complicated by the nature of the data to be collected.

Even if bricks are formed from a mould that has been made true, the result, from the traditional style of brick-making, is not a simple geometric shape but one with a complex topography that is individual to each and every brick. The reasons for irregularity lie partly in the shrinkage that is bound to have taken place as the bricks dried, particularly since a fairly wet mix is likely to have been used (if one takes modern traditional brick-making as a guide). Moreover, each time that a mix of mud was prepared the proportions of its constituents are likely to have varied slightly, leading to a slightly different degree of shrinkage. A further cause of irregularity is disturbance whilst drying. Modern traditional brick-makers tend to lay out their bricks very close to one another. As the brick-maker lifts the wooden mould free from the most recently made brick, jiggling it to prize it free, it is very easy for him to bump it against the neighbouring brick in the previously made row, distorting it slightly. With the larger-sized bricks favoured at certain periods in the past the jiggling of the mould as it was removed will probably also have distorted each brick as soon as it was made. Furthermore, bricks are normally made on an earth surface which has not been prepared with great thoroughness. The undersides of bricks can therefore be more irregular than the other faces and bear the impressions of loose debris left on the working surface, whilst a slight convexity sometimes develops on the top surface during drying.

Given the imprecisions of manufacture, the proposal to measure ancient bricks to the nearest millimetre (Mond and Myers 1934: 49; Hesse 1970, 1971, endorsed by Spencer 1979a: 147) is not easily met, for brick faces are often not true planes. A dimension exactly recorded, therefore, can itself be a compromise. A high level of precision implies that many measurements will be taken of each individual brick and then be subject to a procedure of statistical reduction. Furthermore, complete bricks, the best basis for measurement, are available only if removed from a wall. If one chooses bricks from the uppermost preserved course, which will at least offer complete top surfaces to measure, one is making the assumption that this arbitrarily chosen layer is representative of the wall as a whole. A random selection of bricks chosen for measurement from the wall is not then possible. If one measures lengths and breadths below the uppermost preserved courses then inevitably these dimensions will not come in true pairs, but each length and breadth will belong to a different brick. Furthermore, weathering or the original smearing of mortar over the wall face often makes it difficult to discern the original edges of the bricks. My own view, formed in the course of trying to measure large numbers of bricks, is that accuracy beyond the nearest half centimetre runs the risk of being illusory (accepted by Hesse 1970: 104, his objection to rounding being the temptation to round to the same value; his histograms have half-centimetre divisions; note his view, however, that the arbitrariness of measurement in millimetres makes it easier to plot individual bricks as a scatter of points since few will be identical and thus occupy the same position on the graph). On the other hand, as outlined below, one of the things that one is looking for is slight but significant deviation from a length/width ratio of 2:1, and millimetre accuracy is here more appropriate.

The variability in brick sizes from a single manufactory means that, in order to describe the size of bricks in a given wall, many sets of measurements ought to be taken (Hesse 1970, 1971, recommends 100), although often in practice the number will be limited by the size and condition of the wall fragment in question. The range of variability can then be expressed both diagramatically and as a statistical mean. The common practice in the past of simply stating an average size of brick is insufficiently precise and, at worst, can lead to the conflation of dimensions from bricks that were not made from a mould of the same size. If, on the other hand, one is interested in the original dimensions of the wooden brick moulds used, the figures to select from a given batch of measurements should be the largest and not the mean, in view of the fact that a good deal of the variation will have been caused by shrinkage of the bricks as they dried.

Petrie's work on the town site at Abydos represents an early pioneering attempt to reach conclusions on a complex multi-period site (Petrie 1903: 50–2, 1938: 5). He principally wished to identify connections between walls, but he was also able to sketch out the limits of variance from one period to another. His tabulated results provide measurements to one tenth of an inch, but for ease of reference he also introduced the concept of the 'nominal' size, a figure which approximated to an average width in a set of measurements but was also chosen so as not to duplicate the nominal size of another set where the actual width measurements might overlap. The nominal sizes were included amongst the annotations added to the plans of walls. Many years later, at another multi-period site in Palestine (Tell el-Fara), Petrie chose to present the length and width measurements of bricks from different walls as a scatter of points on a graph, prefiguring the much later work of Hesse (Petrie 1930a: 21, pl. LXIII).

An important clarification of what lies behind the taking of brick measurements has been provided by Hesse (1970, summarised in Hesse 1971), based on his fieldwork at the largely Middle-Kingdom brick fortress at Mirgissa in Nubia. This is a textbook presentation which should be read by anyone interested in the subject of mud bricks. Hesse sets out his data in two ways: as histograms of length, breadth and (ideally) thickness, at half-centimetre intervals (as in Fig. 3.2a, although there the millimetre divisions have been kept); and (as Petrie had done at Tell el-Fara) as points on a graph where the axes record length and breadth (as in Fig. 3.2b; this is possible only when paired measurements of individual bricks have been recorded, see p. 84). Given the accidental sources of variation, when dealing with bricks from a single ancient manufactory the range of measurements ought to follow a statistically normal distribution, and in practice they approximately do, enabling a mean to be calculated, along with measures of standard deviation.

Normally on an archaeological site a series of sets of brick measurements will be taken, representing individual walls or buildings. It is then useful to compare the sets as a whole, with a view to detecting clusters of similar sets and their separation from other clusters. Hesse's procedure is to represent each set or sample as a circle with radius proportional to the coefficient of correlation between length and breadth. The circles themselves are plotted on a graph of length–width axes by reference to the centre of each circle, which is the mean value of the set of measurements. The centre is actually marked by a cross, the length of whose arms represents the standard deviation (Fig. 3.2c). This is a neat and efficient graphical way of presenting sets of measurements and is suited to the common situation in which it has not been possible to collect them in strict length/width pairs.

Archaeological judgements based on brick sizes are often bound to be tentative. Normally the principal aim will be to separate constructions of different date, bearing in mind examples in which more than one brick source is evident. The cause might be the inclusion of older, re-used bricks, or the simultaneous or phased access to the products of different brickyards which used different moulds. We really have no idea whether the sizes of brick moulds were dictated by authority or whether, through convenience, they approximated to one another at any given time. Wooden brick moulds have a limited working life and, on a major job, would probably have to be replaced. In the end, as with all archaeological data, inherent uncertainties should breed caution in interpretation (as admitted in Mond and Myers 1934: 49).

Beyond seeking information to help interpret an individual archaeological site there is the possiblity of establishing norms in brick sizes, period by period, which will act as a general guide to absolute dating. Although this approach is attractive, there is little reason for thinking it to have much value, for lack of consistency in the brickwork of ancient constructions has often been noted. A modest Early Dynastic tomb at Armant, built from a mixture of three different types of brick made from Nile silt and desert marl, is an extreme case (Mond and Myers 1937: 24), but even major buildings can display variations, in size or material, or both, sometimes but not always when alterations were made. Examples are the Valley Temple of Menkaura at Giza (Reisner 1931: 73); the massive mud-brick core of the pyramid of Amenemhat III at Dahshur (Arnold 1987: 10, 82); the mortuary temple of Thutmose III (Ricke 1939: 33–4); the platform shrine at Malkata South (Watanabe 1986: 6); the Memphite tomb of Horemheb (Martin 1989: 8–9); site K (and site E?) at Malkata. The acceptance of variability of brick sizes on the same project perhaps receives some confirmation in a textual source, the building records of Papyrus Reisner I of the early Twelfth Dynasty, where the scribe makes a distinction between 'brick' and 'large-size brick' in the same operation (Simpson 1963: 76; or does the

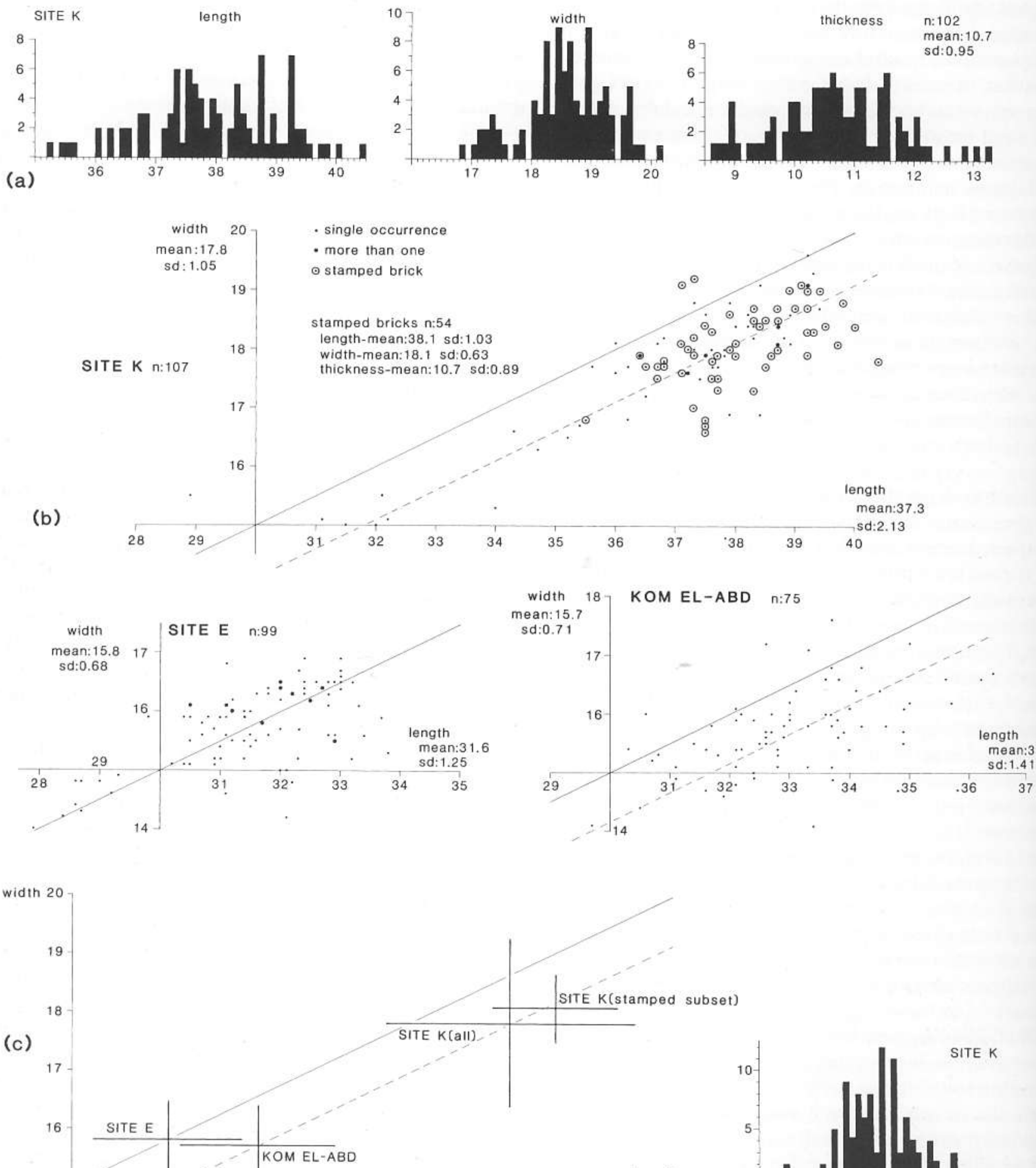


Figure 3.2 Brick data from three buildings of Amenhotep III: sites E and K at Malkata, and Kom el-ʿAbd to the south of these (based on a study by John McDonald for the University Museum of Pennsylvania). (a) Histograms of dimensions for site K (where the source material consisted entirely of loose bricks); (b) Point scatters for length and breadths of the three brick samples. The continuous diagonal lines represent a 2:1 ratio between length and breadth; the broken lines represent the actual means which, with the E and K samples, suggest the use of brick moulds in which the length was somewhat greater than twice the width; (c) Plot of the means and standard deviations for the three samples, and for a sub-sample from site K bearing impressions from a royal stamp. Note that the bricks from site K probably derive from the use of moulds of more than one size; (d) Histogram of length:breadth ratios of bricks from site K. Note that the peak of frequencies falls not at a ratio of 2:1 but around 2.1:1.

latter term refer to a significantly different category, e.g. large square flooring bricks?). Since brickwork was normally plastered any variability would not actually have remained visible.

An ancient acceptance of non-standardisation in brick sizes, which implies simultaneous use of the products of different brick-makers, has practical implications for the archaeologist. It not only makes it difficult to use brick sizes as a means of dating. If one were trying to link rubble or reused bricks on a site to their original home building, one would have to consider that a lost upper part of a wall might not necessarily have used the same bricks as surviving stretches of foundations.

Spencer (1979a: 147–8, pls. 41–4) has presented a wide range of brick measurements in a series of point scatters to represent length and breadth, period by period (Fig. 3.3). For the Archaic period the values cluster around a norm of about 24 × 12 cms. During the Old Kingdom this size remained in use, but the range of sizes was increased up to a maximum of about 42 × 21 cms. Thereafter, until the Byzantine period, the smaller sizes were avoided, and instead the broad spread of values only commences at around 30 × 15 cms. The preference for a size of brick that was considerably larger than that current in Egypt in recent times was perhaps a consequence of regular large-scale public works in this material. The sizes range up to what would probably have been the largest that could be made by simple technique without the risk of them regularly breaking whilst being handled, given the extremely weak tensile strength of mud bricks.

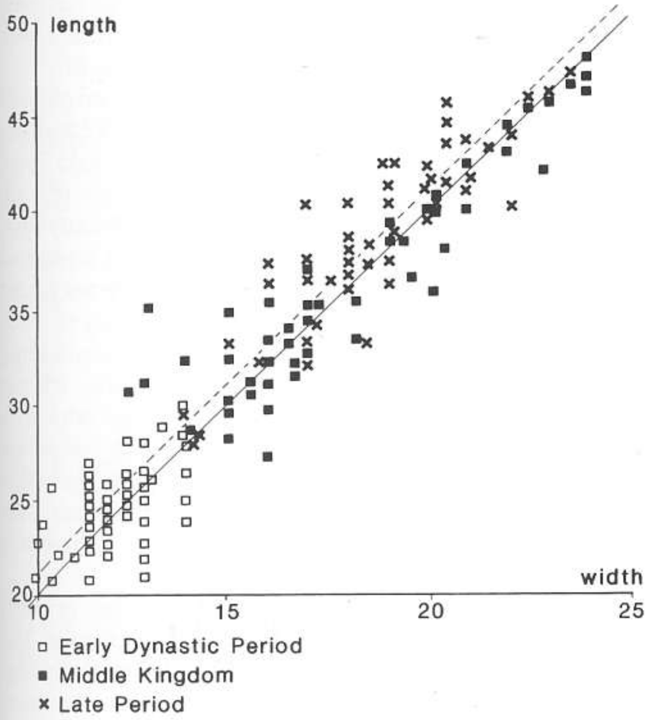


Figure 3.3 Point scatter of sample brick sizes from the Early Dynastic period, Middle Kingdom and Late Period. Each point represents average (or approximate) measurements (after Spencer 1979a: pl. 41). The continuous diagonal line represents a 2:1 ratio between length and breadth; the broken line represents an approximation to the mean.

It has been claimed that, throughout Egyptian history, bricks fall into two groups: large ones for major public works, and small ones intended for houses and small private tombs (Clarke and Engelbach 1930: 209; Spencer 1979a: 147), although examples of cross-usage occur. This is natural enough, in view of the often thinner walls and smaller features of the latter, whereas, with major buildings (up to the scale of complete brick pyramids in the Middle Kingdom) a prime consideration would have been how to contribute quickly to the mass of the building. Larger bricks use less mortar and thus reduce shrinkage during drying, and their greater area brings better bonding and thus greater strength. A case which does seem to illustrate this divided preference is provided at Kahun. Petrie found an actual wooden mould which he states produced a brick of 28.4 × 14.2 × 8.64 cm and then quotes these dimensions for the brick size of Kahun. Presumably these are the internal dimensions of the mould, but he does not make explicit whether he separately measured batches of bricks in the walls for comparison (Petrie 1890: 26, 1938: 5; Griffith 1898: 59). It would be useful to have this information. This size is at the very bottom of the range for the Middle Kingdom, but Kahun also produced a papyrus fragment with a set of accounts concerned with bricks, where they are described according to their length in palms. Two sizes are cited, of five and six palms, thus of 37.3 and 44.8 cms. Sizes in this range are found in contemporary brick pyramids, including that of Senusret II, builder of Kahun itself (Griffith 1898: 59; Arnold 1987: 10, 82; Arnold 1988: 24, 29, 31). A rather specialised case of deliberate choice of two brick sizes in the same building is illustrated by some large Early Dynastic tombs, where a smaller size was used for the panelling which decorated a wall made from larger bricks (Fig. 3.11b; Emery 1938: 3, fig. 1; Emery 1958: 41; 1968; Spencer 1979a: 20–1; but note Emery 1949: 90, fig. 52a for a contemporary example where this was not done). Separation of size according to the grandeur of construction was, however, only a tendency. When brick measurements from one period are grossed together they do not actually form two clusters, representing a large and a small norm, but spread themselves between the two extremes.

It is in the nature of bricklaying to seek to use bricks whose length is approximately twice the breadth. Even if bricks are all laid in the same direction, e.g. all as stretchers, in which the length is parallel to the wall face, for a neat finish at the corners in which the bricks dovetail into one another this ratio of $l = 2w$ will be necessary. However, modern factory-made bricks in Britain (for example) have a length which is actually twice the width plus the thickness of one vertical joint to allow for the extra joint when alternate courses are laid as headers. Whilst sets of real measurements from ancient Egypt provide constant pragmatic demonstrations that an approximate 2:1 ratio was normal, at the same time they also show a frequent tendency for a slight skewness towards a greater length, of between 1 and 2 cm (Figs 3.2b, 3.2c and 3.3); in the latter each point represents an average; it is present in some of the Mirgissa groups (Vercoutter 1970: 106) though one shows a paradoxical tendency towards a greater width. Although ancient Egyptian bricklayers tended to leave minimal vertical joints, a run of headers would inevitably accumulate a surplus of space over a corresponding half-quantity of stretchers. Since actual brick moulds are very rare we cannot be sure that they were designed to produce bricks which had this slight extra length to accommodate the additional header joint, but the general mass of dynastic measurements certainly hints that this might often have been so. Figure 3.2c (based on truly paired measurements from a sample of loose bricks in good condition) seems to be a clear demonstration.

It is also possible to speculate on whether brick sizes were related to modules of measurement of wider application. Again the suggestion comes from Hesse (1970: 110; 1971: 433) that a formula for brick sizes of length = 2 × width = 4 × thickness (a multiple of seven) might reflect the cubit in use at that time. This does not seem to be the case, however. The few ancient citations of brick measurements express them in terms of a length given in whole palms (Griffith 1898: 59; Simpson 1960). In view of the variation in brick sizes at any one period, and even within a single large construction, one must feel doubtful as to whether standards for brick-makers were ever prescribed. Even the citations in whole palms might represent scribal notations for brick sizes which were convenient approximations and were not standards to which brick-makers had to adhere.

Thermal characteristic is another measurable property of bricks and roofing materials, and has the potential for enabling the internal environment of a mud-brick building to be reconstructed (Endruweit 1994), although this requires knowledge of how high rooms were and whether the building possessed more than one storey, factors which usually have to be estimated. Traditional wisdom is that mud-brick is a good insulator, leaving buildings cool in summer and warm in winter, but this characteristic is, to some extent, dependent on the composition of the bricks and on local environment. Personal experience (also Spence 1996), supported by thermal measurements (unpublished study at Amarna by R. Hughes), is that mud bricks can act as heat reservoirs, retaining cold night temperatures during the day in winter and hot daytime temperatures during the night in summer. The result is uncomfortable.

Bricklaying

It was normal practice not to build brick walls up from a foundation of stones but to use bricks from the outset. The exceptions are a few desert sites (e.g. Kumma in Nubia, some Deir el-Medina houses). For the first course of a wall of two bricks or more in width the bricks were sometimes laid as headers on their long edges. This was particularly useful for compensating for variable depth in the trench. The depth of foundations could vary a great deal, from virtually nothing to several metres (Fig. 3.13a). Foundations were commonly laid without doorways being marked. As a result, when the upper brickwork has been lost, the pattern of access across the continuous lengths of wall can only be guessed at (e.g. at Nag el-Madamud, Robichon and Varille 1939).

For free-standing walls, when the thickness of the wall itself was thought to be insufficient, buttresses gave support, though normally built separately and bonded only by mortar and plaster. In the Middle and New Kingdoms an ingenious means of adding lateral stability to a relatively thin enclosure or revetment wall was to build it on a serpentine or undulating line. Examples are known at both civil (Hölscher 1939: 70–1; Vercoutter 1970: 97–101; Frankfort and Pendlebury 1933: 5, pl. III) and religious buildings (Ayrton *et al.* 1904: 12, 17, pls. XXXVI, LIII; Petrie *et al.* 1912: 41, pls. XXXIX, XLIV.1) and the suggestion has even been made that, in the latter cases, the shape might have had religious associations (Arnold 1979: 24–5, n. 81).

Some walls of very great thickness were pierced with narrow channels one or two courses high (Clarke and Engelbach 1930: 210; Spencer 1979a: 73, citing Karnak; Spencer 1979a: 78, Dendara; Reisner *et al.* 1967: 157: pl. LXXXIII, reporting on Mirgissa in Nubia; Pendlebury 1951: 92, Small Aten Temple). Although it has been suggested that they aided the drying of the bricks, they were not placed equidistantly, as is to be expected. The building of brick walls could involve the erection of wooden scaffolding (large post-holes have been found in front of major walls at Amarna) and a good way of anchoring it into the brickwork as it rose would be to fix cross-members into temporary holes between the bricks (putlocks). It is quite likely that many of the 'channels' served this purpose, though the Mirgissa examples stand out as a special case where this explanation does not fit.

A very wide range of possible patterns of laying bricks is available to a bricklayer, especially with thicker walls. The aim is always to avoid the danger of cracking if vertical joints are stacked above each other. Most walls from Dynastic Egypt alternated courses of headers and stretchers offset sideways (Figure 3.5 is an exception from the Ramesseum in which alternate header courses were laid on their sides). The courses of stretchers could themselves be offset by the length of half a brick each time so that the exact pattern was repeated only every fifth course (Figs 3.4c, 3.10a, 3.15). The full set of ancient variations has been codified into

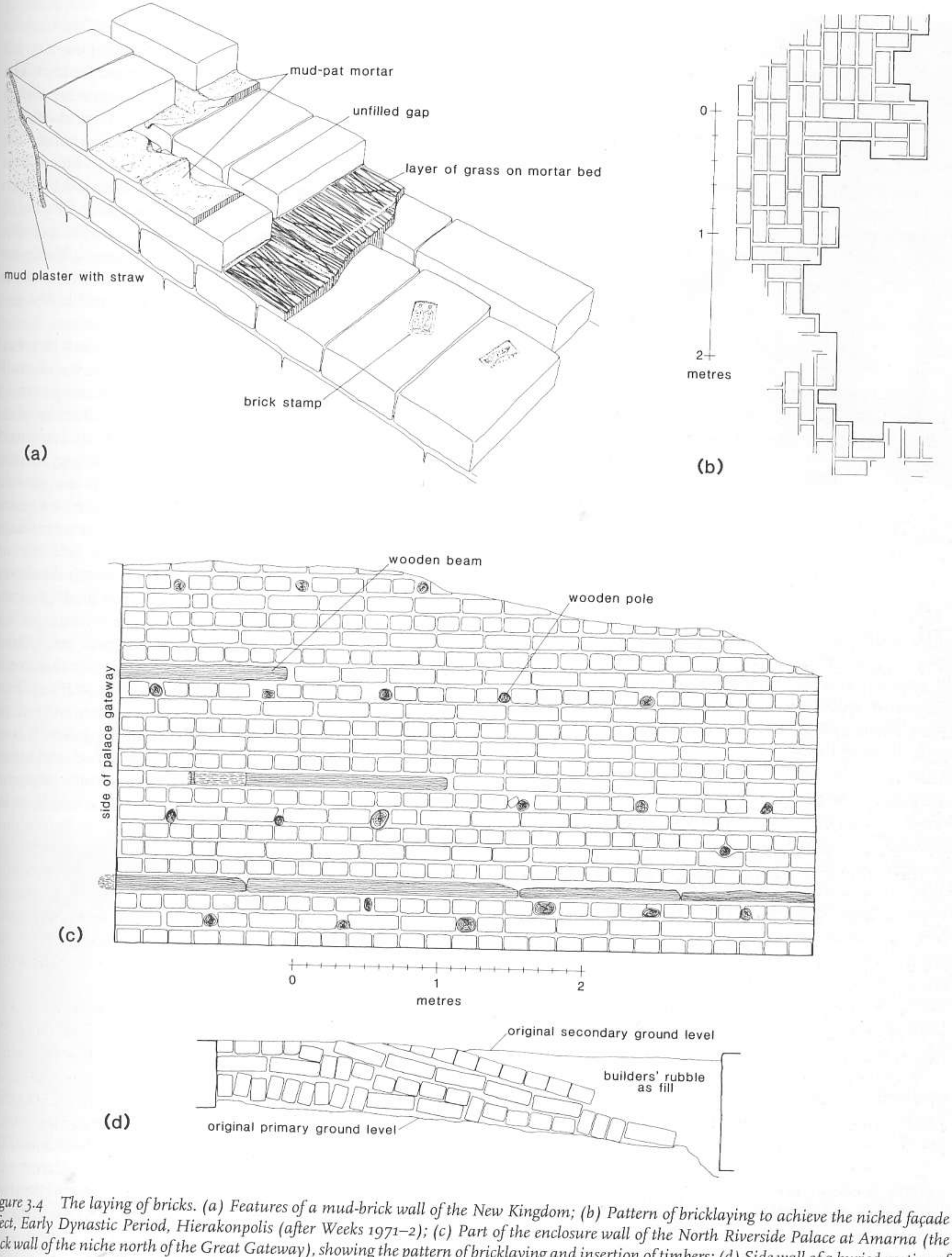


Figure 3.4 The laying of bricks. (a) Features of a mud-brick wall of the New Kingdom; (b) Pattern of bricklaying to achieve the niched façade effect, Early Dynastic Period, Hierakonpolis (after Weeks 1971–2); (c) Part of the enclosure wall of the North Riverside Palace at Amarna (the back wall of the niche north of the Great Gateway), showing the pattern of bricklaying and insertion of timbers; (d) Side wall of a buried portion of a ramp at Amarna (Kom el-Nana), showing how bricks laid on their edge were used to increase the thicknesses of brick courses.

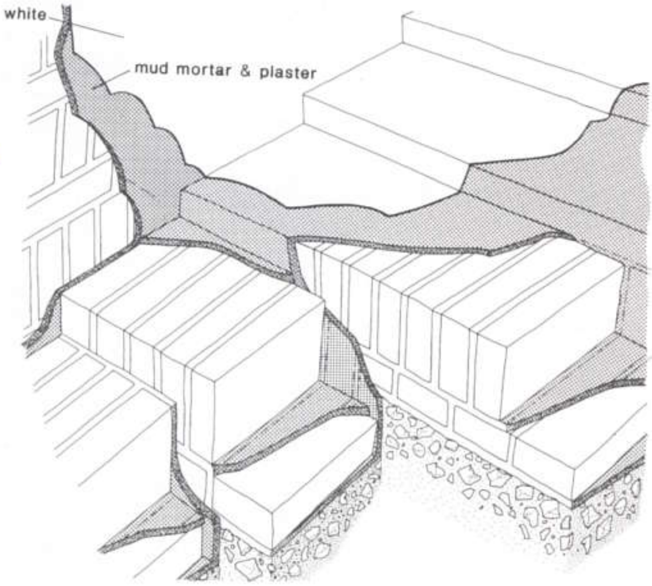


Figure 3.5 A common method of making the steps of a staircase was to use bricks laid on their edge, as here at the Ramesseum (after Thorel 1976: 50). Note the header courses of bricks laid on their edge in the wall beside the steps.

a corpus of bonds (Mond and Myers 1934: 47–52, pls. CXII–CXIV; Spencer 1979a: 7, 136–9, pls. 1–20). It should, however, be normal for the archaeologist to make explicit the pattern or patterns (bonding) used, and most definitely not to draw unmeasured brick shapes on plans simply as a space-filling convention to indicate brickwork. This can easily disguise the fact that, on larger projects, considerable variation in the pattern of laying was tolerated, and even conspicuous departures from the horizontal in courses which had to pass over uneven ground and instead ran parallel to the natural slope (Fig. 3.12 = Mirgissa; Reisner *et al.* 1967: 155–6; Vercoutter 1970: pl. VIII; Serra East: Hughes 1963: pls. XXVIIb, XXIX). Complicated patterns made it even more difficult for the builders to maintain accuracy and regularity. An example is the Early Dynastic palace-façade wall inside the town at Hierakonpolis, where the detailed archaeologist's plan shows numerous anomalies in the bricklaying (Fig. 3.4b; Weeks 1971–2). Another case of intricate patterning in brick is provided by the elaborate sets of archer's loopholes in some of the Middle Kingdom fortresses in Nubia (Fig. 3.11c; Emery *et al.* 1979), but the regularity with which they were laid out raises the possibility that they were formed around wooden shapes. Bricks could also be made to special shapes, some of them curved, but this aspect is reserved for a later section.

Part of the bricklayer's job was to compensate for unevennesses, accidentally developed through variability in brick sizes, uneven foundations, or poor workmanship (Fig. 3.4d); others arose deliberately, when walls were built with inward-sloping (battered) surfaces or the bedding planes were sloping or curved (see pp. 91–2). Mud bricks are easy to break or cut in order to provide pieces to fill small or uneven spaces, but there were a few simple tricks to employ as well. Bricks laid on their long edge added thickness to a course (and were useful in making staircases, Fig. 3.5); wide internal spaces either left open or filled with mortar (Fig. 3.4a) enabled wall thickness to be adjusted and irregular brick lengths in header courses to be lost to sight; bricks laid diagonally were also a means of adjusting thickness (Hölscher 1910: 29, Abb. 23; Thorel 1976: 44). Because vertical joints were often narrow or negligible it was easier to maintain regularity of bonding with bricks which approximated to the 2:1 ratio of length to width (see the discussion above on brick sizes). Nevertheless, actual examples show that it was sometimes necessary to introduce a half brick in a stretcher course to return the courses to their intended pattern of bonding (Fig. 3.4c, courses 3 and 11 from the top). Although walls were normally plastered, many well-preserved examples display considerable care and skill in achieving an even pattern of laying, and the likelihood that the makers of brick moulds sometimes departed from the 2:1 ratio to accommodate an extra header joint adds to the impression that we are often looking at the work of a skilled trade.

One danger which builders strove to avoid was the cracking of walls through uneven distribution of loads. A common measure to prevent this was to insert amongst the courses horizontal timber beams or narrower poles, both laterally and longitudinally, at vertical intervals that could vary from five to fourteen courses (the latter at Elkab; Figs 3.4c, 3.13c). They were particularly needed in very thick masses of bricks where, for the bricks in the interior, careful bonding of courses was normally abandoned, and sometimes even the use of mortar. Since timbers only started at the first interval above ground level, a wall needs to be

Figure 3.6 Section of niched 'palace-façade' brickwork at First-Dynasty tomb 3507 at Saqqara. Note the impressions of cylindrical wooden poles over the tops of the niches.

preserved to a height of a least half a metre for this to be detectable. The practice was often accompanied by spreading a layer of thick grass or reeds over an entire working surface that might or might not coincide with the level at which the timber was being inserted (Figs 3.4a, 3.7; Clarke and Engelbach 1930: 210; Spencer 1979a: 131–2, 135), a practice which is probably illustrated in the brick-making and building scene in the tomb of Rekhmira (TT100), where yellow fronds are shown protruding from a wall (Davies 1943: 55–6, pl. LX). Examples of timber and grass insertions are sufficiently widely spread chronologically to suggest that this was a continuous tradition in larger constructions from the Early Dynastic period onwards. The amount of timber (probably acacia in many instances) required would have been substantial: an estimate of 3,700 logs has been made for Mirgissa fortress, for example (Reisner *et al.* 1967: 157, Uronarti). More rarely, vertical timbers protected corners (Reisner *et al.* 1967: 21). In the brickwork of a Fourth-Dynasty tomb at Meidum (no. 6, Rahotep) logs of trees up to three metres long had been set, nearly upright (Petrie 1892: 16).

From the New Kingdom onwards builders seem to have begun to understand better the forces at work inside very thick masses of brickwork and to have adapted their techniques. The most obvious signs are to be seen in later temple enclosure walls. These were built as a series of blocks of brickwork in which the bricks of each alternate block were laid in beds that were concave along the wall's length, the courses of the other blocks being either all horizonal or all convex (Figs 3.13, 3.15). This alternation was often emphasised, too, by alternating the thicknesses of the blocks. The term 'pan-bedding' has sometimes been applied. Careful preparations were made to ensure that the curve of the bedding-planes was even and regular. At Philae a massive stone bed had been laid out in a curve as a foundation for the pan-bedding of the brick wall above (Petrie 1938: 11, pl. IV.15); at Edfu the pan-bedded sections of brickwork stand on a deep foundation of horizontally-laid bricks (Spencer 1979a: 81); in other cases stonework reinforcing the corners also retains the slope of the curve (Spencer 1979a: 78). Examples occur between the Nineteenth-Dynasty (enclosure wall of the temple of Seti I at Abydos, Frankfort 1933: 13, pl. XIII.1) and Roman times (the wall of this type at the Kom el-Sultan, Abydos – Figure 3.15 – is of the Late Period not the Middle Kingdom, as Petrie 1903: 6, pls. XLVIII.3, XLIX supposed). The style was applied to the building of cellular foundation platforms where the sides were also given concave lines in plan (e.g. Fougerousse 1933; Spencer 1979b), a feature which sometimes appears in the plans of walls, too (Fig. 3.13). It also came to be used for the walls of towns and large houses and other buildings, at least in Greco-Roman times (e.g. at Karanis in the first century AD, Husselman 1979: 33–5, pls. 12–14; Clarke and Engelbach 1930: 211; Spencer 1979a: 117; house models: Davies 1929: 250, fig. 14; Engelbach 1931: pl. III). An alternative, illustrated by the Medinet Habu outer enclosure wall of Rameses III, was to run the concave beds perpendicular to the wall face (Fig. 3.13a; Hölscher 1951: 3, pl. 41). Concave beds did not replace the use of timber inserts; they continued to be laid into the brickwork as an added binder (Fig. 3.13c).

Figure 3.7 Niched brickwork on the Second-Dynasty 'funerary palace' at Abydos, the Shunet el-Zebib. In the main mass of the brickwork the more pronounced horizontal planes mark layers of grass.

The design is very well-suited for overcoming structural problems: of uneven settlement of the underlying ground, scaling or spalling of the surface of the brickwork, distortion as the bricks dried leading to cracking, and shear cracking especially in the case of a foundation platform which is going to bear the load of building above (e.g. Clarke and Engelbach 1930: 210–11; Petrie 1938: 10–12). Chevrier (1964) has provided mathematical support and experimental verification, and powerful witnesses are the tall Roman houses at Karanis built in this way, which continued to stand to considerable heights after the town had been abandoned yet remained free from cracking until buried in drift sand (Husselman 1979).

The building of large temple enclosure walls was included amongst the pious acts of kings and formally commemorated as such, at least from the Eighteenth Dynasty onwards (Traunecker 1975). Often made to look like the walls of a fortress (Kemp 1972; Golvin and Hegazy 1993), they were seen symbolically as providing essential protection against the forces of disorder. It is conceivable, therefore, that their design drew upon mythology, although this does not preclude the possibility that symbolic interpretation was secondary to a design which arose from practical utility. One explanation of this kind (Barguet 1962: 31–2; also Spencer 1979a: 114–5) looks to an element of temple mythology, in which each temple was thought to stand upon the primaeval mound of creation, newly emerged from the waters of Nun. The undulations of the wall convey the watery environment. An example at Deir el-Medina preserves battlements and a walkway along the top, and these actually retain the undulations of the bedding-planes of the individual sections of the wall and so emphasise that they were integral to its appearance (Golvin and Hegazy 1993). On the other hand, the employment of concave bedding at Medinet Habu, because it ran at right-angles to the face, was invisible from the outside.

Whatever the original thought behind it was (and I would support those who see it as esentially a technological improvement) we seem to be dealing with an important and distinctive development in architectural aesthetic, the substitution of curving for straight lines. It appears in large buildings where, in contrast to stone-built temples, the outlines were not so strictly dictated by specific design models, and their general visibility would have been a startling contribution to the built environment.

Soil for mortar, plaster, and flooring

Soil provided the mortar used for laying bricks, its compositional relationship to the bricks depending to a large extent on whether the bricks were made on site, and thus from the same earth, or were imported. In the latter case bricks and mortar could be significantly different, as with the whitish mortar of desert clay mixed with straw used with alluvial mud bricks in the Eleventh-Dynasty temple at Deir el-Bahari (Arnold 1979: 6, 16, 25). Coarse filler such as chopped straw was, however, often not used. Cases have been noted where gypsum appears to have been used as mortar when adjacent to stonework (Martin 1989: 9, 12). It is important to be sure that this was a deliberate choice and not the accidental consequence of gypsum used for the bedding of stones spreading into the normally open vertical joints of adjacent brickwork (Mallinson 1995: figs 5.6, 5.9).

Mortar normally formed a bed beneath each new course. It was often (at least in the New Kingdom) laid down as separate little piles which the weight of the new brick would spread out into circular pats (two per brick, Fig. 3.4a). Vertical joints tended to be very close and with little or no mortar within them. Moreover, where brickwork had considerable depth, as in pylons, enclosure walls, and pyramids, the internal brickwork could be laid without mortar at all (e.g. Golvin and Hegazy 1993: 149, pl. IIa; Hölscher 1951: 3). The plastering of wall surfaces above ground, inside and out, made 'pointing' (when the bricklayer smooths and presses mortar into all joints) unnecessary. Nevertheless, the practice was known and occurs on the foundation courses of some good quality buildings (at Amarna, at least), thus below the level of the plastering. Whether or not it was the intention, it would presumably have provided a barrier against the fauna that likes to live in wall cavities.

It is important to distinguish mortar from plaster. They do different things and this is reflected in composition. Plaster not only improves the appearance of a wall and helps to protect it against weathering, it also adds to its mechanical strength (Petrie 1938: 6–7). In composition what normally distinguishes plaster from mortar is the high concentration of straw, the inclusion of which reduces cracking. Subsequent loss of straw from insect attack leaves it very friable and, since it was also the normal medium on which painting was done, wall paintings from domestic or religious buildings of mud brick only survive in exceptional circumstances. An unusual mix of a silt-lime plaster with straw chaff has been identified in the Fourth-Dynasty *mastaba* of Nefermaat and Atet at Meidum (No. 16) (Borkowski and Majcherek 1991: 28–9).

Floors are an aspect of soil architecture which tend to receive less attention than walls, yet are, at the same time, often less straightforward to deal with, the reason being that it is not always clear how deliberate their creation has been. Floors can be deliberate layers of mud plaster over a base of mud bricks, which were sometimes made specifically for flooring and have sets of dimensions of their own, often exactly or approximating a square, of between 30 and 43 cm (Spencer 1979a: 119; see also above for fired brick tiles used to create floors). In the case of compact muddy surfaces over open areas, however, the possibility exists that they came into existence through the combined action of trampling and of wetting the ground, a puddling process in itself. Such by-products of human behaviour can recur over the same area to produce a laminated effect. Deliberately made mud floor plaster probably benefits in the same way that wall plaster does in being given a relatively high organic content, usually derived from chopped straw, and being applied in a fairly plastic state, thus without the addition of too much water. Another form of external mud rendering, midway between the plaster of walls and floors, was the surfacing of sloping revetments, such as the glacis of a fortress (e.g. at Mirgissa: Reisner *et al.* 1967: 151).

The detailed study of the composition of floors leads one into a vital aspect of archaeological interpretation, for floors can contain a record not only of how they were made but also, from material that subsequently becomes incorporated into them, of what activities were carried out on them (a clear example is Hecker 1986). The evidence is often microscopic, but a technique has been developed for taking and studying large thin-sections of archaeological deposits which include floors (Matthews and Postgate 1994). Specialist skill and access to an appropriate laboratory are required, but first results (not from Egyptian sites) are so promising as to imply that the technique could play an important part in interpreting the results of excavation on settlement sites in Egypt, whether in the desert or on the floodplain.

One specialised use of spread soil took advantage of its lubricant property when wet. Used in conjunction with reinforcing timbers to take the weight, a layer of mud was the basis for prepared roads over which heavy loads were dragged. The best-preserved example is a slipway near the Middle-Kingdom fortress of Mirgissa in Nubia which had enabled boats (presumably loaded on sledges) to be hauled past a particularly difficult stretch of the river (Fig. 3.8a; Vercoutter 1970: 204–14). The remains of similar examples have been found at a quarry at Lahun and beside one of the pyramids at Lisht (Arnold 1991: 86–92). These examples need to be interpreted in the light of the well-known scene of the transport of a colossal statue in the tomb of Thuthotep at Deir el-Bersha (Newberry [1895]: 16–26, pls. XII–XIX; Arnold 1991: 277–8) and a similar one in the tomb of Ty at Saqqara. As it is dragged on its sledge a man pours water, presumably to ease the gliding, an effect which modern experiments have replicated (Chevrier 1970: 20–5).

Roofing

An important sub-section of the topic of soil architecture is roofing, which took two forms: flat roofs of mud laid over wooden beams, and vaults and domes of brick. Occasionally actual roofs of ancient buildings have survived but mostly the roofs of above-ground structures will have collapsed. Even then, at least on desert sites, evidence for roofing can still be found amongst the fragments of rubble. In the past this has often been ignored by archaeologists. As a result there is insufficient evidence for judging the relative frequency of the two kinds, both by historical period and by type of building. The plan of a building might sometimes point to the answer; for example, vaults need a certain thickness to accommodate both the springing and, if not balanced by a parallel vault, the lateral force that a vault creates. On the other hand the presence of columns might be thought to indicate a flat roof, although the throne room in the palace at Medinet Habu possessed long vaults above the columns (Hölscher 1941: 38–9, pl. 26; 1951: 29).

Flat roofs require a rigid framework of beams to take weight, and a covering surface laid over them to provide a ceiling or roof. The evidence for ancient practice shows that the covering surface could consist of a layer of bricks (e.g. Emery 1949: 74, fig. 36; 1961: 184–5, fig. 108) or (probably more commonly) of a layer of plant material (thin poles, the central ribs of palm leaves – *gereed* – coarse grass, or woven matting) covered by a thick layer of mud (Fig. 3.8b; Petrie 1890: 23; 1891: 8; Peet and Woolley 1923: 57–8, fig. 6; Frankfort and Pendlebury 1933: 5, 9–11; Lacovara 1990, 8, fig. 2.11; Kemp, 1985: 8–11; Tytus 1903: 13, are variations but are the reconstructions reliable?). The width of spans would depend on the thickness of the timber cross beams which could be given intermediate support from columns. At Amarna flat roofs were usually not more than about 3.5 metres across. For aesthetic reasons the underside, including that of the protruding beams, could also be plastered with straw-rich mud plaster, which could then be painted. When ceilings and roofs of this kind collapse, the mud coverings break into pieces which will continue to retain the impressions of beams and other supporting material (which will normally eventually decay). Such roofing-fragments are important structural evidence and should be looked for and recorded during excavation.

Vaulted roofs are better documented, partly because of their use in tombs where they have had better chances of survival. The earliest examples recorded come from the First-Dynasty necropolis at Saqqara (Fig. 3.9a = Tomb 3500: Emery 1958: 102, pls. 116, 120; 1961: 185, fig. 90); domes have been recorded in Fourth-Dynasty tombs at Giza (Fig. 3.9d; Junker 1941: 25, 30–3, Taf. III; Larsen 1950; Abu-Bakr 1953: 129–43; for later examples see Spencer 1979a: 48, 123–6). Vaults are known to have covered spans of around five metres (Martin 1989: 55–6; Hölscher 1951: 29) and more, one in the mortuary temple of Amenhotep son of Hapu reaching 7.70 metres (Robichon and Varille 1936: pl. XI; Spencer 1979a: 87, following Hölscher, cites a possible case of a span of 8.60 metres at Medinet Habu). In order to create a flat surface above adjacent vaults, either for a roof or for the floor of an upper storey, the intervening spaces had to be filled. Bricks or rubble were used in the only surviving examples (Fig. 3.9b; Emery and Kirwan 1935: 34, 37, fig. 13, pls. 6 and 9; Ghazouli 1964: 145, pl. XVIA; Thorel 1976: 34, 41–2, 47) but by Coptic times smaller relieving vaults were being built into these spaces instead (e.g. at St Simeon's Monastery at Aswan). A further use of vaulting was to create relieving arches to protect doorways or chambers which lay within large masses of masonry (e.g. Minault-Gout and Deleuze 1992: pls. 11–19).

Most ancient vaults seem to have been of the pitched type in which each arc of bricks was laid at a slight angle to the vertical, so that the weight of each new one was borne by those already in place (Fig. 3.9; Van Beek 1987: 81). It has remained a living tradition especially in Nubia (e.g. Mileham 1910: 8–10; also Fathy 1969: 16–18, pls. 7–18). Its attraction is that it enables vaults to be constructed without the use of temporary supports. Although ordinary bricks can serve for this type of vault, special bricks were sometimes made. Normally they have two distinguishing characteristics. They were thinner, resembling tiles (Fig. 3.10), and did not need the standard 1:2 length:width ratio. Specimen dimensions are 41 × 23 × 5 cm (Martin 1989: 55–6); 60 × 22 × 7.5 cm (Ghazouli 1964: 144); 40 × 19 × 37 × 6 cm (Robichon and Varille 1936: 38); 40 × 20 × 40 × 7 cm (Frankfort 1933: 143), the last two with a slightly wedge-shaped design, which in other cases was accompanied by a slight curvature of the edges (Spencer 1979a: 142, fig. 90). The other characteristic was a scoring of one face (to be the underside), or even of both faces, by dragging the fingers down its length during

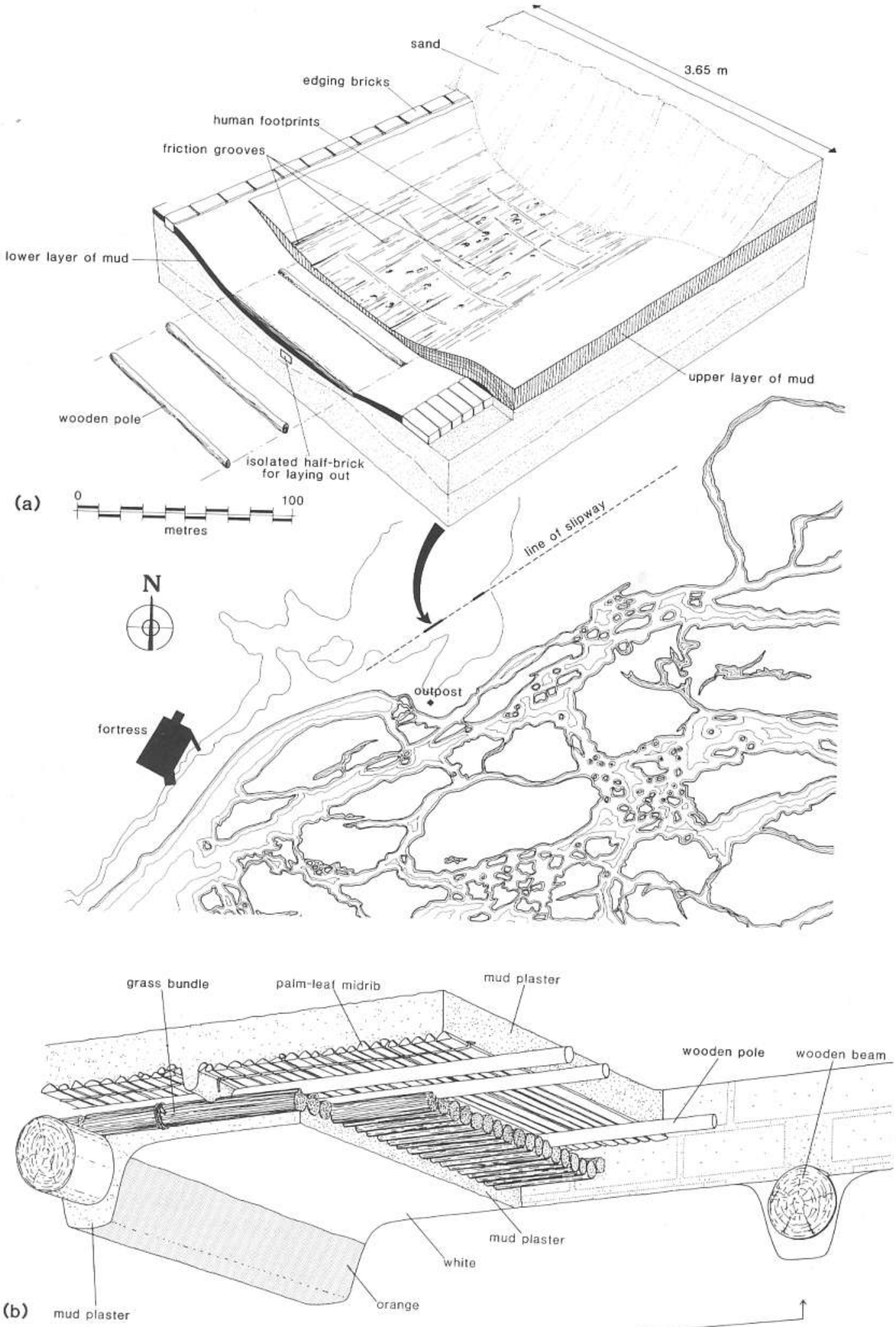


Figure 3.8 *Uses of spread mud layers. (a) In a boat slipway at Mirgissa, Nubia (after Vercoutter 1970); (b) As a roof covering in a reconstruction of roof design at Amenhotep III's palace at Malkata, site E, square af21 (1973 excavations of the University Museum of Pennsylvania).*

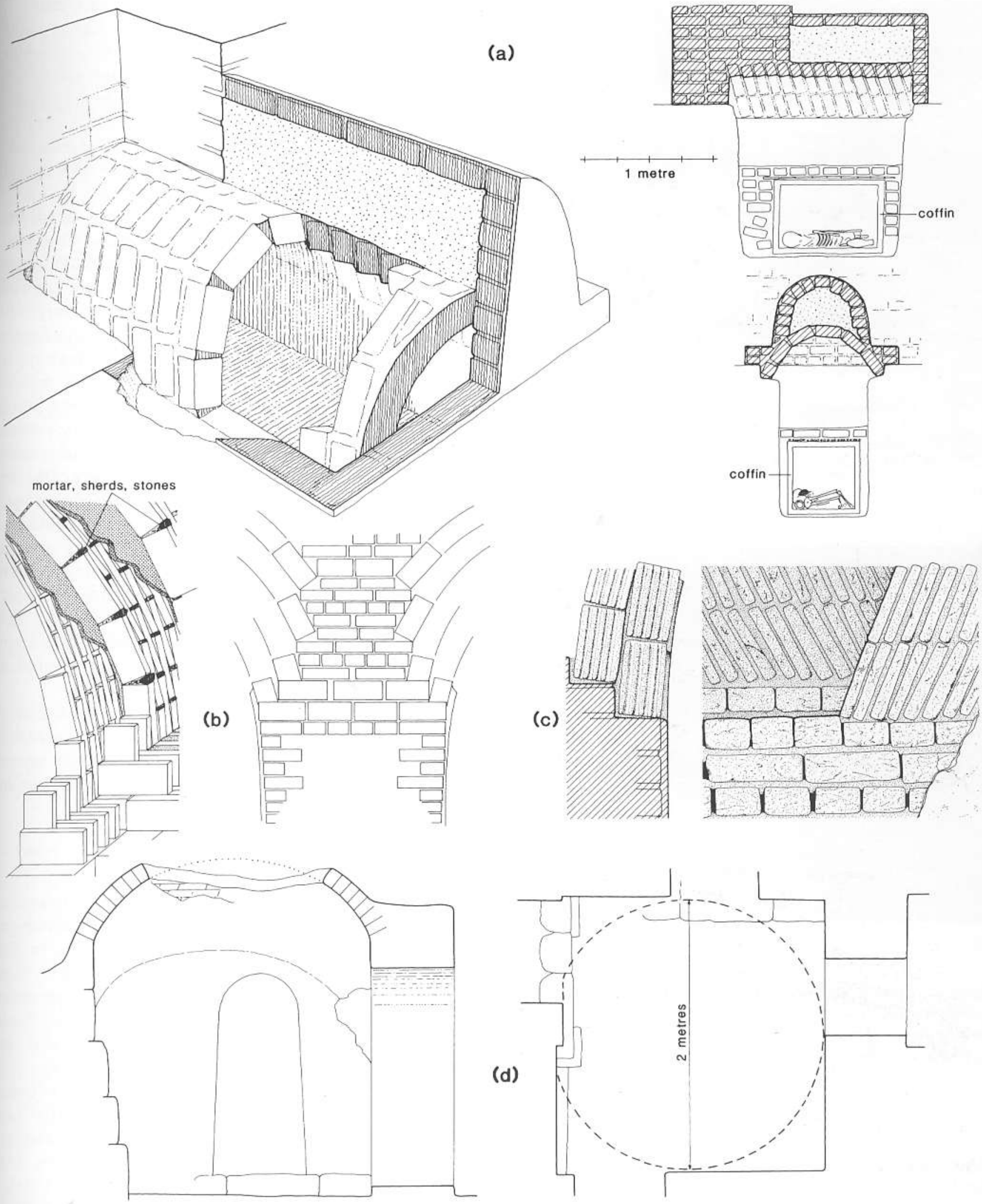
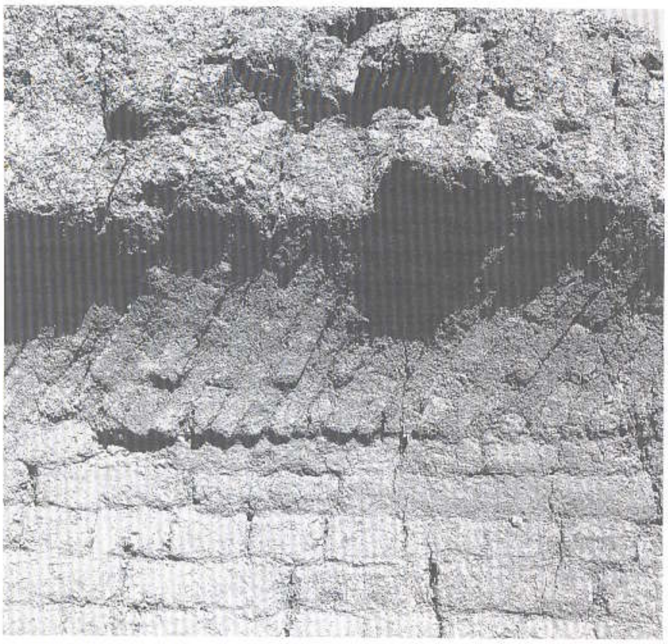
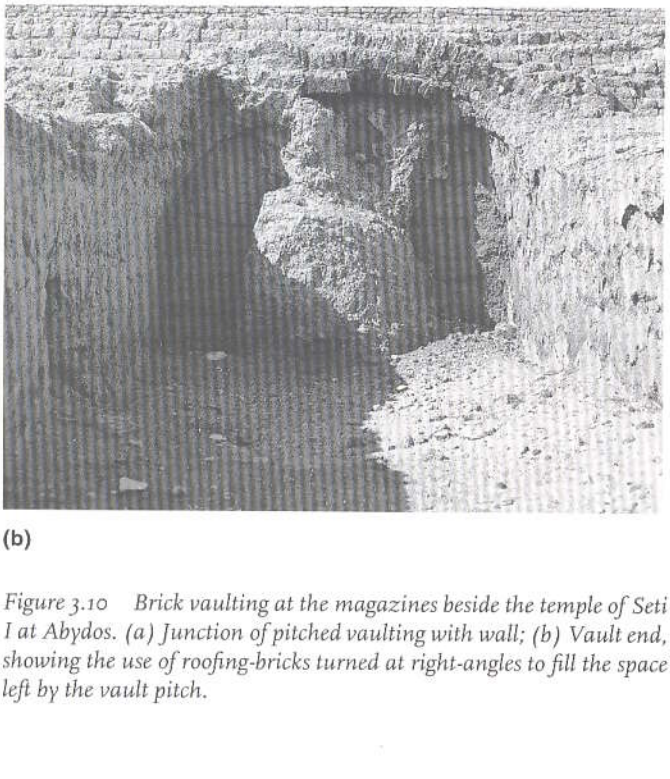


Figure 3.9 Brick vaults and domes. (a) The earliest example, which covers a subsidiary burial at Saqqara tomb 3500, First Dynasty (after Emery 1958); (b) Brick vaulting at the Ramesseum with alternate pitching for double or multiple vault layers (after Thorel 1976); (c) A detail of the same, showing the grooved surfaces of the vaulting bricks; (d) Domed brick chapel at the Fourth-Dynasty tomb of Seneb at Giza (after Junker 1941).



(a)



(b)

Figure 3.10 Brick vaulting at the magazines beside the temple of Seti I at Abydos. (a) Junction of pitched vaulting with wall; (b) Vault end, showing the use of roofing-bricks turned at right-angles to fill the space left by the vault pitch.

manufacture to create 'frogging' (Fig. 3.9c). This keyed the dried mortar on to the otherwise smooth surface of the brick and so helped to prevent shear loads from above splitting it away, and also perhaps augmented the suction of the wet mortar by allowing it to act on a greater surface area (Martin 1989: 51). It is important to identify fragments of such roofing tiles if found loose in rubble during excavation.

In some examples of pitched vaults the tiles or bricks were laid in two (and even up to four) layers, often with alternating angles of tilt (Fig. 3.9b, 3.9c; Emery and Kirwan 1935: 37, fig. 13, 43, fig. 22, pls. 6 and 9; Martin 1989: 51, pls. 46 and 157; Ghazouli 1964: pl. XIIB; Frankfort 1933: 14, pl. XI.4; Van Beek 1987: 79, 81). In a well-preserved cellar vault at Amarna pairs of reeds were inserted between the rings of the vault (Frankfort and Pendlebury 1933: 52–3, fig. 6).

To what extent true vaults were built using vertical arcs of brick is not clear. A Sixth-Dynasty chapel at Giza is one example, built with specially shaped bricks with interlocking zig-zag edges (Fig. 3.11a = Fisher 1924: 114–7, pls. 13.2, 17–19). The vertical placing of the arcs was necessary to the creation of an effect of rounded ribs on the underside, which was part of the moulding (see the section on special shapes). True vaults are more likely to require wooden formwork which will temporarily support the arcs. Sets of square holes for the ends of wooden beams in arc-patterns preserved in stone walls at Medinet Habu probably derive from such a building system, but the appearance of the roof and ceiling (was it also ribbed?) is now lost (Hölscher 1941: 38–9, pl. 26, 1951: 29; Spencer 1979a: 87). One should not rule out the possibility that, for large building projects, professional (or at least specialised) vault-builders were employed, who came with their own equipment. Support would also have been needed for arches, commonly built over doorways, but this could have been achieved very simply, through the use of lengths of bent palm-leaf rib or more substantial pieces of curved wood.

Many examples, mainly from tombs, are also known of corbel vaults of brick, in which the space was gradually closed by slightly projecting each course of bricks beyond the one beneath until the bricks of both sides met in the middle (Spencer 1979a: 126–7).

Soil as filling material

Large building (and perhaps demolition) projects in ancient Egypt required the use of extensive ramps for the movement of building materials between different levels. In one method of construction parallel walls or a network of chambers were built of brick and then filled with soil (desert or alluvial) (Badawy 1957: 64–5; Arnold 1991: 86–98; Petrie 1912: 55, pl. XXXII). A comparable practice was also employed for foundation platforms of large buildings (e.g. Janosi 1996) and occasionally for thick walls (e.g. Ziermann 1993). The most notable examples come from the Late Period, when civil and religious buildings were often set upon massive cellular pedestals filled with soil (e.g. Fig. 3.14; Kemp 1977; Petrie 1888: 52–61, pls. XLIII, XLIV; Holladay 1982: 31–1, pl. 40). These examples notwithstanding, Egyptian builders often display a preference for creating required mass (e.g. in thick enclosure walls and temple pylons) through solid brickwork.

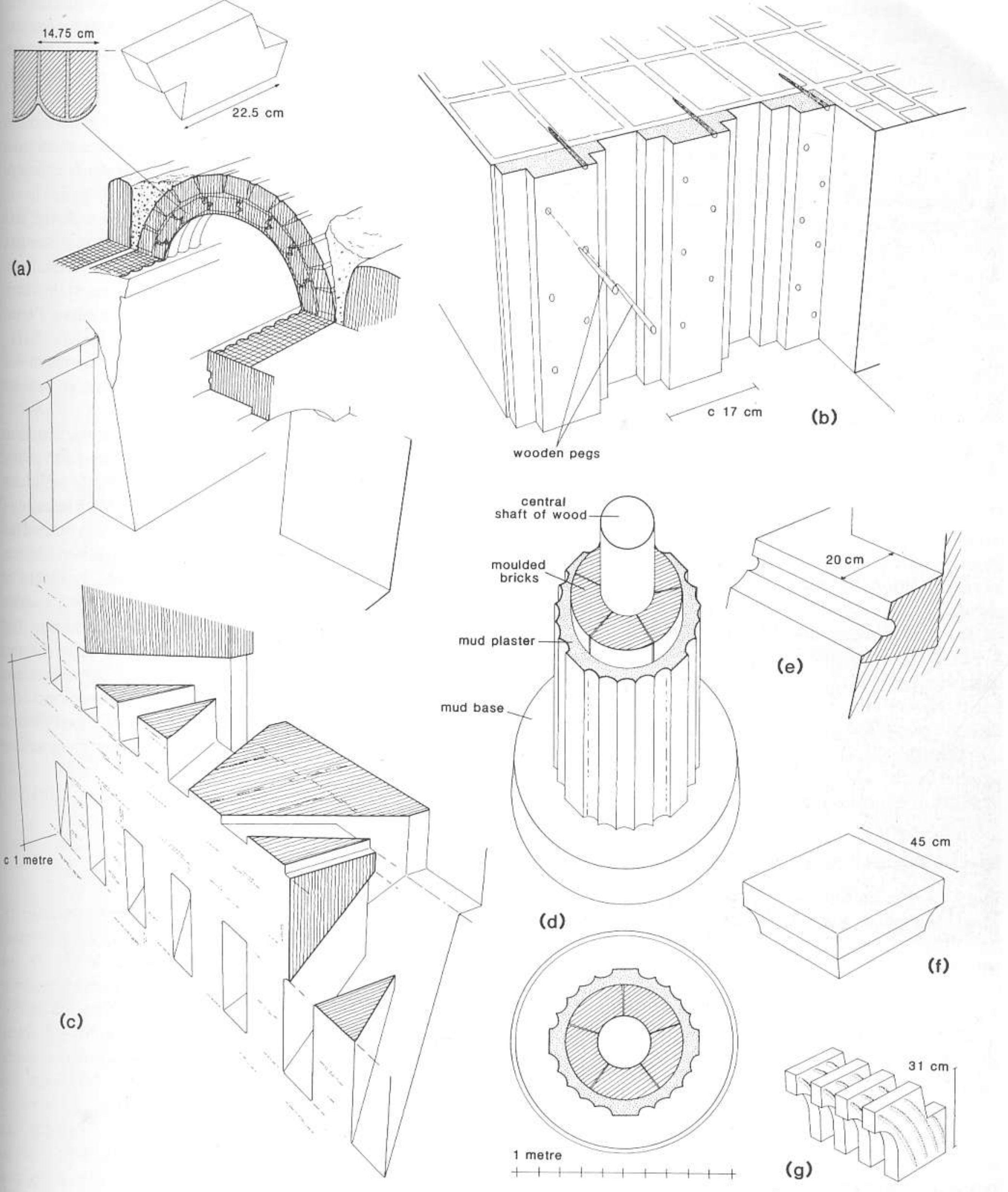


Figure 3.11 Architectural mouldings in mud. (a) Ribbed vaulted roof in a Fourth-Dynasty chapel at Giza which used specially moulded bricks (after Fisher 1924); (b) Moulded mud panels fixed to a Third-Dynasty tomb façade (no. 3070) at Saqqara by wooden pins (after Emery 1968); (c) Archers' loopholes in the fortress wall at Buhen, Twelfth-Dynasty (after Emery et al. 1979); (d) composite column from building R41.5 at Amarna; (e) Parapet moulding for an ornamental pool at Maru-Aten, Amarna (after Peet and Woolley 1923: 119, fig. 19, pl. XXXVII); (f) and (g) Cornice mouldings from Deir el-Medina (after Bruyère 1926).

Some of the evidence for the use of loose soil also comes from building texts, although vocabulary difficulties still hinder translation (Simpson 1963: 73–5, 78). In the best known (P. Anastasi I) the soil is sand, and the interpretation seems to be that the removal of the free-flowing sand allowed a heavy mass, a colossal statue in this case, to be set up vertically on its pedestal (Arnold 1991: 70).

The claim has been made by Badawy (1957: 59–60) that the Egyptians used the rammed-earth method of construction, citing as examples 'platforms replacing pavement in archaic huts, enclosure walls constructed of two facings filled in, constructional ramps consisting of a network of coffers in brick filled in with earth'. If, as I suspect, these examples involved the filling of spaces defined by permanent walls then the term 'rammed earth' is not appropriate. It is better kept for the technique in which earth is rammed by compression between temporary formwork (usually of wood) which, when removed, leaves a solid construction behind. The key to success is to use an almost, but not quite, dry mix of soil in which the action of ramming is not impeded by the need to expel a lot of water. A large amount of strong wooden planking is required and the means of fixing it securely as the mud is compressed. The result can be more solid than that achieved by building in bricks made by the traditional method. I know of no examples of true rammed earth construction in ancient Egypt, but, especially on damp floodplain sites, they might be difficult to identify. A Fourth-Dynasty *mastaba* at Meidum (no. 16, of Nefermaat) had been filled with 'layers of Nile mud, poured in and left to harden before a fresher mass was applied' (Petrie 1892, 1938: 8), but nor is this a true example of the practice; nor the brick quarry ramp at Qau el-Kebir, made from parallel brick walls filled with loose mud (Petrie 1930b: 16, pl. XXII.4; Arnold 1991: 93).

Special shapes and vernacular style

The Egyptian architectural style took its inspiration from wood and plant forms. We are most familiar with the formalised shapes as they were rendered in stone, starting with the Step-Pyramid enclosure. Sporadic examples show, however, that the same or related forms could be reproduced in mud as well, sometimes through the use of specially shaped moulds. Examples are vaults from Old-Kingdom chapels at Giza, sometimes painted red, shaped to represent curved ceilings of reed bundles (Fig. 3.11a = Fisher 1924: 114–7, pls. 13.2, 17–19; Abu Bakr 1953: 129–43; Spencer 1979a: 25, 142; Kuhlmann 1996); *cavetto* cornices and *torus* mouldings at Deir el-Medina and Amarna (Fig. 3.11e, f, g; Spencer 1979a: 142; Frankfort and Pendlebury 1933: 6–7; Pendlebury 1951: 141, fig. 20; Kemp 1985: figs 1.4, 1.5, 2.3); and, again at Amarna, columns of rounded mud bricks built around a central wooden post and faced with fluted mud mouldings (Fig. 3.11d = Pendlebury 1951: 22, 109). Curved bricks made in curved moulds were used at Amarna for column bases (Clarke a Engelbach 1930: 215; Pendlebury 1951: 132) and for circul grain silos (personal observation, house Q44.1). They a also attested in vault construction (Deleuze 1981; Minau Gout and Deleuze 1992: 72).

The substitution of mud and mud bricks for stone cou extend to moulded lotus-clump columns with screen wal (Pendlebury 1951: 139, pl. LV.4) and to statues, althou surviving examples are extremely rare: the bulls' hea modelled in clay, into which real horns were inserted, la out along the base of some First-Dynasty tombs at Saqqa (Emery 1954: 8–9, pl. VII; 1958: 6–8, 75; 1961: 71, pls. 8, statue groups of plastered brick added to some of the cor dors of the Ramesseum in the Third Intermediate Peri (El-Achirie and Fonquernie 1976: 11–13, pls. XXXIV–XLIa b; Schumann Antelme 1976: 71–6, 172–4); figures of B moulded in high relief in a Ptolemaic shrine at Saqqa (Quibell 1907: 12–14, pls. XXVI–XXIX).

The First Dynasty had also seen, however, the introdu tion of a style of ornamental brickwork used for palac façades and the tombs of the élite which might well hav been independently inspired by the brick architecture Mesopotamia. Panelling and imitation dooways formed th basis of the lower parts of walls (Figs. 3.6 and 3.7). (In on case the panelled effect itself was achieved by means o pre-cast mud slabs fastened to the façade by long woode pegs, an early form of architectural cladding, Fig 3.11b = Emery 1968). The upper parts bore complex pattern which are known mainly from artistic representations, an these, according to one excavator, were sometimes moulde in mud (Emery 1954: 139; 1961: 181, but without illustra tions). The same was true of decorative elements i

Figure 3.12 Part of the lower ramparts of the Twelfth-Dynasty fortress at Mirgissa, Nubia. Note the angled bedding-planes to take the brick-work uphill.

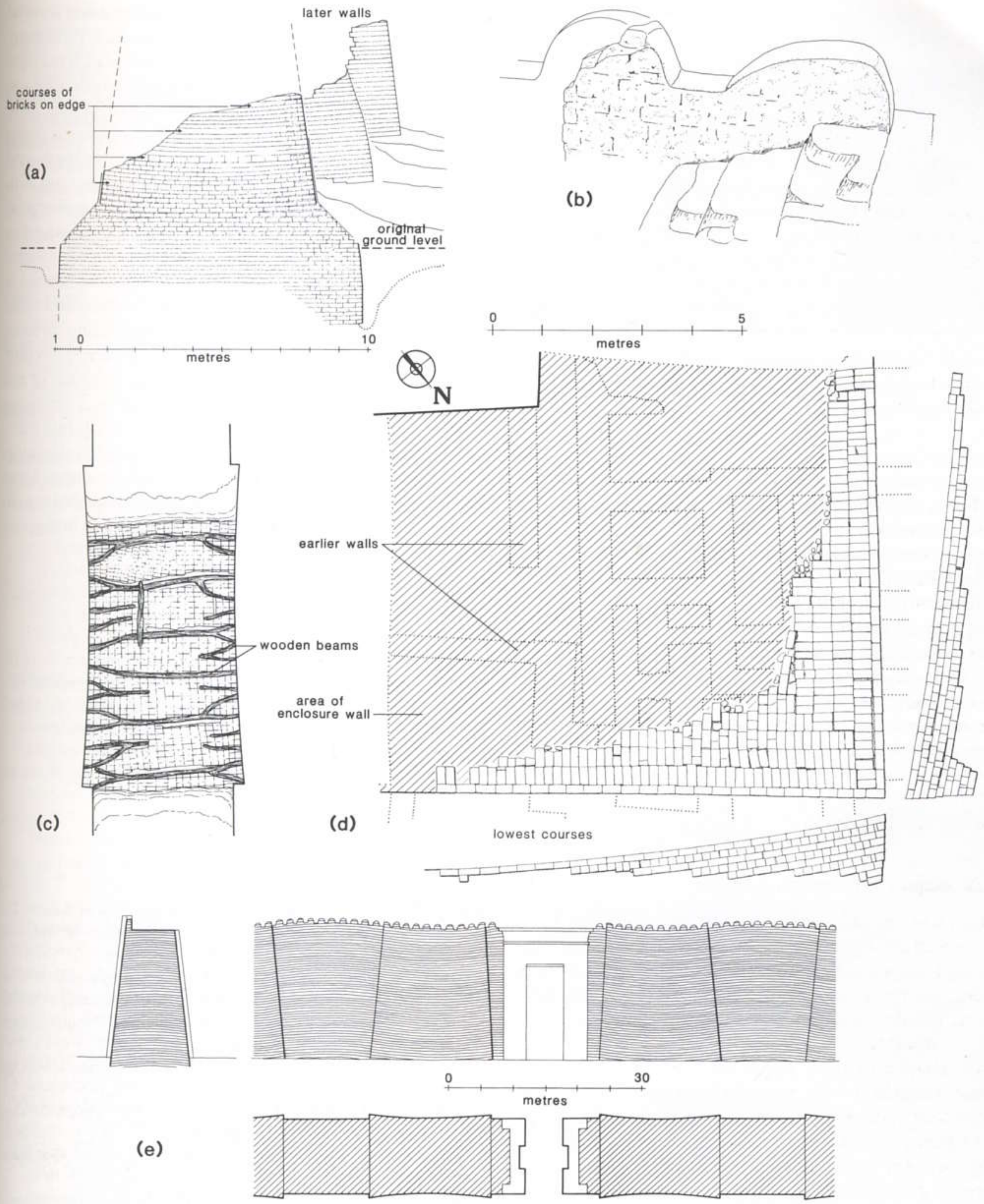


Figure 3.13 New Kingdom and Late Period ramparts. (a) Section through the enclosure wall at Medinet Habu (after Hölscher 1951); (b) Sketch of preserved brick crenellations at the Late-Period fortress on Dorginarti Island, Nubia (after Knudstad 1966: pl. XXIVa); (c) Plan of one course of bricks and timber beams in the enclosure wall of the Montu temple at Karnak (after Christophe 1951: pl. VI); (d) Plan of the foundation brickwork at the north corner of the Monthu temple at Karnak, built over earlier constructions (after Christophe 1951: pls. XVI, XVII); (e) Reconstruction of the centre of the east side of the Thirtieth-Dynasty enclosure wall at the Amun temple at Karnak (after Golvin and Hegazy 1993).

Figure 3.14 Cellular brick foundation platform for the Palace of Apries at Memphis, viewed to the north. The cellular chambers were originally domed.

Amarna houses (Frankfort 1929: 55, 57). Fortifications in mud brick, which used curved walls, elaborate systems of loopholes, and crenellated battlements (Figs 3.11c, 3.12, 3.13b; for two surviving examples see Knudstad 1966: 185, pl. XXIVa; Golvin and Hegazy 1993) provided builders with yet a further set of models.

The lack of tensile strength in mud can make fancy shapes difficult to achieve without reinforcement. Occasional finds of reinforcement in the form of wood or rope which will normally have survived only as impressions in the mud show that simple means to overcome this were understood, as in the case of window grilles, roughly square in section, moulded from mud around wooden core Amarna (Frankfort: 1929, 57; Frankfort and Pendleb 1933: 10; also Fig. 3.11d). Linen can also be useful. It has b noted at Amarna laid over mud columns, to which paint applied (Pendlebury 1951: 139), and Emery (1954: 139; 1 182) cites architectural elements from Early Dynastic to at Saqqara which were 'of extraordinary strength weight, obtained apparently by reinforcing the mud w small strips of flax linen and drying it when under g pressure'. One product was a lintel measuring, in its bro state, 63 × 18 × 10 cm.

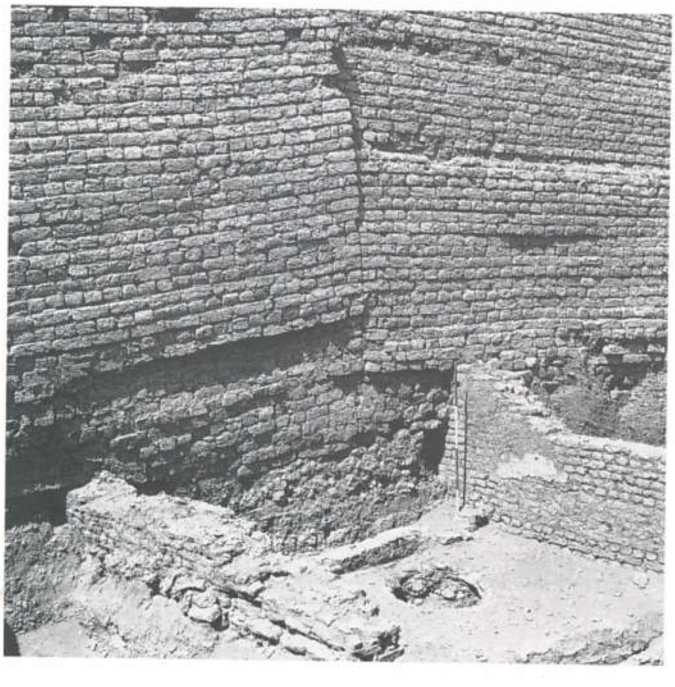


Figure 3.15 A section of the Late Period pan-bedded enclosure wall at the Kom el-Sultan, Abydos, built over house walls of the Old Kingdom.

The total evidence for architectural detailing in mu not great, but, in view of its vulnerability to decay and of fact that ancient buildings frequently survive only as fo dations, this is not really surprising. The evidence certai points to an awareness by builders of the potential of architecture for producing both decorative and utilitar shapes, but whether they employed it to bring into ex ence a class of vernacular architecture, primarily domes is impossible to tell in the present state of knowledge. Si the forms of brick buildings would have contributed sign cantly to how ancient Egypt really looked, this is an impo ant field of research.

Acknowledgements

Dr Katherine Spence kindly read a draft-version of th chapter and made many valuable suggestions which I ha incorporated into the final text.

References

Abu-Bakr, Abdel-Moneim 1953. *Excavations at Giza 1949–19* Cairo: Government Press.

Arnold, D. 1979. *The Temple of Mentuhotep at Deir el-Bahari.* T Metropolitan Museum of Art Egyptian Expedition. Ne York: MMA.

1987. *Der Pyramidenbezirk des Königs Amenemhet III. in Da schur.* Band I. Die Pyramide. Deutsches Archäologisches I stitut, Abteilung Kairo, Archäologische Veröffentlichung 53. Mainz am Rhein: von Zabern.

1988. *The Pyramid of Senwosret I.* The South Cemeteries of Lis I. New York: MMA.

1991. *Building in Egypt; Pharaonic Stone Masonry.* New York an Oxford: OUP.

Ayrton, E.R., Currelly, C.T. and Weigall, A.E.P. 1904. *Abydos Pa III.* 1904. London: EEF.

Badawi, F.A. 1978. Die Grabung der ägyptischen Altertümerve waltung in Merimda-Benisalâme im Oktober/Novemb 1976. *MDAIK* 34: 43–51.

Badawy, A. 1957. Philological evidence about methods of co struction in ancient Egypt. ASAE 54: 51–74.

Barguet, P. 1962. *Le Temple d'Amon-rê à Karnak: essai d'exégès* Recherches d'Archéologie, de Philologie et d'Histoire 2 Cairo, IFAO.

Baumgartel, E.J. 1960. *The Cultures of Prehistoric Egypt* II. Oxford: Griffith Institute.

1970. *Petrie's Naqada Excavation: A Supplement*. London: Quaritch.

Borchardt, L., Königsberger, O. and Ricke, H. 1934. Friesziegel in Grabbauten. *ZÄS*, 70: 25–35.

Borkowski, J. and Majcherek, G. 1991. Mastaba of Neferma'at and Itet. Report of the Polish–Egyptian restoration mission, 1986–1988. In *Meidum* (eds. A. el-Khouli and G.T. Martin). The Australian Centre for Egyptology, Reports 3. Sydney: The Australian Centre for Egyptology, pp. 22–42.

Breasted, J.H. 1948. *Egyptian Servant Statues*. The Bollingen Series, XIII. Washington: Pantheon.

Brown, P.W. and Clifton, J.R. 1978. Adobe I: the properties of adobe. *Studies in Conservation*, 23: 139–46.

Brunton, G. and Caton-Thompson, G. 1928. *The Badarian Civilisation and Predynastic Remains Near Badari*. London: BSAE and Quaritch.

Bruyére, B. 1926. *Rapport sur les fouilles de Deir el Médineh (1924–1925)*. Cairo: IFAO.

Caminos, R.A. 1954. *Late-Egyptian Miscellanies*. London: OUP.

Černý, J. 1976. *Coptic Etymological Dictionary*. Cambridge: CUP.

Chevrier, H. 1964. Technique de la construction dans l'ancienne Egypte. I.– Murs en briques crues. *RdE* 16: 11–17.

1970. Technique de la construction dans l'ancienne Egypte. II. – Problèmes posés par les obélisques. *RdE*, 22: 15–39.

Christophe, L.A. 1951. *Karnak-Nord III (1945–1949)*. Fouilles conduites par C. Robichon. Fouilles de l'Institut français d'Archéologie orientale du Caire 23. Cairo: IFAO.

Clarke, S. and Engelbach, R. 1930. *Ancient Egyptian Masonry: The Building Craft*. London: OUP.

David, A.R. 1986. *The Pyramid Builders of Ancient Egypt: A Modern Investigation of Pharaoh's Workforce*. London, Boston and Henley: Routledge and Kegan Paul.

Davies, N. 1929. The town house in ancient Egypt. *Metropolitan Museum Studies*, 1: 233–55.

Davies, N. de G. 1935. *Paintings from the Tomb of Rekh-mi-re' at Thebes*. New York: MMA.

1943. *The Tomb of Rekh-mi-re' at Thebes*. New York: MMA.

Debono, F. and Mortensen, B. 1990. *El Omari. A Neolithic Settlement and Other Sites in the Vicinity of Wadi Hof, Helwan*. Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 82. Mainz am Rhein: von Zabern.

Deleuze, P. 1981. Note sur une particularité de construction. *BIFAO*, 81, 214.

Dreyer, G., Engel, E.-M., Hartung, U., Hikade, T., Köhler, E.C. and Pumpenmeier, F. 1996. Umm el-Qaab. Nachuntersuchungen im frühzeitlichen Königsfriedhof 7./8. Vorbericht. *MDAIK*, 52: 11–76.

El-Achirie, H. and Fonquernie, B. 1976. Reconnaissance des différentes campagnes de construction pour les annexes nord-ouest (I''') étude detaillée de la salle à colonnes (I''' a–b). In *Le Ramesseum*, X. Collection scientifique, no. 35. Cairo: Centre d'Etudes et de Documentation sur l'Ancienne Egypte, pp. 1–27.

Emery, W.B. 1938. *Excavations at Saqqara: The Tomb of Hemaka*. Cairo: Government Press.

1949. *Excavations at Saqqara: Great Tombs of the First Dynasty*, I. Cairo: Government Press.

1954. *Excavations at Saqqara: Great Tombs of the First Dynasty*, II. London: EES.

1958. *Excavations at Saqqara: Great Tombs of the First Dynasty*, III. London: EES.

1961. *Archaic Egypt*. Harmondsworth: Penguin.

1968. Tomb 3070 at Saqqâra. *JEA*, 54: 11–13.

Emery, W.B. and Kirwan, L.P. 1935. *The Excavations and Survey between Wadi es-Sebua and Adindan 1929–1931*. Cairo: Government Press.

Emery, W.B., Smith, H.S. and Millard, A. 1979. *The Fortress of Buhen: The Archaeological Report*. 49th excavation memoir. London: EES.

Endruweit, A. 1994. *Städtischer Wohnbau in Ägypten: Klimagerechte ehmarchitektur in Amarna*. Berlin: Gebr. Mann.

Engelbach, R. 1931. Recent acquisitions in the Cairo Museum. *ASAE* 31: 126–31.

Fathy, H. 1969. *Gourna, a Tale of Two Villages*. Cairo: Ministry of Culture.

Fisher, C.S. 1924. *The Minor Cemetery At Giza*. The Eckley B. Coxe Jr. Foundation, new series, I. Philadelphia: University Museum.

Fougerousse, J.L. 1933. L'édifice en briques crues. In Montet, P. *Les nouvelles fouilles de Tanis (1929–1932)*. Paris: Les Belles Lettres, pp. 76–88.

Frankfort, H. 1933. *The Cenotaph of Seti I at Abydos*. 39th Excavation Memoir. London: EES.

(ed.) 1929. *The Mural Paintings of El 'Amarneh*. London: EES.

Frankfort, H. and Pendlebury, J.D.S. 1933. *The City of Akhenaten* II. London: EES.

French, C.A.I. 1981. An analysis of the sediment at East Karnak. *JSSEA*, 11: 263–78.

1984. A sediments analysis of mud brick and natural features at El-Amarna. In *Amarna Reports* I (ed. B.J. Kemp). London: EES, pp. 189–201.

Garstang, J. 1907. *The Burial Customs of Ancient Egypt, as Illustrated by Tombs of the Middle Kingdom*. London: Constable.

Geller, J. 1992. From prehistory to history: beer in Egypt. In *The Followers of Horus; Studies Dedicated to Michael Allen Hoffman 1944–1990*. (ed. R. Friedman and B. Adams). Oxbow Monograph 20. Oxford: Oxbow Books, pp. 19–26.

Ghazouli, E.B. 1964. The palace and magazines attached to the temple of Sety I at Abydos and the facade of this temple. *ASAE*, 58: 99–186.

Goldberg, P. 1979. Geology of Late Bronze Age mudbrick from Tel Lachish. *Tel Aviv*, 6: 60–7.

Golvin, J.-C. and Hegazy, El-S. 1993. Essai d'explication de la forme et des caractéristiques générales des grandes enceintes de Karnak. *Cahiers de Karnak, IX 1993*. Paris: Editions Recherche sur les Civilisations, pp. 145–60.

Griffith, F. Ll. 1898. *Hieratic Papyri From Kahun and Gurob (Principally of the Middle Kingdom)*. London: Quaritch.

Hassan, F.A. and Matson, R.G. 1989. Seriation of predynastic potsherds from the Naqada region (Upper Egypt). In *Late Prehistory of The Nile Basin and The Sahara* (eds. L. Krzyżaniak and M. Kobusiewicz). *Studies in African Archaeology*, 2. Poznań: Muzeum Archeologiczne w Poznaniu, pp. 303–15.

Hayes, W.C. 1965. *Most Ancient Egypt*. Chicago and London: University of Chicago Press; and Toronto: University of Toronto Press.

Hecker, H.M. 1986. Report on the excavation of floor [873] of the outer hall of Chapel 561/450. In *Amarna Reports* III (ed. B.J. Kemp). London: EES, pp. 80–9.

Hesse, A. 1970. Essai techno-chronologique sur la dimension des briques de construction. In *Mirgissa* I (ed. J. Vercoutter). Mission Archéologique au Soudan sous la direction de Jean Vercoutter, I. Paris: CNRS, pp. 102–14.

1971. The measurement of ancient bricks and its archaeological interest. In *Mathematics in the Archaeological and Historical Sciences* (ed. F.R. Hodson, D.G. Kendall and P. Tăutu). Edinburgh: University Press, pp. 432–5.

Hoffman, M.A. 1980. A rectangular Amratian house from Hierakonpolis and its significance for predynastic research. *JNES*, 39: 119–37.

Holladay, J.S. 1982. *Cities of the Delta, III: Tell El-Maskhuta*. ARCE. Malibu: Undena Publications.

Holmes, D.L. 1992. Chipped stone-working craftsmen, Hierakonpolis and the rise of civilization in Egypt. In *The Followers of Horus; Studies Dedicated to Michael Allen Hoffman 1944–1990*. (eds. R. Friedman and B. Adams). Oxbow Monograph 20. Oxford: Oxbow Books, pp. 37–44.

Holmes, D.L. and Friedman, R.F. 1994. Survey and test excavations in the Badari region, Egypt. *Proceedings of the Prehistoric Society* 60: 105–42.

Hölscher, U. 1910. *Das hohe Tor von Medinet Habu; eine Baugeschichtliche Untersuchung*. 12. Wissenschaftliche Veröffentlichung der Deutschen Orient-Gesellschaft. Leipzig: Hinrichs.

1939. *The Temples of The Eighteenth Dynasty*. Oriental Institute Publications 41. Chicago: University of Chicago Press.

1941. *The Mortuary Temple of Ramses III*, part I. Oriental Institute Publications 54. Chicago: University of Chicago Press.

1951. *The Mortuary Temple of Ramses III*, part II. Oriental Institute Publications 55. Chicago: University of Chicago Press.

Hughes, G.R. 1963. Serra East: The University of Chicago excavations, 1961–62: a preliminary report on the first season's work. *Kush*, 11: 121–30.

Hughes, R.E. 1988. The geotechnical study of soils used as structural materials in historic monuments. In *The Engineering Geology of Ancient Works, Monuments and Historical Sites; Preservation and Protection* (eds. P.G. Marinos and G.C. Koukis). Rotterdam and Brookfield: Balkema, pp. 1041–8.

Husselman, E.M. 1979. *Karanis Excavations of The University of Michigan In Egypt 1928–1935. Topography and Architecture.* Kelsey Museum of Archaeology, Studies 5. Ann Arbor: University of Michigan Press.

Jánosi, P. 1996. Die Fundamentplattform eines Palastes (?) der späten Hyksoszeit in 'Ezbet Helmi (Tell el-Dabʿa). In *Haus und Palast im Alten Ägypten/House and palace in ancient Egypt* (ed. M. Bietak). Untersuchungen der Zweigstelle Kairo des Österreichischen Archäologischen Institutes, 14. Vienna: Österreichische Akademie der Wissenschaften, pp. 93–8.

Junker, H. 1930. Vorläufiger Bericht über die zweite Grabung der Akademie auf der vorgeschichtlichen Siedlung Merimde-Benisalâme vom 7. Februar bis 8. April 1930. *Anzeiger der Akademie der Wissenschaften in Wien, Philosophische-historiche Klasse* 1930, Nr. V–XIII, 21–83.

1932. Vorbericht über die von der Akademie in Wien in Verbindung mit dem Egyptiska Museet in Stockholm unternommenen Grabungen auf der neolithischen Siedlung von Merimde-Benisalâme vom 6. November 1931 bis 20. Januar 1932. *Anzeiger der Akademie der Wissenschaften in Wien, Philosophische-historiche Klasse* 1932, Nr. I–IV, 36–100.

1941. *Gîza V. Die Mastaba des Snb (Seneb) und die umliegenden Gräber.* Akademie der Wissenschaften in Wien, Philosophisch-historische Klasse, Denkschriften, 71. Band, 2. Abhandlung. Vienna and Leipzig: Hölder-Pichler-Tempsky.

Kemp, B.J. 1972. Fortified towns in Nubia. In *Man, Settlement and Urbanism* (eds. P.J. Ucko, R. Tringham and D.W. Dimbleby). London: Duckworth, pp. 651–6.

1977. The palace of Apries at Memphis. *MDAIK*, 33: 101–8.

1995. Site formation processes and the reconstruction of house P46.33. In *Amarna Reports* VI (ed. B.J. Kemp). London: EES, pp. 146–68.

(ed.) 1985. *Amarna Reports* II. London: EES.

Kitchen, K.A. 1966. *Ancient Orient and Old Testament.* London: The Tyndale Press.

Klebs, L. 1922. *Die Reliefs und Malereien des mittleren Reiches (VII.-XVII. Dynastie ca 2475–1580 v. Chr.).* Abh. der Heidelberger Akad. der Wissenschaften. Phil.-hist. Klasse 6. Abh.

Knudstad, J. 1966. Serra East and Dorginarti. *Kush*, 14: 165–86.

Kuhlmann, K.P. 1996. Serif-style architecture and the design of the archaic Egyptian palace ('Königszelt'). In *Haus und Palast im Alten Ägypten* (ed. M. Bietak). Untersuchungen der Zweigstelle Kairo des Österreichischen Archäologischen Institutes, 14. Vienna: Verlag der Österreichischen Akademie der Wissenschaften, pp. 117–37.

Lacovara, P. 1984. Archaeology and the decay of mudbrick structures in Egypt I: wattle and daub. *NARCE*, 128: 20–21.

1990. *Deir El-Ballas. Preliminary Report on the Deir el-Ballas Expedition 1980–1986.* ARCE Reports 12. Winona Lake: Eisenbraums.

Larsen, H. 1950. True vaults and domes in Egyptian architecture of the Early Kingdom. *Acta Archaeologica*, 21: 211–34.

Lhote, A. 1954. *Les chefs-d'oeuvre de la peinture égyptienne.* Paris: Hachettte.

McHenry, P.G. 1976. *Adobe; Build It Yourself.* Tucson: University of Arizona Press.

1984. *Adobe and Rammed Earth Buildings; Design and Construction.* New York: John Wiley and Sons.

Mallinson, M. 1995. Excavation and survey in the Central City, 1988–92. In *Amarna Reports* VI (ed. B.J. Kemp). London: EES, pp. 169–215.

Martin, G.T. 1989. *The Memphite Tomb of Horemheb Commander-in-Chief of Tut'ankhamun.* Vol. I. The reliefs, inscriptions, and commentary. 55th Excavation Memoir. London: EES.

Matthews, W. and Postgate, J.N. 1994. The imprint of living in an early Mesopotamian city: questions and answers. In *Whither Environmental Archaeology?* (eds. R. Luff and P. Rowley-Conwy). Oxbow Monograph 38. Oxford: Oxbow Books, pp. 171–212.

Mekhitarian, A. 1954. *Egyptian Painting.* The Great Centuries of Painting. Geneva, Paris, New York: Skira.

Mileham, G.S. 1910. *Churches in Lower Nubia.* Eckley B. Coxe Junior Expedition to Nubia: II. Philadelphia, University Museum.

Minault-Gout, A. and Deleuze, P. 1992. *Balat II. Le mastaba d'Ima-Pépi. Tombeau d'un Gouverneur de l'Oasis à la fin de l'Ancien Empire.* Fouilles de l'Institut français d'Archéologie orientale 33. Cairo: IFAO.

Mond, R. and Myers, O.H. 1934. *The Bucheum.* 41st memoir. London: EES.

1937. *Cemeteries of Armant* I. London: EES.

de Morgan, J. 1895. *Fouilles à Dahchour, mars–juin 1894*. Vienna: Holzhausen.

Newberry, P.E. [1895]. *El Bersheh*, part I (The Tomb of Tehuti-hetep). London: EEF.

Nicholson, P.T. 1989. Report on the 1987 excavations. The pottery kilns in Building Q48.4. In *Amarna Reports* V (ed. B.J. Kemp). London: EES, pp. 64–81.

Nims, C.F. 1950. Bricks without straw. *The Biblical Archaeologist* 13: 22–8.

Peet, T.E. 1914. *The Cemeteries of Abydos, part II. 1911–1912*. London: EEF.

Peet, T.E. and Loat, W.S. 1913. *The Cemeteries of Abydos, III: 1912–1913*. London: EEF.

Peet, T.E. and Woolley, C.L. 1923. *The City of Akhenaten* I. London: EES.

Pendlebury, J.D.S. 1951. *The City of Akhenaten* III. London: EES.

Petrie, W.M.F. 1888. *Nebesheh (Am) and Defenneh (Tahpanhes)*, published with Tanis, part II, 1886. London: EEF and Trübner.

1890. *Kahun, Gurob and Hawara*. London: Kegan Paul, Trench and Trübner.

1891. *Illahun, Kahun and Gurob 1889–90*. London: Nutt.

1892. *Meydum*. London: Nutt.

1903. *Abydos*, part II. London: EEF.

1906. *Hyksos and Israelite Cities*. London, BSAE and Quaritch.

1912. *The Labyrinth Gerzeh and Mazguneh*. London: British School of Archaeology and Quaritch.

1917. *Tools and Weapons*. London: BSAE.

1930a. *Beth-Pelet I (Tell Fara)*. London: BSAE and Quaritch.

1930b. *Antaeopolis; The Tombs of Qau*. London: BSAE and Quaritch.

1938. *Egyptian Architecture*. London: BSAE and Quaritch.

Petrie, W.M.F. and Quibell, J.E. 1896. *Naqada and Ballas 1895*. London: Quaritch.

Petrie, W.M.F., Wainwright, G.A. and Mackay, E. 1912. *The Labyrinth Gerzeh and Mazghuneh*. London: BSAE and Quaritch.

Quibell, J.E. 1907. *Excavations at Saqqara (1905–1906)*. Cairo, IFAO.

Randall-Maciver, D. and Mace, A.C. 1902. *El Amrah and Abydos. 1899–1901*. London: EEF.

Reisner, G.A. 1923. *Excavations at Kerma*, parts IV–V. Harvard African Studies 6. Cambridge, Mass: Peabody Museum.

1931. *Mycerinus: the Temples of the Third Pyramid at Giza*. Cambridge MA: Harvard University Press.

Reisner, G.A., Wheeler, N.F., and Dunham, D. 1967. *Uronarti Shalfak Mirgissa*. Second Cataract Forts, vol. II. Boston: MFA.

Ricke, H. 1939. *Der Totentempel Thutmoses' III. Baugeschichtliche Untersuchung*. Beiträge zur Ägyptischen Bauforschung und Altertumskunde, Heft 3 (1). Cairo: Schweizerisches Institut für Ägyptische Bauforschung und Altertumskunde in Kairo.

Rizkana, I. 1996. The prehistoric house. In *Haus und Palast im Alten Ägypten* (ed. M. Bietak). Untersuchungen der Zweigstelle Kairo des Österreichischen Archäologischen Institutes, 14. Vienna: Verlag der Österreichischen Akademie der Wissenschaften, pp. 175–83.

Rizkana, I. and Seeher, J. 1989. *Maadi III. The Non-Lithic Small Finds and The Structural Remains of The Predynastic Settlement*. Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 80. Mainz am Rhein: von Zabern.

Robichon, C. and Varille, A. 1936. *Le temple du scribe royal Amenhotep fils de Hapou I*. Fouilles de l'Institut français du Caire 11. Cairo: IFAO.

1939. Médamoud. Fouilles du Musée du Louvre, 1938. *Cd'E* 14, no 27: 83–7.

Schumann Antelme, R. 1976. Description archéologique. In *Le Ramesseum*, X. Collection scientifique, no. 35. Cairo: Centre d'Etudes et de Documentation sur l'Ancienne Egypte, pp. 52–223.

Simpson, W.K. 1960. The nature of the brick-work calculations in *Kah. Pap*. XXIII, 24–40. *JEA*, 46: 106–7.

1963. *Papyrus Reisner I. The Records of A Building Project In The Reign of Sesostris I*. Boston: Museum of Fine Arts.

Spence, K. 1996. Review of A. Endruweit, Städtischer Wohnbau in Ägypten. *JESHO*, 39: 50–2.

Spencer, A.J. 1979a. *Brick Architecture in Ancient Egypt*. Warminster: Aris and Phillips.

1979b. The brick foundations of Late-Period peripteral temples and their mythological origin. In *Orbis Aegyptiorum Speculum: Glimpses of Ancient Egypt; Studies in Honour of H.W. Fairman* (eds. J. Ruffle, G.A. Gaballa, and K.A. Kitchen). Warminster: Aris and Phillips, pp. 132–7.

Thomas, E. 1964. The four niches and amuletic figures in the Theban royal tombs. *JARCE*, 3: 71–8.

Thorel, G. 1976. Les salles voutées du groupe I'. In *Le Ramesseum*, X. Collection scientifique, no. 35. Cairo: Centre d'Etudes et de Documentation sur l'Ancienne Egypte, pp. 28–51.

Traunecker, C. 1975. Une stèle commémorant la construction de l'enceinte d'un temple de Montou. *Karnak V. 1970–1972*. Centre franco–égyptien d'étude des temples de Karnak. Cairo: CNRS and IFAO, pp. 141–58.

Tytus, R. de P. 1903. *A Preliminary Report on the Re-excavation of the Palace of Amenhetep III*. NewYork: Winthrop Press.

Van Beek, G.W. 1987. Arches and vaults in the ancient Near East. *Scientific American*, 257, no. 1: 78–85.

Vercoutter J. 1970. *Mirgissa* I. Mission Archéologique Francaise au Soudan, 1. Paris: CNRS.

Vycichl, W. 1983. *Dictionnaire étymologique de la langue copte*. Leuven: Peeters.

Watanabe, Y. 1986. *The Architecture of 'Kom El Samak' At Malkata-South; A Study of Architectural Restoration*. Studies in Egyptian Culture, no. 5. Tokyo: Waseda University.

von der Way, T. 1992. Indications of architecture with niches at Buto. In *The Followers of Horus; Studies Dedicated to Michael Allen Hoffman 1944–1990*. (eds. R. Friedman, and B. Adams). Oxbow Monographs 20. Oxford: Oxbow Books, pp. 217–26.

1993. *Untersuchungen zur Spätvor- und Frühgeschichte Unterägyptens*. Studien zur Archäologie und Geschichte Altägyptens, 8. Heidelberg: Heidelberger Orientverlag.

Weeks, K.R. 1971–2. Preliminary report on the first two seasons at Hierakonpolis. Part II. The Early Dynastic Palace. *JARCE*, 9: 29–33.

Weinstein, J.M. 1973. *Foundation Deposits In Ancient Egypt*. Ann Arbor, Michigan: University Microfilms, no. 73–24, 237.

Wiesmann, H. 1914. Adobe. *ZÄS*, 52: 130.

Ziermann, M. 1993. *Elephantine XVI. Befestigungsanlagen und Stadtentwicklung in der Frühzeit und im frühen Alten Reich*. Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 87. Mainz am Rhein: von Zabern.

4.

Painting materials

LORNA LEE AND STEPHEN QUIRKE

Introduction

The present colour of an object may be due to intrinsic coloration or to colours applied as paints or dyes, the appearance of which may have altered since application due to degradation. Colour is to be distinguished from pigment, the organic or inorganic colouring substance. A paint on the other hand is defined as a mixture of a pigment and a binding medium, and may be applied directly to the object or onto a painting ground. At present, few analyses of ancient Egyptian binding media have been undertaken, a problem which reflects difficulties of analysis and limited availability of well-provenanced samples. Results of organic analysis can be difficult to interpret because organic materials in a paint sample may be due not only to the binding medium, but also to original coatings such as a varnish applied over paint layers, as well as to more modern additions (binding media are discussed separately with other adhesives in Chapter 19, this volume).

Once sufficient analyses of binding media have become available, it will be necessary to reunite the analyses of both pigment and medium with consideration of the painting ground, which may be expected to affect pigment selection and texture. This chapter primarily addresses the problem of identifying pigments and, to a lesser extent, their provenance, before presenting the more recent findings on methods used in ancient Egypt for preparing ground, and above all the preparation of painted plaster surfaces in the Theban tomb-chapels of the Eighteenth Dynasty.

Egyptian pigments before the Roman period are in most instances inorganic substances, explaining the extraordinarily good preservation of colour on many Egyptian antiquities and monuments. The chemistry of inorganic materials has offered fewer problems for analysts than the identification of organic components of ancient samples, but the researcher needs to be aware of certain complications affecting all methods of scientific research. The ideal sample comes from an undisturbed stratum of a securely dated and provenanced object; the historian is required to help select for analysis the most suitable items, and to identify any problems associated with their archaeological context. Ideally samples should be taken by the analyst, rather than supplied; at the least the analyst should be familiar with the particular sampling method, as well as with conditions of retrieval in the case of field sampling, and of storage in the case of museum sampling. Previous methods of treatment and storage can present a major obstacle to clean sampling, as adequate recording of treatment began only relatively recently; this creates a modern prehistory of the monument or object which is unknown to the analyst before beginning work, but which may affect, and possibly seriously distort results. Selection of a sample thus depends both on a historical sensibility to the relative importance of different items, in the endeavour to cover an informative geographical, historical or socio-economic range, and on appreciation of conditions in the field or at the place of storage. The exact original location of the sample within the painted surface must be recorded, because this is crucial for later interpretation of results; for example, unexpected components may in some cases be explained by the direct intrusion of adjacent pigments, or contamination from the degradation patterns of those pigments, or indeed later restorations. The condition of the sample remains an important consideration throughout laboratory testing, and, in the case of non-destructive testing, in storage after analysis.

If the analyst is insufficiently sensitive to the historical context and questions concerning a sample, or the historian is insufficiently informed on the methods and potential of analysis, they remain unable as a team to extract secure data from their sample. Moreover, both must be aware that their analysis is of the *modern* condition of the object; pigments may degrade over time, producing new colours and losing their original identity, and this possibility must be taken into account. Therefore the scientific monitoring of the presently visible colour ought to follow analysis of the pigment and medium, if any indication of the ancient colour value is to be obtained. Distinction of hues is generally less problematic for polychromatic colouring traditions, as in Dynastic Egyptian art, than for colouristic traditions as in Renaissance and later Western European art.

Nevertheless, linguistic demarcations of the colour spectrum inevitably reflect cultural and individual selection, often subjective and rarely self-conscious; this creates a need for some objective scheme of colour measurement. For instrumental measurement of present colour of ancient Egyptian painted surfaces, see Strudwick (1991); where instrumentation is not available, it is useful to refer to visual aids such as the Munsell code to define fields of colour.

An additional problem for comparison and collation of results by different teams is material nomenclature. In view of the variations in terminology, Table 4.1 lists the chemical formulae of materials as named by us in this article. Without the chemical formula, it is not possible to guarantee the identity of one analysed sample with another; the list is a summary, and does not give details of the possible variations under the names, particularly in the cases of red ochre (containing haematite) and Egyptian blue. It should be remembered that one chemical formula may apply to more than one pigment, and that definitions in chemical terms provide only the first step toward identifying a material by its provenance and manufacture.

The most extensive single project of analysis for ancient Egyptian pigments to date has been that conducted between 1980 and 1991 by the Max-Planck Institut für Kernphysik in Heidelberg, with the Egyptological assistance of the Institute of Egyptology at Heidelberg University (1980–2), the Institute of Ancient History at Konstanz University (1982–4), and the Pelizaeus-Museum, Hildesheim (1989–91; see Blom-Böer 1994). This project involved analysis of 1,380 pigment samples from painting on stone surfaces (tomb-chapels, sarcophagi, temples) and wall-paintings (tomb-chapels, burial chambers), ranging from the Fifth Dynasty to the early Roman period but predominantly of the late Old, early Middle and New Kingdoms, with the weight of the evidence from Thebes. The samples were analysed in reflective light, with scanning electron microscopy (SEM), and electron microprobe techniques (EMPA).

Table 4.1. *List of chemical formulae of compounds cited in the text (in alphabetic order)*

anhydrite	$CaSO_4$
atacamite	$Cu_2Cl(OH)_3$
azurite	$Cu_3(CO_3)_2(OH)_2$
calcite	$CaCO_3$
cassiterite	SnO_2
chrysocolla	$CuSiO_3.2H_2O$
cobalt blue	$CoO.Al_2O_3$
copper wollastonite	$(Ca,Cu)_3(Si_3O_9)$
cuprorivaite	$(Ca,Cu)Si_4O_{10}$
dolomite	$Ca,Mg(CO_3)_2$
Egyptian blue	mainly cuprorivaite $CaCu(Si_4O_{10})$with copper wollastonite $(Ca,Cu)_3(Si_3O_9)$, silica SiO_2 and glass
goethite	the alpha form of FeOOH
gypsum	$CaSO_4.2H_2O$
haematite	Fe_2O_3
huntite	$Mg_3Ca(CO_3)_4$
iron ochre	natural earth pigment consisting of silica (in an Egyptian context this will be quartz) and clay, coloured with iron oxide (see red ochre and yellow ochre)
jarosite	$KFe(SO_4)_2(OH)_6$
kaolinite	$Al_2Si_2O_5(OH)_4$
limonite	general field term for poorly characterised hydrated iron oxides
malachite	$Cu_2(CO_3)(OH)_2$
natron	sodium sesquicarbonate: $Na_2CO_3.NaHCO_3.2H_2O$
orpiment	As_2S_3
pararealgar	the gamma form of AsS
paratacamite	$Cu_2(OH)_3Cl$
pyrite	FeS
pyrolusite	MnO_2
realgar	the low temperature form of AsS
red ochre	type of iron ochre coloured by anhydrous iron oxide (haematite: Fe_2O_3)
silica	SiO_2
titanomagnetite	$Fe_3O_4.Fe_2TiO_4$
vermilion	HgS
yellow ochre	type of iron ochre coloured by various hydrated forms of iron oxide, mainly goethite (FeOOH)

The British Museum project of pigment analysis

Introduction

As part of a conservation project for the treatment of painted papyri, particularly for consolidation prior to facing for removal of acidic backing-paper, samples of nine colours from eight manuscripts dating from the New Kingdom to the Roman period have been analysed since 1991 by the authors. From the collections of the Department of Egyptian Antiquities in the British Museum, six historical phases were identified in the history of colour illustration on papyrus:

1. mid-Eighteenth Dynasty;
2. Nineteenth Dynasty;
3. Twentieth Dynasty;
4. Twenty-first to early Twenty-second Dynasties;
5. Twenty-sixth Dynasty to early Ptolemaic;
6. late Ptolemaic to early Roman.

(These phases may require modification when extended to other collections, e.g. fusion of (3) and (4), division of (5) into earlier and later phases).

Representatives of colour range in each historical phase were selected for sampling and the pigments analysed using x-ray fluorescence (XRF), x-ray diffraction (XRD), and examination under polarised light microscope (PLM) of particles mounted in *Meltmount*. Where further elemental analysis was required, samples were mounted on a carbon block and examined by scanning electron microscope with energy dispersive x-ray analysis (SEM).

Methods of analysis used in the British Museum project

Sampling

In the British Museum conservation project, the sample was limited where possible to the minimal amount (~25 µg); where a lake pigment (an organic dye on an inorganic substrate) was thought to be present, a larger sample (~0.5 mg) was taken in order to allow separation of the organic dye from the inorganic substrate. If the nature of the artefact allowed, two small samples of each colour were taken, the first on a gelatin strip, and the second a powder sample of a few particles only, directly into a small gelatin capsule. Position of the sample on the original object was recorded on a photograph or xerox.

The limitations of small sample size should be borne in mind; if the sample is taken from a less homogeneous pigment, the results may be misleading. It should also be noted that a series of layers may be present, as has been detected with the ochre and orpiment layering of yellow on Theban temples, and sampling should be sensitive to layering as well as ground preparation. In the case of the papyri, there is no ground to be analysed; ground has generally been analysed less often, except in studies of Theban tomb-chapels.

X-ray fluorescence spectroscopy (XRF)

XRF is a non-destructive method of analysis, and is used for identification of the predominant elements in a pigment sample (Goffer 1980); it can be applied directly to pigment mounted on a gelatin strip. Elements within the sample absorb the incident x-rays and re-emit x-rays, the energies of which are characteristic of the elements. XRF analysis gives a spectrum consisting of a series of peaks; the energy at which peaks occur indicate the elements present and the area of the peaks relates to their apparent abundance in the sample.

The limitations of XRF are as follows: elements lighter than magnesium (relative atomic mass = 24), such as sodium, cannot be detected without a vacuum attachment. Other elements, including aluminium, silicon, phosphorus, sulphur and chlorine will only be detected if present in substantial amounts. Nevertheless XRF has the advantage of offering a rapid means of preliminary investigation of a pigment sample.

X-ray powder diffraction (XRD)

This is a means of examining the crystal structures present in the pigment sample (Goffer 1980). As with XRF, XRD is undertaken directly and non-destructively using the sampl on the gelatin strip. XRD with a Debye Scherrer camer produces a film containing a series of lines, the position and relative intensities of which are characteristic of th crystalline material or materials present in the sample. Th XRD pattern of the unknown substance can then be compared with lines produced by known materials.

The limitations of XRD are as follows: a large library o XRD data is available for comparison with unknowns, bu this library (ICDD) consists primarily of patterns collecte from pure substances. Ancient pigment samples are often mixture of components and may include dirt and dus obscuring the identification process. Pigments applied to gesso or ground layer cannot always be sampled withou inclusion of substrate components, and the latter may the interfere with analysis. If the pigment is microcrystalline o non-crystalline, it will not produce a distinct XRD pattern ill-defined patterns may also result from pigments whic have degraded since application. In certain cases, differen compounds produce similar XRD patterns, e.g. the coppe chlorides atacamite and paratacamite.

Polarised light microscopy (PLM)

The sample of powder particles collected from the pigmen in the gelatin capsule is examined under a microscope; i only a limited sample is available, it is possible to use th material collected on the gelatin strip, but this may b difficult to remove. The sample is mounted on a glass microscope slide using *Meltmount*, a material of know refractive index (1.66), and is then examined in transmitte light using a polarised light microscope, at up to 40× (objective) magnification. This method allows the researchers to determine the number of components presen in a pigment. Several features of each component particl can be assessed; the colour, refractive index (taking int account that of the mounting medium), shape and size o the particles become clear in plane polarised light, and this information can be corroborated and expanded by subsequent observation between crossed polars. Identifications are made by comparison with mounted reference pigments and in conjunction with the results from the previousl described instrumental techniques. The limitations of PLM are as follows: certain pigments, such as haematite and vermilion, have similar characteristics, and this could confuse identification if PLM were to be used in isolation without confirmation from other methods of analysis. Unusual materials may lie beyond the reach of the available reference sources. Some pale colours may appear almost colourless when dispersed onto a microscope slide and viewed at high magnification, as occurs for example with small particles of Egyptian blue. Therefore it is useful to view such samples in reflected light before examination with transmitted light; PLM reveals limited information in the case of opaque particles, although the size and shape of the opaque particles and the characteristics of any associated materials can be very informative. Very finely ground pigments can also present problems due to the minute size of the particles. Insufficient data may be gained from some pigments, particularly Egyptian copper pigments. The latter often contain a number of phases within one particle, and the characteristics of the particle will therefore be a combination of those of each phase; this can result in confusing information, as discussed below for Egyptian blue.

Results of the analyses

The results of the analyses of pigments on papyrus combine with those from earlier identifications during the conservation of coffins, tomb-chapel wall-paintings, linen and other objects in the British Museum collections.

Together, the conservation analyses from the British Museum form a substantial database for comparison with the results of the Heidelberg project, as well as those given by Lucas (1962) from earlier studies, and extend the range of study into areas and periods which have received less attention, notably the organic surfaces painted in the First millennium BC. It should be remembered that the range of painting grounds and colours available for analysis varies from one period to another, with the broadest range in the New Kingdom and Ptolemaic to Roman periods. This is particularly important in considering the historical implications of analyses for the New Kingdom and Third Intermediate Period; in these periods, without analyses of pigments from organic surfaces, the analyses of pigments from stone surfaces alone might give the impression that the palette changed at the end of the New Kingdom simply because so few Third Intermediate Period coloured stone surfaces are available for sampling. Similarly, the earliest attested appearances of the less widespread mineral pigments huntite (white), realgar (orange-red) and orpiment (yellow) were from the early New Kingdom in the earlier analyses, predominantly from painted plaster and stone surfaces, but the British Museum analysis of organic surfaces such as wooden coffins has now extended the attested date-range for huntite and orpiment back to the late Middle Kingdom, a period for which few painted stone and plaster objects are available for sampling. Most recently huntite has been reported from late Old Kingdom painted figures (Heywood forthcoming) and more research is clearly needed in this area.

In the context of the present book, material of the Ptolemaic and Roman periods has generally been excluded except when it has been necessary to draw a contrast with usage attested in the various phases of the Dynastic Period. However, it should be noted that the latest Dynastic evidence cited may extend into the Ptolemaic Period owing to the homogeneity of funerary workshop products in the fourth to third centuries BC (Late Period to early Ptolemaic Period); further research is needed to establish secure criteria for distinguishing material from before and after the arrival of Alexander the Great in Egypt in 332 BC.

Pigments of the Predynastic and Early Dynastic periods

Pyrolusite, a natural black ore of manganese obtainable from Sinai, was found at the Lower Egyptian Predynastic site of Maadi (Lucas 1962: 340), and might have been used as a pigment or as eyepaint. For Upper Egypt, the evidence is somewhat less scarce. From Gebelein, Schiaparelli retrieved Predynastic paintings of human figures and boats on linen, now preserved in the Egyptian Museum, Turin (Inv. Suppl. 17138). Petrie reported, but did not identify, plastered and painted cloth, with red, green, black and white pigments, and leather painted in red, green, black (or blue) and yellow, from Predynastic contexts at Naqada (Lucas 1962: 338). These pigments on organic materials would be among the most important surviving evidence for the history either of organic dyes or of inorganic pigments. The most extensive Predynastic painted surface is the burial chamber of a ruler of the late Naqada Period, at Hierakonpolis, excavated by Quibell and Green at the end of the nineteenth century (see Kemp 1973); this was subsequently dismantled, and substantial fragments are displayed in the Egyptian Museum, Cairo. From this monument, Quibell and Green (1902: 21) reported that the black pigments 'do not seem to be pounded charcoal'. They also noted, but did not identify, a white pigment. No modern analyses of Predynastic pigments are available to us, other than studies of the decorated pottery. The characteristic Predynastic purple-decorated buff ware of the Naqada period has been analysed in the post-War period (Hope *et al.* 1981).

There are no recent reports of identifications of Early Dynastic pigments available to us. Lucas (1962: 338) noted painted mud-brick corridors and walls with black, blue, red and yellow motifs among the First-Dynasty *mastaba* tombs at Saqqara, but also commented that the pigments were not identified. In addition, he cites the excavation report on the Third-Dynasty *mastaba* of Hesyra at Saqqara (S2405 [A3]) the mud-brick walls of which bear paintings in red, brown, yellow and, to a lesser extent, black, green and white (Quibell 1913: 5–9, pls. VIII–XIV). Identification of the green pigment would be of considerable importance for our knowledge of the early history of artificial green and blue pigments (see pp. 108–13 under blue and green).

Pigments of the dynastic period (Fourth–Thirtieth Dynasties)

Introduction

The following discussion includes material from the Fourth to the Thirtieth Dynasties, with some comparative material of the Ptolemaic and Roman periods (fourth century BC to fourth century AD). Although it has not proven practicable at this stage of research to avoid the colour-by-colour approach of the Lucas' *Ancient Egyptian Materials and Industries*, the shortcomings should be noted: it creates a foreign and anachronistic focus on English-language colour terms, few if any of which can be said to correspond exactly to the Egyptian perception of colour, and it reinforces the impression of a small range of colours, in marked contrast to the great range of hues present in any Theban tomb-chapel, for example in the ranges of browns, reds and pinks.

At present, the colour-by-colour approach may be justified to some extent at least by the relatively small range of materials used in the paintings of the Dynastic period, as opposed to the great variety in mixtures and techniques of application. It should be emphasised, however, that the object of study is not so much single colours, as the various palettes in use for particular surfaces across the different periods of ancient Egyptian history. When more data become available, it will be convenient to group results of pigment analyses secondarily by colour, and first by workshop along perhaps the following lines: stone sculpture and relief; painting on wood (particularly the funerary workshops); painting on papyrus (again primarily funerary in the surviving record); painting on plaster, subdividing into the domestic and funerary spheres (see pp. 117–19 for a discussion of the types of painting ground).

Within a composition according to the rules of Egyptian canonical art, each pigment is applied evenly across an outlined surface, the artist aiming at polychromatic effect rather than colouristic shading (Brunner-Traut 1977: 121, 127 n. 51). The emphasis of the palette thus falls on the pure and intense colours, with a consequent delimitation of the materials in use. The principal colours may be summarised as three pairs: black and white; red and yellow; and blue and green; variants to this framework include brown, grey, orange, pink and purple. The painting ground plays its part in selection of the range and hue of colour in each composition. While factors such as royal privilege and economy are often important influences on colour choice, the nature of the painting ground itself is also an influential factor. The importance of the ground can be seen in the use of pure orpiment for yellow on New Kingdom royal red quartzite sarcophagi and, on a smaller scale, non-royal funerary manuscripts, as compared with mixed orpiment and ochre on limestone and sandstone temple reliefs of the same period (see pp. 115–16 under yellow). Awareness of background hue and its effect on colour may be seen in the preparation of clean plaster walls of tomb-chapels, and in the apparently deliberately darker walls of sarcophagus chambers in mid-Eighteenth Dynasty royal tombs, evoking the faded brown of an aged papyrus scroll.

Black

In almost every analysis of Egyptian pigments, black has proven to be carbon. Lucas (1962: 339) estimated that the fineness and evenness of particles indicated that it was soot, and suggested that it had been scraped from cooking vessels. One sample of black was found to contain burnt plant material traces characteristic of charcoal (Eton College, Myers Collection, coffin depicting Thutmose III *c.* 960–900 BC).

Lucas (1962: 340) noted the identification of a black pigment in a Twelfth-Dynasty tomb at Beni Hasan as pyrolusite, the manganese ore found at Sinai, but the analysis was undertaken by Spurrell in 1895, and finds no more recent corroboration. Nevertheless, the black on an Eighteenth-Dynasty pottery vessel was more recently identified as oxide of manganese, although here too more information concerning the method of analysis is needed (Lucas 1962: 384). One colour on a Ramesside papyrus (BM EA9949) appeared black, but was found by the present authors to be very dark Egyptian blue, a degradation pattern which may be expected in other instances even if it remains to be explained in detail. In sum, there is almost no evidence for the use of materials other than carbon for obtaining black in painting during the Dynastic period. The exception is the black paint applied to faience objects before firing (cf. Kaczmarczyk and Hedges 1983).

Blue

Egyptian blue

The principal blue pigment was Egyptian blue, discussed here under the headings:

(a) method of analysis;
(b) components and method of production;
(c) texture and hue;
(d) distribution within Egypt;
(e) patterns of degradation; and
(f) attestations outside Egypt.

Other blue pigments identified in analysis are treated at the end of this section.

Method of analysis Egyptian blue is a multi-phase material, and for this reason XRD may be insufficiently sensitive to detect all components. Similarly, PLM cannot be used to identify each of the various phases present. In order to gain more precise information, a sample must be mounted in resin and polished to produce a cross-section; this can then be examined and analysed in a scanning electron microscope with x-ray analysis. However, especially when dealing with pigments taken from objects, the use of this technique is often limited by the required sample size. It is important that sample size be stated in scientific reports, as the quality of the results may depend in part on this.

Egyptian blue was identified in general in the British Museum conservation project using PLM with confirmation from XRD and elemental analysis.

Components and method of production Egyptian blue is a synthetic pigment composed of various phases containing silica, copper and calcium, made by heating together silica, copper alloy filings or a copper ore such as malachite, lime (calcium oxide), and an alkali such as potash or natron (sodium sesquicarbonate $Na_2CO_3.NaHCO_3.2H_2O$, found naturally occurring in Egypt). This may be compared with the description in Vitruvius (*On Architecture* VII: ch. XI, 1), where it is said that *caeruleum* 'blue (pigment)' was manufactured at a factory at Pozzuoli established by Vestorius following procedures found at Alexandria; according to Vitruvius, the Vestorius factory produced its *caeruleum* by fusing together sand, copper filings and *nitrum* 'soda' (Granger 1970, 123–4). Blom-Böer suggests that the three principal ingredients were calcite, malachite and quartz sand, and comments that this substance is fused by heating and ought therefore, strictly speaking, not be termed a frit (Blom-Böer 1994: 62); it has also been suggested that the term 'frit' should be reserved for the initial phase of glass or glaze production (see Chapter 8, this volume). Nevertheless 'blue frit' is widely used in the Egyptological literature as a synonym for 'Egyptian blue'; if frit is defined as a sintered polycrystalline material, use of the term can be justified for Egyptian blue. The melting point was lowered to below 742 °C by the addition of the alkali. Chemically the malachite, silica and calcite turn to cuprorivaite, carbon-dioxide and water vapour:

$$Cu_2CO_3(OH)_2 + 8SiO_2 + 2CaCO_3 \rightarrow 2CaCuSi_4O_{10} + 3CO_2 + H_2$$

This crystalline product consists of rectangular blue crystals, often in many layers. The major component is cuprorivaite, $(Ca,Cu)Si_4O_{10}$, with unreacted quartz, often accompanied by copper-bearing wollastonite, $(Ca,Cu)_3(Si_3O_9)$. There are also varying amounts of alkali-rich glass. By the reign of Thutmose III, copper ore was replaced in at least some cases by bronze filings, as has been deduced from the presence of tin oxide, SnO_2 (Jaksch *et al.* 1983: 533–5). Other minor components noted by the Max-Planck project include pyrite (FeS), titanomagnetite ($Fe_3O_4.Fe_2TiO_4$, thought to be a result of the use of desert sand as a raw ingredient), and cassiterite (SnO_2).

Texture and hue The hardness, texture and resultant colour of Egyptian blue when used as a pigment depend on the initial components, the microstructure of the sintered product, and final particle size after grinding to produce a pigment. Tite, Bimson and Cowell (1987) categorise Egyptian blue as dark blue, light blue or diluted light blue. The dark blue is low in alkali, with a microstructure showing coarse crystals of cuprorivaite. The light blue is also low in alkali, but the cuprorivaite crystals are smaller, and intimately mixed with the other components. The diluted light blue is high in alkali, and as a result contains a large proportion of glass; this results in a paler blue material which is also harder than the low alkali products. The glass-rich materials are often found in the Eighteenth Dynasty and later, and this has been associated with the advanced technology of glass production at this time. Both the light blue and the diluted light blue are thought to have been produced by at least a two-stage process, with regrinding of the material before resintering, to produce the intimate mixture of components revealed in their microstructures. Any of these materials can be ground to form a pigment. Egyptian blue was often thickly applied, with coarse particles up to 50 µm across. In general a higher degree of grinding will produce smaller particles, which appear paler than if they were coarsely ground (see Ullrich 1985). Some paler blue samples were found to contain white, generally calcite or gypsum, although this may be residual $CaCO_3$ in Egyptian blue itself. In some cases the white appeared to be contamination; thus on the Eighteenth-Dynasty shroud of a man named Amenhotep (BM EA73806) calcite was found in the Egyptian blue sample, but the shroud had been folded for many years in storage, possibly already partly in antiquity, and observation suggested that the calcite had offset onto the blue areas due to prolonged contact. This ambiguous result reflects the limitations in removing small samples.

In a report on analyses of blue pigment samples from the Eighteenth-Dynasty Workmen's Village at Amarna, Weatherhead and Buckley (1989: 206–8) have drawn attention to the present visual difference between turquoise-blues and other blues, and they have concluded from their results that a turquoise hue was obtained by adding significantly higher amounts of sodium in the form of impure natron. A similar ratio of copper to calcium was noted as in a green sample, and the future study of intentional variation in hues of artificial pigments needs to demarcate the observed turquoise from the green as much as from the blue. Possible effects of degradation on the present hue must be noted (see 'Patterns of degradation', p. 110).

Distribution within Egypt Spurrell, Laurie and Smith (see Lucas 1962: 342) report Egyptian blue on objects as early as the Fourth Dynasty and the Max-Planck project identified it as the blue pigment in all samples analysed, from the Fifth Dynasty to the Roman period, apart from the grey-blue pigments in the First Intermediate Period tomb-chapels of the local governors Ankhtifi and Setka in el-Moʿalla and Aswan respectively (Blom-Böer 1994: 73). The blue on the famous Eighteenth-Dynasty head of Queen Nefertiti (Berlin, ÄM21300) has also been identified as Egyptian blue (Wiedemann and Bayer 1982). All blue samples in the British Museum conservation project were likewise found to be Egyptian blue, and no tin was detected in these despite their date (New Kingdom to Roman period).

The Theban tomb-chapels of the mid-Eighteenth Dynasty provide variable data concerning blue and green artificial pigment distribution; in general they are sparingly used on these plastered limestone wall surfaces, as in the tomb of Tjanuni (TT74; Brack and Brack 1977: 108), and exceptions may perhaps be explained by the higher importance of the tomb-owner rather than by a chronological difference, as in the extensive use of blue and green in the only slightly later tomb-chapel of Horemheb (TT78; Brack and Brack 1980: 15). In a slightly earlier Theban tomb-chapel from the reign of Amenhotep II (TT104), both blue and green appear in some instances to have been applied thinly and then covered by a layer of a wax-like substance which has now darkened, but this surface has not been analysed or dated (Shedid 1988: 23).

Patterns of degradation One of the most important findings by the Max-Planck project concerned the degradation of artificial blue pigments to superficial green (Schiegl *et al.* 1992). According to these samples from painted stone surfaces, all Old and Middle Kingdom samples of what seemed to be green proved to be originally Egyptian blue; in this, the intense blue cuprorivaite $(Ca,Cu)Si_4O_{10}$ predominates, and the green copper wollastonite $(Ca,Cu)_3(Si_3O_9)$ represents a minor component. From the New Kingdom onwards, the samples which now appear green were shown by analysis to consist of green frit, in which the copper wollastonite predominates over the lesser component of cuprorivaite.

The main conclusion of these analyses was that apparent Old and Middle Kingdom greens were in fact the product of degradation of the multi-phase synthetic pigment Egyptian blue, and that such natural features as plant stems and tree tops were originally painted light blue. Specifically it has been shown that the glass phase in Egyptian blue can devitrify, resulting in the secondary formation of copper chloride and/or malachite. This not only causes colour change, from blue to green, but also renders the pigment spongy and friable. In other cases, loss of the pale blue glass may not result in the formation of chlorides, but the Egyptian blue will become a darker blue. The source of the chlorides for the first of these two degradation patterns has not been identified; if the glass is chloride-rich, some source for this component still needs to be found. It is also not clear at what stage in this decay the degradation products become responsible for the general hue of the pigment. It should be noted too that the small amount of copper wollastonite, present as minute crystals in the interstices of cuprorivaite in Egyptian blue, would also be subject to degradation.

Against the background of these discussions it may be noted that some Old and Middle Kingdom organic surfaces are coloured with apparent emphasis on a strong contrast between green and blue; on the wooden coffin of a lady named Khuit, from Asyut (BM EA46634) the one line of green hieroglyphs runs above a markedly blue *wedjat*-eye pair, and in at least this instance a First Intermediate Period or early Middle Kingdom artist seems to have intended and obtained distinct blue and green pigments on an organic ground. This coffin is unpublished, and has been dated from the offering formula and the style of two statuettes (BM EA45124 and EA45200) which are thought to be from the same tomb; the green pigment was shown in analysis to be malachite (see p. 112 under 'Green').

The selection of pigment and consequently of colour may therefore depend in these cases more on the surface to be painted than the intended colour symbolism or the range of the contemporary palette. In this respect, the identification of binding media as well as the evaluation of texture of pigment may in the future explain the selection of certain pigments and thus the presence of colours on particular types of surface, with possible variations between stone, wood and papyrus. The palettes of the various workshops must therefore be differentiated as carefully as the periods and regional distribution of pigments, the workshops being distinguished provisionally as the following: soft stone, hard stone, painted plaster, and organic (in the surviving record predominantly funerary equipment).

A pale blue glass has also been reported (Schiegl *et al.* 1992); this is produced from similar materials to those used for Egyptian blue, but contains no calcium. It has been suggested that this can degrade to produce copper chloride or malachite, turning green.

Egyptian blue has darkened to appear now as black on one Ramesside papyrus (BM EA9949). The malachite with Egyptian blue that has been detected in samples from the Twentieth-Dynasty Book of the Dead papyrus of the noblewoman Anhay (BM EA10472) appears to be the degradation product of a pigment applied as Egyptian blue. In discussions of degradation it is important to refer back to the object from which a sample has been taken. Degradation of pigments on artefacts in the British Museum has produced a patchy, clearly discoloured appearance, and it seems unlikely that a degradation mechanism in a painted field could result in an evenly coloured alteration product. In future research it may be helpful to define the criteria whereby a colour surface is judged degraded or not.

Attestations outside Egypt Outside Egypt the same compound is found as the material for small artefacts and inlays in Western Asia from the middle of the third millennium BC (Early Dynastic III Period in Mesopotamia). Western Asia is at least as likely as Egypt (and possibly more likely) to be the place of origin for production of the compound as a material for inlays and other plastic forms; we have not found analyses establishing its early use as a pigment in that area (Moorey 1985: 188–93; 1994: 186–9 for material such as inlays, 322–9 for pigments in wall-paintings). It is also attested in the Mediterranean world from at least the end of the Middle Bronze Age or beginning of the Late

Bronze Age. The samples from the Thera frescoes of the sixteenth century BC included tin (Filippakis 1978); this indicates that the introduction of bronze filings to replace copper filings took place either earlier in Egypt than is attested in analysed samples, or outside Egypt with the technology imported back into Egypt from the Mediterranean area in the fifteenth century BC.

It is not certain at what date Egyptian blue began to be produced in Roman Italy. However, the relevant passages in Vitruvius and Pliny (first century AD) seem to imply that manufacture of the material had at that time only recently been established at Pozzuoli (Wallert 1995: 179). Laurie dated the latest examples in Italy to the second to seventh centuries AD, but this range has been extended to the ninth century AD by more recent analyses of pigments in the church of San Clemente, Rome (Lazzarini 1982).

Blue pigments other than Egyptian blue

Cobalt blue is attested in Egypt for the Amarna period on pottery, but not on either the so-called *talatat* blocks (in temples) or the tomb-chapel wall-reliefs of the same period. A source for cobalt has been reported from Kharga Oasis, but a central European provenance is also possible in view of the limited timespan in usage. There seem to have been more intensive Aegean–Egyptian contacts – either direct or via Syria – during the reigns of Amenhotep III and Akhenaten in the late Eighteenth Dynasty, and this might provide the trading network for a short-lived cobalt supply from the far side of the Balkans. Blom-Böer (1994: 62) suggests instead that the limit in time may be linked to a connection between cobalt blue and the sun-cult as interpreted in the reign of Akhenaten. It should also be noted that, apart from the Predynastic period, pottery was commonly painted only in the late Eighteenth to early Nineteenth Dynasties, and that therefore the absence of cobalt as a pigment in other periods might relate more to the choice of surface than to the availability of the mineral within Egypt. Lucas (1962: 344) mentions a report by M. Toch of cobalt blue from the Fifth-Dynasty tomb of Perneb from Saqqara, but he points out that this was later shown to be a misidentification of Egyptian blue (calcium-copper silicate; see Williams 1932: 27, n. 34).

In the First Intermediate Period tomb-chapels of Ankhtifi at el-Moʿalla and Setka at Aswan, the Max-Planck project found blue-grey pigments consisting of a mixture of calcite and carbon black, and of an iron-titanium compound and calcium carbonate (Blom-Böer 1994: 73). These bear greater similarity to the analyses of greys than to those of blues.

Azurite (also designated chessylite), a naturally occurring blue carbonate of copper found in Sinai and the Eastern Desert, was reported by F.C.J. Spurrell (1895) in the following examples: a shell used as a palette in a Fourth-Dynasty context at Meidum, a cloth over the face of a Fifth-Dynasty mummy, also at Meidum, and a number of Eighteenth-Dynasty 'paintings', presumably wall-paintings. There is, however, no more recent corroboration of Spurrell's findings (Lucas 1962: 340). The Max-Planck project (covering the Fifth Dynasty to the Roman period) reported no instances of azurite, and it has been concluded that identifications of blue pigment as natural azurite are not secure; Blom-Böer (1994: 61–2) suggests that the apparent absence of azurite from the Egyptians' palette was perhaps a result of its poor quality and impermanence as a pigment.

It should be noted that there is no evidence that either powdered lapis lazuli or powdered turquoise were used as pigments. According to Lucas (1962: 343–4), the lapis pigment ultramarine is not attested before the eleventh century AD.

Brown

Lucas states that iron oxide or ochre was used for the colour brown, citing analyses of samples dating to the Fourth Dynasty, Amarna period and Late Period (Lucas 1962: 344). He also notes the late nineteenth-century identification by Spurrell of Fourth-Dynasty brown samples as red painted over black. Winlock recorded that the models from the late Eleventh- or early Twelfth-Dynasty tomb of Meketra at Deir el-Bahari included brown pigment obtained by varnishing over a deep yellow ochre. The Max-Planck project identified ochre (generally red, but sometimes brown or yellow) as the material used for brown from the Fifth Dynasty to the Roman period throughout Egypt. Lucas records the Dakhla Oasis as a provenance for good ochre.

The British Museum conservation project found that the brown pigment on one early Eighteenth-Dynasty papyrus (BM EA10477) was a mixture of haematite with orpiment and carbon black. The brown pigment on a Twenty-first- or early Twenty-second-Dynasty papyrus (BM EA10029) was found to contain haematite and carbon black. It should be noted that a green sample containing orpiment yellow and Egyptian blue had turned brown at the edges on one papyrus of the late Ptolemaic or early Roman period (BM EA9916), perhaps from sulphurous emissions in the photochemical degradation of the orpiment component of the green.

A red-brown on a Nineteenth-Dynasty papyrus at the University of Philadelphia Museum was identified by XRF and wet chemical analysis as realgar with iron oxide (Evans *et al.* 1980). The Max-Planck project found that a rare beige hue in samples ranging from the Fifth Dynasty to the Ramesside period, within Upper Egypt, consisted of a mixture of yellow ochre and white pigments; it should be stressed that the hue intended by the artist at application is not always clear from these analyses (Blom-Böer 1994: 73–4).

Green

Although one or two instances of malachite applied as a green pigment are known, the ancient Egyptians generally employed for this colour a synthetic material which is often termed 'green frit' in the literature (for discussion of the use of frit for this product, see p. 109 in the analogous case of Egyptian blue). The major phases of this material are copper wollastonite and a glassy phase rich in copper, sodium and potassium chlorides. It is made in reducing conditions by mixing similar ingredients as for Egyptian blue, but with higher lime, and lower copper content. Two types of green frit have been identified – a glass-rich form, and a wollastonite-rich form; both types may be present in one melt if mixing during manufacture was insufficient. Minor components of green frit may be pyrite (FeS) and covellite (CuS) from a sulphide-rich copper ore.

It has been reported that copper chlorides were used as green pigments from the Fifth Dynasty, and that they were among the first synthetic pigments used. However, the identification of an artificial pigment applied as green before the Eighteenth Dynasty has now been called into question by the results of analyses from stone surfaces by the Max-Planck project. El-Goresy (in Schiegl *et al.* 1992) suggests that copper wollastonite may have been unintentionally produced in highly reducing conditions during sintering of Egyptian blue, but it should be noted that the glassy phase associated with the copper wollastonite would have a much higher calcium content. Basic copper chloride, paratacamite or atacamite, is found in analyses of green pigment samples from surfaces as late as the end of Twelfth Dynasty, but recent investigation by the Max-Planck project led to the conclusion that atacamite may be a degradation product of artificial copper pigments, and that only a few examples of green earlier than the New Kingdom were applied as green, the remainder being applied as light blue. Schiegl specifically disputes that copper chloride pigments were intentionally produced before the New Kingdom, and proposes instead that they are secondary formations due to the degradation of glass-rich phases in sintered materials; weathering of the alkali-rich glass can result in the formation of chlorides and/or malachite, causing the pigment to become paler, spongy and friable (see p. 110, Egyptian blue).

An early Middle Kingdom limestone relief fragment in the Metropolitan Museum of Art, New York, seems to have both water and leaves painted with the same colour, a blue-green. By contrast, the above-cited First Intermediate Period or early Middle Kingdom wooden coffin of Khuit (BM EA44634) has one line of green hieroglyphs and two distinctly blue *wedjat*-eyes; analysis has shown the green of the hieroglyphs to be malachite. This raises the question of whether different painting grounds may have required different media: thus painting on limestone may have excluded green at a time when painting on wood could use both green and blue.

Of three analysed samples of green material identified as pigment from the Eighteenth-Dynasty Workmen's Village at Amarna, two were found to be the green-blue copper ore chrysocolla ($CuSiO_3.2H_2O$), while the third was an artificial material, 'green frit', similar in composition to the turquoise-hue blue pigment samples from the same site (see p. 109 under 'blue'; Weatherhead and Buckley 1989: 208). On papyrus the artificial green pigment or 'green frit' is the pigment of the green colour used in the earliest examples of coloured illustrations, established by analysis of the opening vignette of the mid-Eighteenth-Dynasty Book of the Dead of Nu (BM EA10477). Green frit was probably also the pigment used for the bright green on a Third Intermediate Period papyrus at the British Museum (BM EA9919).

Blom-Böer (1994: 65) reports also a copper-bearing vitreous pigment (*Kupferglas*) from Fifth-Dynasty to Twelfth-Dynasty samples as a possible green pigment, but it ranges in colour from blue to bright green, and its original colour is difficult to assess; samples comprise basic copper chloride and malachite. This may account for the malachite identified as the clearly degraded green on one Thirtieth-Dynasty or early Ptolemaic funerary papyrus (BM EA9944), if not the malachite and calcite mixture on another green from the same papyrus. Malachite was powdered for use as an eye-paint, but no instance of its use as a pigment on stone surfaces was found by the Max-Planck project in samples from the Fifth Dynasty to the Roman period (Blom-Böer 1994: 64, 74–5); it may occur as an ingredient or a 'degradation byproduct' of the 'green frit' discussed above. Malachite has now been found on a First Intermediate Period or early Middle Kingdom coffin at the British Museum (BM EA44634) in a condition which does not suggest degradation from another pigment (see p. 110). However, even if malachite was sometimes applied as a pigment, there was evidently a preference for green frit at most periods.

The Max-Planck project also detected an unexpected possible pre-New Kingdom green in samples of modern red or yellow appearance; these were identified as an iron-bearing vitreous pigment, originally green or brown, which had degraded to the mineral jarosite, with its reddish or yellow hue (Blom-Böer 1994: 63). However, recent analyses by Andrew Middleton and Sylvia Humphrey in the Department of Scientific Research at the British Museum have identified jarosite as a pigment in samples from light yellow colour fields on early Middle Kingdom coffins where there is no sign of degradation on macroscopic observation, and similar results have been reported from the conservation of temple wall paintings at Karnak (see p. 116, under 'Yellow').

The green on a Nineteenth-Dynasty papyrus at the University of Philadelphia Museum was identified by XRF and wet chemical analysis as Egyptian blue mixed with orpiment (Evans *et al.* 1980). This might account for the arsenic sulphide identified from a green pigment from the Royal Tomb at Amarna (Iskander 1987), although the recorded XRD data have been found to be more consistent with a copper compound (Weatherhead 1995: 396). From the late

Ptolemaic or Roman period, the British Museum conservation project found that the green colour on a funerary papyrus (BM EA9916) consisted of Egyptian blue with orpiment. This rare, and presumably more expensive, mixture of blue and yellow to produce a green seems to follow those New Kingdom antecedents, but no parallel can yet be cited from the intervening 1,000 years.

Grey

Lucas reports that a number of Fourth-Dynasty and Fifth-Dynasty samples incorporated a grey obtained by mixing gypsum white with carbon black (Lucas 1962: 346). Reisner had asserted that the grey colour used to paint pottery at the Upper Nubian site of Kerma was obtained from a sandy stone but this is yet to be confirmed (Lucas 1962: 346). Blom-Böer (1994: 74) reports carbon black, or combinations of gypsum with carbon black, from the Fifth to the Twentieth Dynasties, but notes, as with other mixed colours, the difficulty in distiguishing contaminated samples and establishing the original hue intended by the artist at application.

On one of several Ptolemaic and Roman-period papyrus fragments from Elephantine, Ashmunein and the Fayum, a grey pigment was identified by XRD as kaolinite mixed with quartz (Buschle-Diller and Unger 1996: 114).

Orange

Lucas (1962: 346) refers to analyses of orange which identify the colour as red painted over yellow, or else as a mixture of red and yellow, but he does not identify *which* red or yellow pigments, nor does he mention realgar or orpiment in this context. The Max-Planck project found orange in samples from the Sixth Dynasty to the Roman period throughout Egypt to be red ochre, with or without white pigments (Blom-Böer 1994: 5).

In the British Museum conservation project the orange colour used on an early Eighteenth-Dynasty papyrus (BM EA10477) was found to be orpiment or pararealgar with red iron oxide; the orange colours in one Ramesside and one Thirtieth-Dynasty or early Ptolemaic papyrus was identified as pararealgar, and that in a late Ptolemaic papyrus (BM EA9916) was found to be similar to realgar. In at least one Eighteenth-Dynasty funerary papyrus (BM EA9968) realgar has been identified as the substance used for a red-orange ink in a rubric that has now turned into yellow pararealgar (for further discussion of this example, see the section on 'media used on papyrus' in Chapter 9, this volume). On realgar, see p. 114, in the section on 'red'.

Pink

Lucas (1962: 346) refers to the following identifications of pink pigments: Spurrell identified the pink paint used in the Old and New Kingdoms as a mixture of red ochre and gypsum white (see Petrie 1892: 29; Spurrell 1895: 231), while Borchardt (1923: 32) reached the same conclusion concerning the pink paint used on the Nefertiti head from Amarna (Berlin, ÄM). For the Hellenistic and Roman periods, Russell (1893–4: 374–5, 1893–5: 67–71) identified the pink colour in a tomb-painting (presumably on a wall or ceiling) as madder painted over gypsum white. Madder is a dyestuff obtained from the roots of the madder plant, native to Persia and the eastern Mediterranean (Cardon and du Chatelet 1990: 164; and see Chapter 11, this volume). Wagenaar (see Lucas 1962: 346) identified a late pink as finely powdered shell, but this has not been corroborated.

The Max-Planck project found pink on samples from the Fifth to the Twentieth Dynasties to be invariably a red ochre with or without white pigment (Blom-Böer 1994: 75). The unusual bright pink on the Third Intermediate Period papyrus BM EA9919 was found to consist of an organic substance over a gypsum ground, and it is possible that this might be an early example of the use of madder, consistent with the results of Russell (Lucas 1962: 346). The change in palette from the Ptolemaic Period included a greater use of pink, with new inorganic as well as the above-cited organic materials; thus the pink-red on a funerary papyrus of the late Ptolemaic or early Roman period was found to be vermilion (HgS) (BM EA9916).

Purple

True purple seems not to have been used in Egyptian painting, and the colour is not mentioned by Lucas except with reference to Predynastic pottery (Lucas 1962: 384). True purple is not to be confused with the dark red background colour on the inside walls of early Twenty-second-Dynasty anthropoid coffins from Thebes; this appears to be a mixture of yellow and red ochres, judging from the analysis of the paint on two such coffins in the British Museum.

Red

Lucas (1962: 346–8) divided the naturally occurring iron oxides into two groups: red iron oxides (anhydrous oxides of iron) and red ochres (hydrated oxides of iron). The division may be expressed in different terms from the geological standpoint; the ochres are among natural mineral pigments coloured by the presence of iron, either the hydrous iron oxide, 'limonite', or the anhydrous iron oxide, 'haematite' (Thorpe and Whiteley 1954: 631–2). Limonite is a component of yellow ochre, whereas red ochre contains abundant haematite, and the common red pigment is accordingly identified as haematite in analyses; note however that the term haematite tends to be reserved within Egyptology for the mineral in its metallic black appearance, as a material used for carving into beads, kohl-sticks, seals and other small objects (see Chapter 2, this volume).

The Max-Planck project identified most visually red samples as red ochre from the Fifth Dynasty to the Roman period; they noted only a few instances in which haematite appeared to be used (ranging in date from the Sixth Dynasty to the First Intermediate Period and Eighteenth Dynasty) and they defined these simply as particularly rich in iron oxide (Blom-Böer 1994: 75). The analysis of one red pigment from the Eighteenth-Dynasty Workmen's Village at Amarna also indicated the use of haematite (Weatherhead and Buckley 1989: 208–9).

A brighter red colour (closer to orange) can be obtained by using realgar, an arsenic sulphide. It should be noted that, like orpiment, realgar is an extremely light-sensitive pigment; it degrades to pararealgar, which is orange-yellow. The only uses of realgar which Lucas reports are undated references to analyses performed by Spurrell and Barthoux, as well as the mention of a sample of orpiment streaked with realgar which is said to have been found at Tanis (Lucas 1962: 348). As far as non-Egyptian sources of realgar are concerned, Barthoux (1926) mention St John's Island in the Red Sea, while Blom-Böer (1994: 66) cites Asia Minor, a suggestion which may be backed up by the presence of this pigment among the cargo of the shipwreck at Ulu Burun (off the southern Anatolian coast), dating to the late fourteenth century BC (Moorey 1994: 328). The Max-Planck project found two Eighteenth-Dynasty instances of realgar used as orange-red paint at Thebes: the contents of a receptacle found in the tomb-chapel of Kheruef (TT192); and a sample from a wall of the tomb of Thutmose IV in the Valley of the Kings (KV43; Blom-Böer 1994: 73, 75).

Degraded realgar appears to have been found at Amarna, this being the most likely identification of a pigment lump from an unrecorded location at Amarna which is now in the collection of the Bolton Museum (30.24.70); it was streaked with red and identified as arsenic sulphide (Weatherhead 1995: 395). Another probable instance of pararealgar (i.e. degraded realgar) is a quantity of pigment described by the excavators as 'bright orange-red' which was found in a reshaped pottery vessel excavated at Amarna in 1935 (Weatherhead and Buckley 1989: 217–18).

The British Museum conservation project found that examples of red paint were made of haematite/red ochre in most instances, but on one Nineteenth-Dynasty papyrus it consisted of pararealgar with orpiment and a trace of haematite (BM EA9949). It was at one stage reported that realgar could alter to orpiment upon exposure to light, but this is now discounted (Douglass *et al.* 1992). For these reasons realgar is susceptible to misidentification in both laboratory analysis and visual inspection. There remains in addition the problem of identifying pararealgar as a degraded rather than an original pigment (Corbeil and Helwig 1995).

On one late Ptolemaic or early Roman papyrus (BM EA9916) an orange-red pigment was composed of iron oxide, while a pink-red paint consisted of vermilion. The red on a Nineteenth-Dynasty papyrus at the University of Pennsylvania Museum (E2775) was identified by XRF and wet chemical analysis as realgar (Evans *et al.* 1980). Red lead pigments are not attested before the late Ptolemaic or Roman period (Blom-Böer 1994: 66).

White

Lucas (1962: 348–9) reports that the only two white pigments in ancient Egypt were calcium carbonate (whiting, chalk) and calcium sulphate (gypsum). The Max-Planck project recorded both calcium carbonate and calcium sulphate from the Fifth Dynasty to the Roman period, but they found the latter (usually comprising gypsum and anhydrite in varying proportions) to be the more common (Blom-Böer 1994: 66, 75). In addition, their analyses of white pigments from Theban tomb-chapels of the Twelfth Dynasty and Eighteenth to Twentieth Dynasties revealed magnesian calcite, chosen for its intensity as a first layer under main pigment on tomb-chapel walls (Blom-Böer 1994: 67, 75).

Blom-Böer also notes huntite, a magnesium calcium carbonate, as a pigment comparable to orpiment in terms of its quality and brightness (Blom-Böer 1994: 67, 76). Huntite would have been desirable as a painting material not only on account of its colour, but also for its adhesiveness, its small particle size and its very fine grain, which would also have ensured a smooth painted surface. It is attested in the Persian Gulf, and occurs both in land saltlakes and on the margins of magnesium-rich strata, conditions that can also be found in Egypt; the nearest published north African source known to us is far to the west in Tunisia (Perthuisot *et al.* 1990).

The Max-Planck project found huntite to be the material used for white paint in Eighteenth- to Twentieth-Dynasty samples. The suggestion that huntite was used in a Twelfth-Dynasty sample, from the Theban tomb-chapel of Senet (TT60) is considered uncertain because of the method of sampling adopted in that instance (Blom-Böer 1994: 76 n. 157).

Huntite was also identified as a pigment or pigment component in the analyses of samples of pigments from the walls and from the painting equipment of two mid-Eighteenth-Dynasty Theban tomb-chapels (TT80 and TT104). In both of these analyses, which were undertaken by Fuchs and Burmester (see Shedid 1988: 166), huntite was identified in samples either alone or with other pigments, notably with calcite or gypsum in the samples of white.

The British Museum conservation project found huntite used for white colouring on a Twelfth-Dynasty coffin fragment (BM EA46654), an early Eighteenth-Dynasty shroud EA73807), and three papyri, one dating to the early Eighteenth Dynasty (BM EA10477), another to the Nineteenth Dynasty (BM EA9949) and the third to the Twenty-first to Twenty-second Dynasties (BM EA9919). The attested date range of the mineral has thus been extended beyond the New Kingdom, although it should be noted that the absence of later examples among the results of the Max-Planck project is probably to be explained by the fact that the Third Intermediate Period is not well-represented among the surviving coloured stone monuments which form their primary sources. The pigment appears on richly coloured objects, providing a corollary to the selection of orpiment for yellow and realgar for red; in general it occurs on smaller scale surfaces or in lesser quantity than the other white pigments. It would be reasonable to conclude that it belonged to the more restricted and costly palette alongside realgar and orpiment.

Wagenaar (Lucas 1962: 349) identified a white as powdered shell or cuttlefish bone: this has not been corroborated. In this context it should be noted that another papyrus of the Third Intermediate Period (BM EA10029) bore an unidentified white, which contained calcium, phosphorus and low levels of magnesium according to the SEM (EDXA) analysis; this might suggest hydroxylapatite, from bone, but the XRD pattern was not consistent with this, and the material remains enigmatic.

Yellow

This colour is most commonly found to consist of yellow ochre, comprising iron bearing materials, notably goethite (the alpha form of FeOOH) and limonite (the yellow to brown hydrous oxide) together with varying amounts of clay and siliceous matter (see Thorpe and Whiteley 1954: 631). More rarely the arsenic sulphide orpiment has been found. Thus Lucas (1962: 349–50) reports yellow ochre (hydrated iron oxide) and – from the late Eighteenth Dynasty onwards – orpiment, a naturally occurring arsenic sulphide. He also refers to the identification by Reisner (1923: IV–V, 292–3) of the use of ground sandstone for yellow pigment at Kerma, but this requires confirmation. Laurie (1913) identified massicot (a yellow oxide of lead) in a sample of yellow pigment found on a palette dating to *c.* 400 BC, (Lucas 1962: 351) while John had identified vegetal yellow pigments about a century earlier. The yellow in the Theban tomb-chapel of Amenuser, first minister under Hatshepsut in the early Eighteenth Dynasty (TT131), was found by XRD to be yellow ochre (Dziobek 1994: 101).

The Max-Planck project identified as yellow ochre the yellow pigments on samples from Fifth Dynasty to the Roman period, but they found orpiment in pure form only on Eighteenth- and Nineteenth-Dynasty sarcophagi of kings, and on the walls of the tomb of Thutmose IV (KV43). One of the major findings of the project was the mixture of orpiment and yellow ochre applied to New Kingdom temple and tomb walls; Blom-Böer (1994: 63–4, 74) reports layering of first yellow ochre, then orpiment and finally yellow ochre again on the walls of tombs and temples in the New Kingdom, thus giving the ochre the greater intensity of colour characteristic of orpiment. This suggests a differential application of the mineral depending on the surface area and/or status of the monument. With regard to status, however, it should be noted that analyses of samples of yellow pigment from two Eighteenth-Dynasty Theban private tomb-chapels revealed no orpiment, whereas painting materials discovered in the same chapels included pigment blocks identified as orpiment (TT78, tomb-chapel of Horemheb, see Brack and Brack 1980: 100, and TT192, tomb-chapel of Kheruef, see Blom-Böer 1994: 74 n. 149). This suggests that in some instances orpiment, although perhaps present in the tomb-paintings, might simply not have been detected, either because it has faded with exposure to light, and therefore has not seemed to present a coloured surface worth sampling, or because it has been used in a mixture with yellow ochre, and only the ochre stratum of the layered application has been analysed.

With regard to sources for orpiment (arsenic sulphide) outside Egypt, Moorey (1994: 328) cites Julamerk in Kurdistan, Goramis in Iran, as well as Syria and Anatolia, noting that orpiment was part of the cargo on the Ulu Burun shipwreck mentioned above; earlier studies give Kharga Oasis and St John's Island in the Red Sea as possible provenances closer to the Nile Valley.

In the Workmen's Village at Amarna samples of yellow pigment were found on analysis by SEM to consist of (1) quartz grains with a thin iron-rich coating and (2) small inclusions of iron and titanium within the core material. The chemical constituents of these samples therefore appeared to be consistent with the most common yellow pigment of the Dynastic period, goethite or yellow ochre (Weatherhead and Buckley 1989: 209). However, another sample from the 1922 excavation dumps at the Village proved to be orpiment, perhaps deriving from the decoration of the 'South Tombs', the tomb-chapels of members of the royal court which lay a few kilometres to the southeast.

Of even greater importance to the study of Egyptian yellows is a segment of a limestone grinding-bowl on which were found coarse particles of a yellow pigment visually identified as orpiment. This object was found discarded in a well at the industrial area Q48.4 to the south of the central city at Amarna; in her report on the find, Weatherhead (1995: 396–7) suggests that the orpiment may have been ground coarsely because it was intended for application to wood or stone objects, in view of the fact that coarsely applied orpiment was found on a wooden model coffin excavated from the central city. Weatherhead also documents a number of earlier finds at Amarna, including the following: several pieces of yellow pigment excavated in 1921 from a house in the main city (O49.17); fragments found with the painting of the Amarna princesses from the King's House (UC2262, 2289), which originally contained orpiment that is no longer visible (presumably faded on exposure to light); and among the tombs of the nobles (tomb-chapel of Ahmose No. 3), which included at least one instance of orpiment with yellow ochre. She also notes the presence of orpiment on the papyrus fragments from the shrine of the royal statue (BM EA74100), and on the limestone head of Nefertiti from the sculptor's workshop (Berlin ÄM21300). Other instances cited as red-streaked or containing realgar are identified as degradation from realgar, and are thus the degradation product pararealgar rather than orpiment (see section on 'red', p. 114).

The date of the earliest use of orpiment is difficult to determine, although it is certainly earlier than the Eighteenth Dynasty. Analysis of yellow on the late Old Kingdom stele of Sheshi (Louvre E 27.133) revealed a mixture of yellow ochre with an unidentified arsenic compound, and a yellow ochre with traces of sodium chloride and arsenic was identified from the late Old Kingdom tomb-chapel paintings of Metjetji (Louvre E 25.548; Ziegler 1990: 314, 316). These results are strikingly reminiscent of the Max-Planck discovery of layered ochre and orpiment in New Kingdom examples, and may carry the use of orpiment in Egypt back to *c.* 2400 BC.

Unequivocal identifications of yellow as orpiment fix the latest possible date for its introduction as the Twelfth Dynasty, *c.* 1900 BC. In the British Museum conservation project, orpiment was found on a Twelfth-Dynasty coffin in the British Museum (BM EA46644), thus confirming the results of an earlier analysis of pigments on two Twelfth-Dynasty coffins in Boston (Museum of Fine Arts, outer coffin of Thutnakht and fragment 21.816g from the coffin of his wife; Terrace 1968: 167–8). Orpiment was also identified as the yellow pigment on early Eighteenth-Dynasty linen shrouds (BM EA73806–7), papyri of the Nineteenth Dynasty (BM EA9949 and 9968), Twentieth Dynasty (BM EA10472), Third Intermediate Period (BM EA9919 and 10029), Thirtieth Dynasty or early Ptolemaic (BM EA9944) and late Ptolemaic period (BM EA9916). In the case of the Nineteenth-Dynasty papyrus BM EA9949, pararealgar was identified as a minor component alongside orpiment; the two occur naturally together, and this does not affect the identification of the pigment as orpiment. On the early Eighteenth-Dynasty papyrus BM EA10477 the yellow was identified as an arsenic sulphide, the exact structure of which has not been identified. No pigment layers have been detected in the papyri. The darker yellow on the late Ptolemaic example BM EA9916 was found to be pararealgar, a degradation product of orange-red realgar. Orpiment was also the yellow pigment used in a tomb-painting from the Theban tomb-chapel of Nebamun (BM EA37978), of the reign of Thutmose IV in the mid-Eighteenth Dynasty.

Following these analyses of British Museum samples, it has been noted that the buff or dull yellow given by ochre can often be distinguished from bright orpiment by preliminary visual inspection of ancient examples not faded by exposure to light. Orpiment has a laminar structure, creating a scintillating effect quite unlike the matt surface of ochre. However, visual identification should always be confirmed by analysis. The yellow paint on a Nineteenth-Dynasty papyrus at the University of Pennsylvania Museum (E2775) was identified by XRF and wet chemical analysis as orpiment (Evans *et al.* 1980).

Noll originally identified as jarosite the yellow pigment on Eleventh-Dynasty pottery from el-Tarif, and noted it also on the Minoan wall-paintings from Thera. The Max-Planck project encountered additional instances, and Blom-Böer noted Cyprus as a possible provenance for the mineral in the absence of known Egyptian sources. However these additional instances, from tomb-chapel walls (Fifth to Sixth and Eleventh to Twelfth Dynasties, Lower and Middle Egypt), were explained as the result of degradation, and not considered evidence for the use of jarosite as an original ancient Egyptian pigment (Blom-Böer 1994: 63). The analysts suggested that the original material as applied would have been a green or brown vitreous material, perhaps produced in the same manner as – if not identical in composition to – the other vitreous materials used for greens and blues. This hypothesis may now need to be modified in the light of more recent findings such as painting equipment found at Karnak, from which jarosite was identified without reference to degradation, and with note of a possible source for the mineral in the western desert at Aswan (Le Fur 1994: 45 and map p. 32). In addition, Andrew Middleton and Sylvia Humphrey of the Department of Scientific Reseach at the British Museum have identified as jarosite the light yellow pigment on several early Middle Kingdom coffins (unpublished analyses). The question of degradation remains, but needs to be assessed against the original objects as well as the analytical results; there is no obvious reason for the jarosite on the early Middle Kingdom coffins to be considered as the result of degradation. Jarosite, despite being a rare mineral, ought therefore to be considered among the list of known Egyptian pigments.

Gilding

In the context of painting, it may be mentioned that gilding is attested on a small number of illustrated funerary papyri, of New Kingdom and Late Period date, notably the opening vignette of the Book of the Dead of Anhay (BM EA10472), and a large scale vignette in the Book of the Dead of a head-goldsmith named Khar (BM EA9949). Another example earlier in the New Kingdom is found on the Book of the Dead of Tjenena in the Louvre (N3074; de Cenival 1992: 8, 70). Although gold leaf is analagous in these instances to a pigment, it is probably best discussed in the context of metallurgy, see Chapter 6, this volume.

Summary

There appears to be a consistent core palette throughout the Dynastic period, comprising red and yellow ochre, blue and green artificial pigments, carbon black, and calcite or gypsum white. This basic palette is supplemented from at least the late Middle Kingdom onwards by a less commonly attested, perhaps less available (imported ?) set of materials giving more intense colour: orpiment for yellow, realgar for orange-red, and huntite for white. Detailed differences in attestations across time, and reasons for selection of particular materials in particular contexts remain to be studied. Other pigments, such as vermilion, seem to have been introduced only in the late Ptolemaic or Roman period; these, and the implied change in colour appreciation (e.g. the use of pink), may reflect Alexandrian trade and exchange of flora and commodities with the East, notably Persia and India, rather than new exposure to central Mediterranean contacts.

These results concern the basic pigments in the palette, and analysis to identify these inevitably focuses attention on individual samples. Identification of the palette alone can give the impression that the Egyptian artist was constrained by a limited palette for block fields of colour. It leaves to one side the question of different hues of the same colour on one object, where the same broad colour is present in different hues obtained either by different materials or by different application of the same material. There is also the question of shading within one colour field on an object, where the artist applies the material to obtain specific effects of light and shade, volume, or hue. Thick application of pigments on painted plaster gives darker shades, while thin application can help to provide virtually transparent effects, and the addition of white supplies lighter hues; the techniques of painting also provide different results, as when the painter draws a half-dried reed loosely over the surface for thin lines (Shedid 1988: 23–4). These problems fall into the scope of art history, but the identification of pigments provides the basis for an understanding of their application.

The question of the methods used to prepare the raw materials requires further study. At Amarna, the red and yellow pigments appear to have been ground on stone vessels; one pottery vessel with re-shaped hexagonal rim contained a bright orange-red pigment (realgar?), and a pottery vessel base contained an unidentified yellow pigment, but these are presumably painters' pots rather than vessels for grinding (Weatherhead and Buckley 1989: 216–18). The artificial pigments at the same site were found in a small bag shape, indicating the fusion of the raw materials or a second firing of an initially fused pigment, and then shaped either into discs or into round or bowl-shaped cakes of material (Weatherhead and Buckley 1989: 210–16); future research into the industrial areas and analyses of finished and unfinished objects and their moulds may reveal the stage in production at which a distinction was made between, on the one hand, pure painters' materials, and on the other hand, pigments or artificial compositions intended for other purposes (e.g. inlays, jewellery or larger moulded figures such as *shabtis*).

Painting substrates

The various types of surface to which the Egyptians applied pigment may be summarised under the following headings:

Soft stone

Limestone architecture; sarcophagi and statuary; sandstone architecture and statuary (for pottery see Chapter 5, this volume).

These are attested for the whole of the Dynastic period, with peaks of production in the surviving record for the New Kingdom and from the Late Period to the early Ptolemaic period.

Hard stone

The royal quartzite sarcophagi of the New Kingdom were painted in pure orpiment, but for other hard stone architecture and sculpture the presence of ancient pigment is not well-documented. In the case of pink granite relief and architecture, the question is complicated by the nineteenth-century practice of making designs visible with a modern pigment, usually of a distinct red hue, for example a Ptolemaic *naos* in the British Museum (BM EA1134), on which the red pigment is a modern vermilion.

Plaster

The most extensively studied painted surfaces from ancient Egypt are the tomb-chapels on the West Bank at Thebes. In the Theban necropolis the local limestone is rarely fine enough to allow relief carving or other manipulation, therefore the artists generally resorted to preparing a surface of plaster upon which the pigment could be applied in *tempera* rather than in *fresco secco*, in other words they ensured that the pigment adhered to the surface by use of a binding medium without remoistening of the plaster surface. The great majority of these painted plaster surfaces are walls and ceilings of Eighteenth- and Nineteenth-Dynasty tomb-chapels, and sometimes burial chambers. Painted Theban tomb-chapels are less well attested for the Twelfth to Thirteenth and Twentieth to Twenty-fifth Dynasties, and fewer examples of pigment analyses are available from tombs of these periods.

The Theban tomb-chapel of Ineni (TT81) is one of the earliest in the Eighteenth Dynasty for which an accurate description of painting ground and decoration technique is available (Dziobek 1992: 22–6). The highly fragmentary rock surface was smoothed and any unevenness covered by the reinforcing layer of coarse gypsum (five to fifteen centimetres thick); into this mortar some thin limestone flakes were mixed. Over the mortar a layer of probably the same material, only finer, was applied, most carefully on the west green artificial pigments, carbon black, and calcite or gypsum white. This basic palette is supplemented from at least the late Middle Kingdom onwards by a less commonly attested, perhaps less available (imported ?) set of materials giving more intense colour: orpiment for yellow, realgar for orange-red, and huntite for white. Detailed differences in attestations across time, and reasons for selection of particular materials in particular contexts remain to be studied. Other pigments, such as vermilion, seem to have been introduced only in the late Ptolemaic or Roman period; these, and the implied change in colour appreciation (e.g. the use of pink), may reflect Alexandrian trade and exchange of flora and commodities with the East, notably Persia and India, rather than new exposure to central Mediterranean contacts.

These results concern the basic pigments in the palette, and analysis to identify these inevitably focuses attention on individual samples. Identification of the palette alone can give the impression that the Egyptian artist was constrained by a limited palette for block fields of colour. It leaves to one side the question of different hues of the same colour on one object, where the same broad colour is present in different hues obtained either by different materials or by different application of the same material. There is also the question of shading within one colour field on an object, where the artist applies the material to obtain specific effects of light and shade, volume, or hue. Thick application of pigments on painted plaster gives darker shades, while thin application can help to provide virtually transparent effects, and the addition of white supplies lighter hues; the techniques of painting also provide different results, as when the painter draws a half-dried reed loosely over the surface for thin lines (Shedid 1988: 23–4). These problems fall into the scope of art history, but the identification of pigments provides the basis for an understanding of their application.

The question of the methods used to prepare the raw materials requires further study. At Amarna, the red and yellow pigments appear to have been ground on stone vessels; one pottery vessel with re-shaped hexagonal rim contained a bright orange-red pigment (realgar?), and a pottery vessel base contained an unidentified yellow pigment, but these are presumably painters' pots rather than vessels for grinding (Weatherhead and Buckley 1989: 216–18). The artificial pigments at the same site were found in a small bag shape, indicating the fusion of the raw materials or a second firing of an initially fused pigment, and then shaped either into discs or into round or bowl-shaped cakes of material (Weatherhead and Buckley 1989: 210–16); future research into the industrial areas and analyses of finished and unfinished objects and their moulds may reveal the stage in production at which a distinction was made between, on the one hand, pure painters' materials, and on the other hand, pigments or artificial compositions intended for other purposes (e.g. inlays, jewellery or larger moulded figures such as *shabtis*).

Painting substrates

The various types of surface to which the Egyptians applied pigment may be summarised under the following headings:

Soft stone

Limestone architecture; sarcophagi and statuary; sandstone architecture and statuary (for pottery see Chapter 5, this volume).

These are attested for the whole of the Dynastic period, with peaks of production in the surviving record for the New Kingdom and from the Late Period to the early Ptolemaic period.

Hard stone

The royal quartzite sarcophagi of the New Kingdom were painted in pure orpiment, but for other hard stone architecture and sculpture the presence of ancient pigment is not well-documented. In the case of pink granite relief and architecture, the question is complicated by the nineteenth-century practice of making designs visible with a modern pigment, usually of a distinct red hue, for example a Ptolemaic *naos* in the British Museum (BM EA1134), on which the red pigment is a modern vermilion.

Plaster

The most extensively studied painted surfaces from ancient Egypt are the tomb-chapels on the West Bank at Thebes. In the Theban necropolis the local limestone is rarely fine enough to allow relief carving or other manipulation, therefore the artists generally resorted to preparing a surface of plaster upon which the pigment could be applied in *tempera* rather than in *fresco secco*, in other words they ensured that the pigment adhered to the surface by use of a binding medium without remoistening of the plaster surface. The great majority of these painted plaster surfaces are walls and ceilings of Eighteenth- and Nineteenth-Dynasty tomb-chapels, and sometimes burial chambers. Painted Theban tomb-chapels are less well attested for the Twelfth to Thirteenth and Twentieth to Twenty-fifth Dynasties, and fewer examples of pigment analyses are available from tombs of these periods.

The Theban tomb-chapel of Ineni (TT81) is one of the earliest in the Eighteenth Dynasty for which an accurate description of painting ground and decoration technique is available (Dziobek 1992: 22–6). The highly fragmentary rock surface was smoothed and any unevenness covered by the reinforcing layer of coarse gypsum (five to fifteen centimetres thick); into this mortar some thin limestone flakes were mixed. Over the mortar a layer of probably the same material, only finer, was applied, most carefully on the west wall of the cross-chamber, with 0.1 to 0.3 cm of fine plaster over the mortar; a thicker layer was applied in the statue chamber, before the mortar foundation had dried, causing the cracks in that layer to affect the surface also. Before the plaster was applied, orientation lines were created by flicking a cord over the mortar with a brush giving a line with a thickness of 1 to 2 cm. The pigment chosen for these and other drafting lines was the long-lasting red ochre rather than carbon black, which – although the most durable pigment on surfaces such as papyrus – often seems paler on painted plaster, perhaps because of a difference in binding medium or pigment texture. Over the fine overlay of plaster, red grids of squares were used to guide composition in certain sections only, such as the major scenes on the west wall of the cross-room. Red draft figures followed, and the background colour was then applied; the grids are visible in the tomb of Ineni because the background pigment has fallen away to reveal them. With the drafts still presumably visible through the background colour, the final outlines were drawn with a fine reed, giving contours which were often as thin as 0.05 to 0.1 cm; the method of filling in the colour is not clear in this instance, because all figures are finished.

From the same generation of tomb-chapel decoration, the Theban tomb-chapel of the vizier Useramen (TT61) provides similar evidence (Dziobek 1994: 19–20), with perhaps an additional layer of lime plaster of about 0.5 cm over the coarser mortar containing limestone splinters; the orientation lines, here one to three centimetres thick, may have guided the craftsmen who then applied a layer of fine plaster 0.5 cm thick (0.7–0.8 cm on the south wall of the chamber) upon which any grids were set. The figures were then drafted in red with a 0.2 cm reed, and over these the background colour was painted, followed by the body colouring and, as the final stage, the red outlining of the finished figures.

With regard to Theban tomb-chapels TT80 and TT104, Shedid (1988: 21–3) describes a similar procedure for the next generation of painting on plastered limestone walls, in the reign of Amenhotep II; variations in procedure differ between tomb-chapels and within one tomb-chapel, evidently according to the artists in each team. The variables include (1) presence or absence of grid, presumably depending on the talent of the painter and the complexity of the composition, and (2) presence or absence of draft outlines: these being omitted for example in landscape flora or small details in the long hall of TT80, but included even for figures on a small scale in TT104. No corrections to the red draft figures are attested; instead the figures are coloured directly, the final stages being the outline contours and the black elements of each scene. The final outlines are executed in red-brown, in TT104 and TT80 (cross-room) 0.05 cm for small and 0.15 to 0.2 cm for larger figures, in TT80 (long hall) 0.05 to 0.3 cm for small and 0.2 to 0.4 cm for larger figures. Any amendments to the final outlined figures could be made simply by painting over them in the background colour, at the last stage.

From the brief reign of Thutmose IV come some of the finest surviving examples of tomb-chapel painting, such as the Theban tomb-chapels of Sobekhotep (TT63; Dziobek and Abdel Raziq 1990), Tjanuni (TT74; Brack and Brack 1977) and, extending into the reign of Amenhotep III, Horemheb (TT78; Brack and Brack 1980). The tomb-chapel of Sobekhotep has uneven baserock walls, perhaps resulting from a particularly poor limestone bed, which even an elaborate scheme of mortaring and a final overlay of 0.1–0.5 cm of finer plaster could not remove (Dziobek and Abdel Raziq 1990: 27–8). For the varnishing of specific colours, or entire wall surfaces in the case of Theban tomb-chapel paintings, see Chapter 18, this volume.

Substantial fragments of royal and private palace wall- and floor-paintings survive, although not on the scale available up to eighty years ago; the past 100 years have witnessed the exposure and general destruction of painted walls of late Middle Kingdom townhouses at Lahun, and the painted walls and floors of New Kingdom royal palaces at Deir el-Ballas (Lacovara 1990: 2–3), Malkata (Stevenson Smith 1981: 281–95 with 459–60 nn. 2–34) and Amarna (Weatherhead 1992 and 1994).

Application as *buon fresco* (onto wet plaster) is foreign to Egypt, and is one of the identifying hallmarks of the Aegean painters of the late seventeenth or sixteenth century BC at Tell el-Dab'a (Bietak 1994: 45), as at Tell Kabri in northern Palestine, although the precise technique of Western Asiatic mural painters has not been identified by analysis (Moorey 1994: 328–9).

Organic surfaces: papyrus, wood, textiles

Papyri are illustrated and painted for apparently non-funerary contexts in the Ramesside period, and for funerary texts from the following periods: Eighteenth–early Twenty-second Dynasty, Twenty-sixth Dynasty, Thirtieth Dynasty to Roman period. Another non-funerary example is provided by the painted fragments from the 'House of the King's Statue' (structure R43.2 in the southeastern central city) at Amarna, dated to the reign of Akhenaten or that of Tutankhamun in the late Eighteenth Dynasty (Schofield and Parkinson 1994). Leather rolls were also sometimes used for illustrated Book of the Dead manuscripts in the Eighteenth Dynasty. Selection of colour in preference to black outline drawings, with some red (the second pigment of the scribal palette) partly reflects cost, but also the factors of ownership and chronologically determined practice in the funerary workshops. Most Eighteenth-Dynasty funerary manuscripts bear coloured vignettes, but the Book of the Dead of Nebseny (BM EA9900) uses only the scribal pigments carbon black and red ochre, apparently because as a copyist, Nebseny himself must have compiled his own funerary papyrus using his personal scribal palette. In other instances, even a limited extension to the scribal palette of black and red is enough to ascribe the manuscript to a funerary workshop specialised in colouring (e.g. the Eighteenth-Dynasty Book of the Dead papyrus of Nebamun: BM EA9964).

The Third Intermediate Period offers a clear instance of change in application of pigments, at least on papyrus (Niwinski 1989). The use of colour seems most extensive in the Twenty-first Dynasty, with richly coloured and illustrated Book of the Dead and Underworld manuscripts, the latter drawing on the Litany of Ra and creation vignettes. In the early Twenty-second Dynasty, the Book of the Dead is generally a hieratic manuscript with only a single vignette at the beginning, showing the deceased offering, and this is often in black and red only, as are the new Underworld manuscripts of the period, drawing on the last four hours of the 'Book of the Secret Chamber which is in the Underworld'. Between the two traditions of colour and scribal palette, the Book of the Dead papyrus of Nestanebtisheru (BM EA10554) bears one of the most extensive series of vignettes, but is executed only in black and red.

It can be seen from this survey that colour use changed sharply between early and mid- Third Intermediate Period funerary papyri; this may serve as a reminder that the artists using colour operated within workshops each with their own tradition, specifically their various histories of access to and use of materials. The rare funerary papyri of the Twenty-sixth Dynasty (Verhoeven 1993: 41–2) include richly coloured Theban and Herakleopolitan manuscripts, but also the Book of the Dead of Psamtek, now in the Vatican Egyptian collections, which is a Memphite papyrus executed only in black and red. The illustrated funerary manuscripts of the Thirtieth Dynasty and Ptolemaic Period have not been dated by groups, but colour seems again to have been an important criterion with probable chronological significance (for a preliminary typology see Mosher 1992).

Surviving painted wooden surfaces are rare before the late Old Kingdom, when non-royal coffins began to be decorated more commonly with painted texts and illustrations. From the Middle Kingdom onwards, wooden canopic chests were also painted, and from the New Kingdom *shabti* boxes. In the first millennium BC, Theban burials included a painted wooden stele set against the coffin within the burial chamber. These categories of object offer a more or less continuous tradition within the funerary workshops of painted organic surfaces from the late Old Kingdom to the Roman period.

Painted textiles do not commonly survive at any period, but include mid-Eighteenth-Dynasty shrouds bearing texts and vignettes from the Book of the Dead. The shroud of Resti, an Eighteenth-Dynasty noblewoman (BM EA73807), revealed the same selection of pigments as that found on contemporary funerary papyri, with huntite for white, orpiment for yellow, Egyptian blue for blue and haematite for red. Surviving textiles suggest that dyeing techniques were introduced into Egypt from Western Asia from the New Kingdom onwards (for colour on textiles, see Germer 1992, and Chapter 11, this volume).

For the application of pigments to basketry (in which patterning of materials of different kind or age, rather than artifical colouring, seems to be the norm) see Chapter 10, this volume; for tattoos, and eye and skin adornment see Chapters 17 and 18; for the dyeing and colouring of leather see Chapter 12; and for the use of varnish see Chapter 17.

References

Barthoux, J. 1926. Les fards, pommades et couleurs dans l'antiquité. *Congrés International de Géographie, Le Caire, April 1925*, IV, pp. 251–67.

Bietak, M. 1994. Die Wandmalereien aus Tell el-Dabʿ/Ezbet Helmi. Erste Eindrücke. In *Ägypten und Levante* IV (ed. M. Bietak), pp. 44–58, pls. 14–22.

Blom-Böer, I. 1994. Zusammensetzung altägyptischer Farbpigmente und ihre Herkunftslagerstätten in Zeit und Raum. *OMRO*, 74: 55–107.

Borchardt, L. 1923. *Porträts der Königin Nofret-ete aus de Grabungen 1912/13 in Tell el-Amarna*. Leipzig: Hinrichs.

Brack, A. and Brack, A. 1977. *Das Grab des Tjanuni. Theben Nr. 74* (Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 19). Mainz am Rhein: von Zabern.

1980. *Das Grab des Haremheb. Theben Nr.78* (Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 35). Mainz am Rhein: von Zabern.

Brunner-Traut, E. 1977. Farben. *LÄ* II: 117–28.

Buschle-Diller, G., and Unger, A. 1996. Schreib- und Malmaterial auf Papyrus. *Restauro*, 2: 108–14.

Cardon, D. and du Chatelet, G. 1990. *Guide des Teintures Naturelles*. Lausanne: Delachaux et Niestlé.

de Cenival, J.-L. 1992. *Le livre pour sortir le jour, Le Livre des Morts des anciens Égyptiens*. Musée d'Aquitaine et Réunion des Musées Nationaux.

Corbeil, M.-C. and Helwig, K. 1995. An occurrence of pararealgar as an original or altered artists' pigment. *Studies in Conservation*, 40: 133–8.

Douglass, D.L., Shing, C. and Wang, G. 1992. The light induced alteration of realgar to pararealgar. *American Mineralogist*, 77: 1266–74.

Dziobek, E. 1992. *Das Grab des Ineni Theben Nr. 81* (Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 68). Mainz am Rhein: von Zabern.

1994. *Die Gräber des Vezirs User-Amun Theben Nr. 61 und 131* (Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 84). Mainz am Rhein: von Zabern.

Dziobek, E. and Abdel Raziq, M. 1990. *Das Grab des Sobekhotep Theben Nr. 63* (Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 71). Mainz am Rhein: von Zabern.

Evans, D., Hamburg, D. and Mickelson, M. 1980. A papyrus treatment: bringing the Book of the Dead to life. In *Art Conservation Training Programs Conference, April 28–29 1980*.

Newark: University of Delaware, pp. 109–13.

Filippakis, S.E. 1978. Analysis of pigments from Thera. In *Thera and the Aegean World* I (ed. C. Doumas). London: Thera Foundation, pp. 599–604.

Germer, R. 1992. *Die Textilfärberei und die Verwendung gefärbter Textilien im alten Ägypten* (Ägyptologische Abhandlungen 53). Wiesbaden: Otto Harrassowitz.

Goffer, Z. 1980. *Archaeological Chemistry*. New York: Wiley Interscience.

Granger, F. 1970. *Vitruvius, On Architecture*. Edited from the Harleian Manuscript 2767 and translated into English by Frank Granger (Loeb Classical Library). London: William Heinemann; Cambridge MA: Harvard University Press [volume II, Books VI–X].

Heywood, A. forthcoming. Paper presented at *Colour and Painting in Ancient Egypt*. Symposium, July 11–12, 1996, British Museum.

Hope, C.A., Blauer, A.M. and Riederer, J. 1981. Recent analysis of 18th Dynasty pottery. In *Studien zur altägyptischen Keramik* (ed. D. Arnold). Mainz: von Zubern, pp. 139–66.

Iskander, N. 1987. Other analyses. In *Excavations in the Royal Necropolis at El-'Amarna 1984* (eds. A. El-Khouly and G.T. Martin). Supplement to *ASAE* 33: Appendix 4, pp. 35–43.

Jaksch, H., Seipel, W., Weiner, K.L. and El Goresy, A. 1983. Egyptian blue – cuprorivaite: a window to ancient Egyptian technology. *Naturwissenschaften*, 70: 525–35.

Kaczmarczyk, A. and Hedges, R.E.M. 1983. *Ancient Egyptian Faience*. Warminster: Aris and Phillips.

Kemp, B.J. 1973. Photographs of the decorated tomb at Hierakonpolis. *JEA*, 59: 36–43.

Lacovara, P. 1990. *Deir el-Ballas. Preliminary report on the Deir el-Ballas Expedition, 1980–1986* . Winona Lake IN: American Research Center in Egypt.

Laurie, A.P. 1913. Ancient pigments and their identification in works of art. *Archaeologia*, 64: 315–36.

Lazzarini, L. 1982. The discovery of Egyptian blue in a Roman fresco of the mediaeval period (ninth century AD). *Studies in Conservation* , 27: 84–6.

Le Fur, D. 1994. *La Conservation des Peintures Murales des Temples de Karnak*. Paris: Editions Recherche sur les Civilisations.

Lucas, A. 1962. *Ancient Egyptian Materials and Industries*. 4th edn., rev. J.R. Harris. London: Edward Arnold.

Moorey, P.R.S. 1985. *Materials and Manufacture in Ancient Mesopotamia: The Evidence of Archaeology and Art. Metals and Metalwork, Glazed Materials and Glass*. Oxford: BAR-S237.

1994. *Ancient Mesopotamian Materials and Industries: The Archaeological Evidence*. Oxford: Clarendon Press.

Mosher, M. 1992. Theban and Memphite Book of the Dead traditions in the Late Period. *JARCE*, 29: 143–72.

Niwinski, A. 1989. *Studies on the Illustrated Theban Funerary Papyri of the 11th and 10th centuries B.C.* (Orbis Biblicus et Orientalis 86). Freiburg: Universitätsverlag; Göttingen: Vandenhoeck and Ruprecht.

Perthuisot, J.-P., Castanier S. and Maurin, A. 1990. La Huntite ($CaMg_3(CO_3)_4$) de la Sebkha el-Melah (Zarzis, Tunisie): un exemple de microbiodiagenèse carbonatogène. *Bulletin de la Société géologique de France*, 8/VI/no. 4: 657–66.

Petrie, W.M.F. 1892. *Meydum*. London: Nutt.

Quibell, J.E. 1913. *The Tomb of Hesy: Excavations at Saqqara 1911–12*. Cairo: SAE.

Quibell, J.E. and Green, F.W. 1902. *Hierakonpolis Part II*. London: Quaritch.

Reisner, G.A. 1923. *Excavations at Kerma* I–V (2 vols). Cambridge MA: Harvard University Press.

Russell, W.J. 1893–4. Ancient Egyptian pigments. *Nature*, 49: 374–5.

1893–5. Ancient Egyptian pigments. *Proceedings of the Royal Institution*, 14: 67–71.

Schiegl, S., Weiner, K.L. and El Goresy, A. 1992. The diversity of newly discovered deterioration patterns in ancient Egyptian pigments: consequences to entirely new restoration strategies and to the Egyptological colour symbolism. *Proceedings of the Materials Research Society Symposium*, 267: 831–58.

Schofield, L. and Parkinson, R. 1994. Of helmets and heretics: a possible Egyptian representation of Mycenaean warriors on a papyrus from el-Amarna. *Annual of the British School at Athens*, 89: 157–70.

Shedid, A.G. 1988. *Stil der Grabmalereien in der Zeit Amenophis' II. untersucht an den Thebanischen Gräbern Nr. 104 und Nr. 80* (Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 66). Mainz am Rhein: von Zabern.

Spurrell, F.C.J. 1895. Notes on Egyptian colours. *Archaeological Journal*, 52: 222–39.

Stevenson Smith, W. 1981. *The Art and Architecture of Ancient Egypt* (rev. W.K. Simpson). Harmondsworth: Penguin.

Strudwick, N. 1991. An objective colour-measuring system for the recording of Egyptian tomb paintings. *JEA*, 77: 43–56.

Terrace, E. 1968. *Egyptian Paintings of the Middle Kingdom*. London: George Allen and Unwin.

Thorpe, J.F. and Whiteley, M.A. 1954. *Dictionary of Applied Chemistry* (4th edn.). London: Longmans, Green and Co.

Tite, M, Bimson, M. and Cowell, M. 1987. The technology of Egyptian blue. In *Early Vitreous Materials* (eds. M. Bimson and I. Freestone). London: BMP, pp. 39–46.

Ullrich, D. 1985. Egyptian blue and green frit – characterization, history and occurrence, synthesis. *DACT*, 18.

Verhoeven, U. 1993. *Das Saitische Totenbuch der Iahtesnacht. P.Colon.Aeg. 10207* (Papyrologische Texte und Abhandlungen 41). Bonn: Dr. Rudolf Habelt GMBH.

Wallert, A. 1995. Unusual pigments on a Greek marble basin. *Studies in Conservation*, 40: 177–88.

Weatherhead, F. 1992. Painted pavements in the Great Palace at Amarna. *JEA*, 78: 179–94, pls. 24–5.

1994. Wall-paintings from the North Harim in the Great Palace at Amarna. *JEA*, 80: 198–201.

1995. Two studies on Amarna pigments. In *Amarna Reports* VI (ed. B.J. Kemp). London: EES, pp. 384–98.

Weatherhead, F. and Buckley, A. 1989. Artists' pigments from Amarna. In *Amarna Reports* V (ed. B.J. Kemp). London: EES, pp. 202–40.

Wiedemann, H. and Bayer, G. 1982. The bust of Nefertiti: the analytical approach. *Analytical Chemistry*, 54: 619A–28A.

Williams, C.R. 1932. *The Decoration of the Tomb of Per-neb: the Technique and the Color Conventions*. New York: MMA.

Ziegler, C. 1990. *Catalogue des Stèles, Peintures et Reliefs Egyptiens de l'Ancien Empire*. Paris: Réunion des musées nationaux.

5. Pottery

JANINE D. BOURRIAU, PAUL T. NICHOLSON AND PAMELA J. ROSE

Introduction: Lucas and the study of Egyptian pottery

Lucas intended his *Ancient Egyptian Materials and Industries* to serve as a tool for Egyptologists, as a distillation of the technical information they might require. In contrast, this chapter has been written by three Egyptologists, all of whom are ceramicists regularly working on excavations. In this capacity they are responsible for the recording of pottery in the field as well as for its analysis in the laboratory (although the analysis itself might sometimes be carried out by others), the application of ceramic evidence to the questions set by the excavation, and the generation of questions which may determine future excavation strategy.

This change of viewpoint illustrates a coming of age for ceramic studies within Egyptology. Such was the authority of Lucas, that between the first edition in 1926 and the Fourth edition by Harris in 1962, few archaeologists undertook wide-ranging studies of the raw materials used for pottery-making or of the manufacturing and distribution processes involved. The work of Reisner (1923) and Oliver Myers (Mond and Myers 1937) constitutes the exception to this rule. Then in the 1960's there began the UNESCO campaign for the systematic survey and excavation of Nubian sites before they were flooded by Lake Nasser. The campaign brought into the Nile Valley archaeologists with different educational backgrounds: prehistorians like Bietak and Nordström and the anthropologist W.Y. Adams. It also highlighted a need for up-to-date ceramic chronologies for use in surveys and large-scale excavations. The methodologies created in response to the emergency and their ensuing publication (Bietak 1968; Nordström 1972; Holthoer 1977; Adams 1986) had a profound influence on many aspects of Egyptian archaeology, but on ceramic studies more than any other. Nevertheless it was not until 1976, (Arnold 1976) that a chronological account of manufacturing processes was attempted and a comprehensive study appeared in 1993 (Arnold and Bourriau 1993). This was largely based upon observations made during field recording, and related also to representations of pottery-making in tomb models and scenes.

Unintentionally Lucas had bequeathed to Egyptology the presumption that technology, as defined in this volume, was the domain of the specialist, not the archaeologist. Research was something to be done in the laboratory, library or museum after the excavation was over. One of the most useful studies of New Kingdom pottery is that of Nagel (1938), carried out on the pottery vessels from the houses and tombs of Deir el-Medina. It is a basic study of the function of pottery and draws on comparisons between funerary and domestic assemblages; sadly its value is incalculably reduced by the poor quality of the original field recording. It is the ending of this ultimately unhelpful divorce between field recording and the study of materials and technology of pottery-making, which has permitted the contemporary blossoming of ceramic studies.

The raw materials of pottery manufacture

Extraction

The division between 'Nile silt' and 'marl' clays is now so well-established in Egyptian archaeology that to attempt to change it would be counterproductive. In fact, apart from the contradiction of a 'silt clay' (strictly 'silt' and 'clay' are size terms, for particles respectively 0.06–0.002 millimetres and <0.002 millimetres in diameter) there is little reason to alter these terms so long as they are clearly understood (Nordström and Bourriau 1993: 160, fig. 5).

A 'Nile silt' or 'silt' clay is any that has been deposited by the river between the Upper Pleistocene and the present. Consequently deposits can occur well away from the present course of the Nile as well as within the modern flood plain. The clay is rich in silica and iron and fires red to brown when fired in an oxidising kiln atmosphere. In its raw state it varies from grey to almost black.

'Marl' clays, whose defining property is that they are calcareous, may be subdivided into:

1. Marl clays originating from shales and limestone found along the river between Esna and Cairo.
2. Secondary deposits such as those from the Wadi Qena, source of the most important modern marl clay indus-

try. These clays derive from sediments washed down the *wadi*, mixed with local shales and limestone (Butzer 1974).

Marl clays normally fire to a cream or white colour in an oxidising atmosphere, although the section may show pink or orange zones. These clays are rich in mineral salts, so the surface is frequently covered by a thin layer of effloresced salts which fire to form a white surface easily mistaken for a deliberate 'slip' coating by the unwary. If fired to a high enough temperature, *c.* 1000 °C, this coating can become an olive-green colour and sufficiently vitrified to resemble a green glaze.

In addition to these two groups there are kaolin clays found principally at Aswan. They were not exploited until the early Roman period (Ballet and Vichy 1992: 113–16) but a local kaolinite clay was also exploited in the western desert oases: at Kharga, (Douche – early to late Roman, Ballet and Vichy 1992: 116–19) and at Dakhla ('Ayn Asil – First Intermediate Period; Ballet and Picon 1990). This same oasis clay may have been used for a class of amphorae, kegs and gourds found throughout Egypt from New Kingdom to Saite times (Aston 1996: 9).

There is enormous variation in the fabrics which potters derived from these clays. One non-site specific classification scheme, which has been proposed to describe them, is the Vienna System (pp. 130–32).

A division between marl and silt potters is clearly evident in modern Egypt (Blackman 1927; Nicholson and Patterson 1985a, 1989; Nicholson 1995a), although Brissaud (1982: 76) describes Luxor potters as mixing clays to individual recipes. Archaeological evidence suggests the division extends back at least as far as pharaonic times. It is easiest to observe in Lower Egypt during the Middle Kingdom (Arnold 1982; Bourriau 1996). Whilst we should be wary of taking an environmentally deterministic view of Egyptian pottery production we need to be aware that there seem to be differences in the nature of ceramic production according to the type of clay used.

Since the Nile flows through the length of Egypt, silt clays were very widely available in antiquity, and local industries must have existed on so small a scale that they are not yet recognised archaeologically. An exception to this is Hierakonpolis, where fifteen kilns of the Predynastic period exploiting local Nile sediments have been found (Allen *et al.* 1989). Extraction would generally have been a relatively simple matter of digging clay from the riverbank or irrigation channels. However, some care would be needed to avoid incorporating unwanted vegetable matter or aplastic materials such as shell. One way to avoid undesirable material would be to collect clay that had been left to form 'pans' on the surface as the inundation receded. Such naturally fine, levigated, clay would be obvious as it began to dry out and crack, often peeling from the underlying layers.

The extraction of marl clay is potentially more complicated. The best-known modern source is Ballas in Qena Governorate (Nicholson and Patterson 1985a), where miners extract the clay from large underground workings. The clay is composed of very fine laminae so compacted that it has the appearance of solid rock. Sometimes veins of calcite run through the mass and the miners try to avoid incorporating this material because of the damage it can cause during firing. Mining takes place without the use of any pit props or shoring, and as a result no extraction takes place in the damp winter months when the clay is softer and collapses can occur. Miners may work for one particular group of potters, but are not potters themselves, and this degree of specialisation is typical of the marl clay industry. The clay they extract is taken to the villages by camel or donkey for primary processing by the potters.

Mined marl clay is of the highest quality and is limited in its occurrence, but surface deposits resulting from limestone erosion also occur. Such deposits have been located at Amarna (Nicholson 1989a) and experimentally shown to be suitable for pottery manufacture. Whilst it is unlikely that such surface panned deposits would form the basis of a specialised marl clay potting industry, it is not unlikely that they might be exploited from time to time or mixed with silt clays to enhance their working properties (Brissaud 1982: 76). Evidence for such mixing is hard to identify in pharaonic times (Nordström and Bourriau 1993: 166; Bourriau *et al.* in press) but there is some evidence at Hierakonpolis (Allen *et al.* 1989: 55) and, in the New Kingdom at Qantir (Aston 1989a: 10) and Memphis, of marl clay slips and handles applied to Nile silt vessels (Fig. 5.1).

Primary processing

Many archaeologists still assume that all clays are levigated before use, but this is unwarranted. While there is no evidence of it in the pottery workshop (Fig. 5.2) or ceramics from 'Ayn Asil (Soukiassian *et al.* 1990: 43), there is evidence that it may have been practised upon Plum Red Ware at Hierakonpolis (Allen *et al.* 1989: 55). Levigation is the process by which the coarse fraction of a clay, and any large aplastic inclusions it may contain, is separated out from the fine fraction. Such levigation is usually carried out in one or more levigation tanks or pits, and the well-known potting scene from the tomb of Kenamun (TT93) has sometimes been interpreted as including a levigation pool. Holthoer (1977: 19) interprets an area of grey clay in which a workman is standing as being a pool in which levigated clay is being trampled, despite the fact that such action would defeat the object of levigation by mixing up the fine and coarse clay fractions (Arnold, 1993: 12–13). The workman is more likely to be mixing the clay.

Modern Egyptian marl clay potters working as part of the Ballas industry process their clay in several stages. The first is to break up the large rock-like blocks of clay into

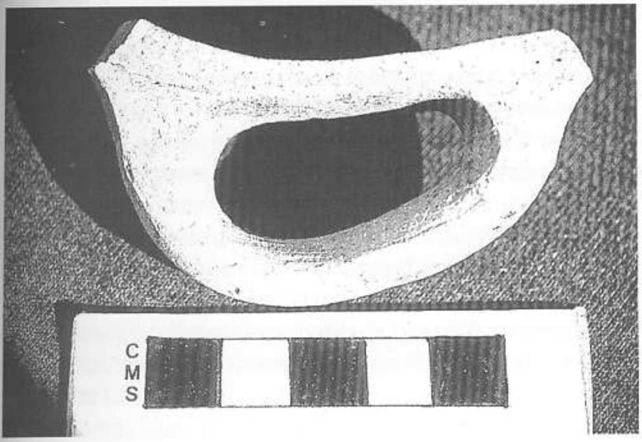


Figure 5.1 Handle of New Kingdom amphora from Memphis. The vessel body is made of a Nile clay but covered with a thick marl clay slip and the handle is made of the same marl clay.

smaller pieces and put them into a shallow circular pit, where they are soaked with water. Despite the solid appearance of the blocks, the individual clay laminae of which they are comprised soon begin to separate and soften.

The second stage in this process is to trample the softened clay using water buffalo. An assistant tramples the material at the same time as he guides the animals, and while so doing picks out any aplastic material – such as pieces of calcite – which he finds underfoot. There are no representations of pharaonic potters using animals to tread their clay, and it is possible that this is a relatively recent introduction. It is also possible that all surviving representations of potters show the preparation of Nile silt clay, where trampling with animals seems to be less common.

The third stage in the preparation of the marl clay is its removal from the outdoor trampling pit and its deposition on the cobbled floor of the potter's workshop. This area is a trampling floor where the clay is thoroughly compacted ('wedged') by stamping. This is carried out in a very methodical manner, usually with two assistants working around the pile of clay whilst standing opposite one another. Similar positioning is clearly shown in the scene from the tomb of Bakt III (BH15) at Beni Hasan (Holthoer 1977: 11–13; Arnold 1993, fig. 3A). During this process any remaining lumps of aplastic material and pockets of air are removed, leaving homogeneous clay with the consistency of butter (cf. Rice 1987: 119). It is from this prepared clay that the potter makes the Ballas jars for which the region is famous.

It should be noted that this clay has not been levigated; nor has it been 'tempered' – the addition of material to improve its working properties. This added material is usually in the form of aplastics such as sand, rock fragments or vegetable matter and has traditionally been known as 'temper' by archaeologists. However, confusion has arisen from the application of the term to all inclusions larger than the clay/silt size fraction in the matrix, whatever their origin. The term 'filler' is more precise in referring only to deliberate additions by the potter. Modern potters also use the term 'grog' but in archaeology 'grog' has come

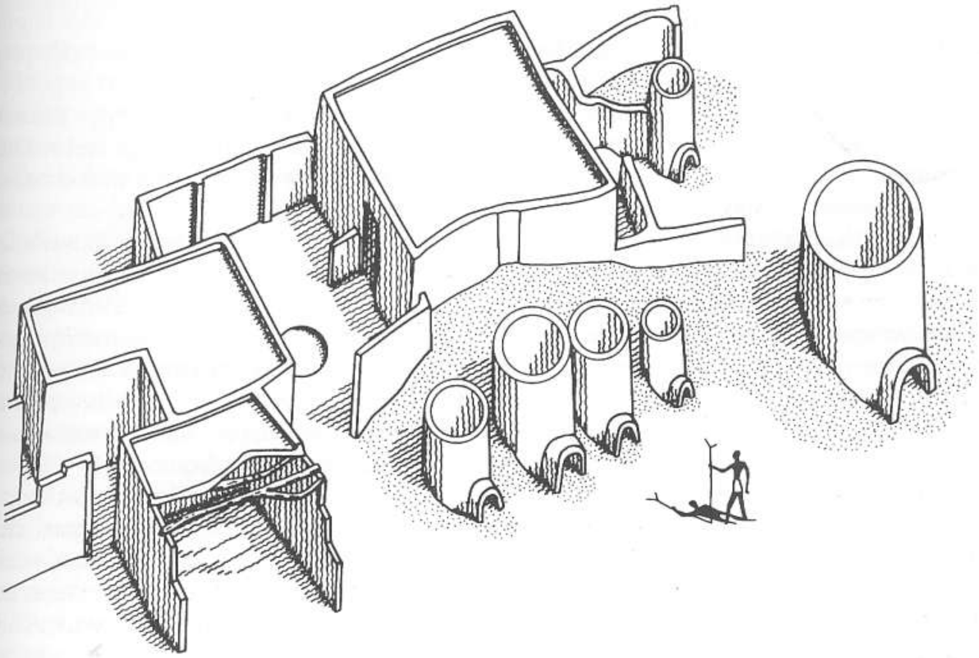


Figure 5.2 Axonometric reconstruction of Workshop 2 at ʿAyn-Asil, Dakhla Oasis. First Intermediate Period. The stippling represents the kiln debris. Courtyard with basin for preparing clay leading to workshop and potter's dwelling. Note the kilns are placed to benefit from the prevailing wind.

to mean the addition of a filler comprised of ground up pottery, and care must be taken not to confuse the two uses of this term (Hodges 1989: 20; Rice 1987: 476).

Nile silt clay is also subjected to soaking and trampling, but all contemporary potters observed by Nicholson carry out this operation within a single trampling pit. The clay is placed in the pit and soaked in order to soften it. It is then trampled by one or more of the potter's assistants. As in the preparation of marl clay, aplastic material is removed during this process. It is likely that such tomb scenes as exist and which show the preparation of clay are showing preparation in a single pit at a silt clay workshop, and such pits have been discovered at ʿAyn Asil (Soukiassian *et al.*, 1990: 46–8) and at Amarna sites Q48.4 (Kirby 1989) and O45.1 (Nicholson 1995b: 13–14).

Modern silt clay potters are known to add material to their clay, and this can include ash, lime, chopped straw, donkey hair, animal dung (sometimes added accidentally!) or sand. From archaeological evidence we can add fine grass, papyrus hairs (Holmen 1990) and calcite (Kroeper 1992: 30). The potters at ʿAyn Asil in the Dakhla Oasis added plant ash to their kaolinite clays (Soukiassian, Wuttmann and Pantalucci 1990: 48). There is an important relationship between clay preparation, firing and vessel function and this will help to determine the nature of any added filler.

Filler, firing and function

The relationship between these variables is a complicated one and numerous permutations are possible. However, since filler materials are a source of much confusion some basic rules should be considered (Rye 1976).

Firing of pots in an open 'bonfire' firing can be very effective (see p. 127*ff*) but lacks control. Temperatures rise rapidly, and as a result the steam generated from moisture remaining in the clay must be able to escape rapidly if the walls are not to blister and become deformed, so spoiling the vessel. The incorporation of coarse material into the clay helps to 'open' the body, thus allowing the escape of the steam without damage to the vessel. As a result, coarse fabrics are well-suited to firings over which the potter has relatively little control or where a rapid rate of temperature increase is desirable. Although this applies primarily to bonfire firings it is also relevant to simple updraught kilns (see p. 128*ff*) and is a common feature of silt clay pottery-making, ancient and modern. The open texture of the fabric also allows greater penetration of hot gases, helping to fire the vessel more thoroughly and economically.

A coarse fabric may also be desirable for functional reasons, because of its greater resistance to thermal shock (Cardew 1952; Woods 1986). A fabric which has a large quantity of aplastic or plant material added as filler has a much greater resistance to thermal shock than does a fine fabric. This is because of the ability of the fabric to cope with differential expansion. When a vessel is heated over a cooking fire, different parts will become heated and expand at different rates and this creates microscopic cracks. In a coarse fabric the propagation of these cracks is limited since as they spread they meet the voids left from the burning out of vegetable matter or voids surrounding aplastic inclusions and so are halted. The structure of a coarse cooking pot can be likened more to a basket than to a rigid container, in that it is capable of some degree of movement as it is heated and cooled. The propagation of cracks in a fine fabric would lead to the shattering of the vessel.

The exact nature of the filler which should be used in cooking pots, crucibles and other vessels subject to heating, has been widely debated. It was long argued that materials such as quartz would be unsuitable because of their expansion, in the case of quartz at 573 °C, which would lead to cracking of the vessel. It has now been convincingly shown by Woods (1986) that this expansion does not crack the vessel; rather, the quartz inclusion sits in a void left when it shrinks on cooling following the firing of the vessel and so is ideally suited to prevent the wide propagation of cracks during subsequent heating. Arnold (1985: 23–9) has compared the thermal properties of various possible filler materials, but in practice virtually any aplastic material is suitable and has been used. In the Egyptian context sand, of which quartz is the major component, is an obvious choice (see p. 131, Marl C).

As well as resistance to thermal shock a coarse or open-textured fabric may be desirable for porosity. The large *zirs* still used in Egypt for the storage of drinking water are examples of coarse siltware vessels fired to a temperature at which vitrification is relatively slight. Water is able to permeate the fabric and evaporate from its surface, so keeping the water cool and fresh. The same principle is applied to the *gidr* and *fakshia* vessels made in Middle Egypt (Nicholson 1995a) and used for the short-term storage and cooling of water. These vessels are heavily tempered with chopped straw, which burns out during firing.

Finer fabrics can also serve as water coolers, but rely for this purpose on the natural porosity inherent in relatively low temperature firings. Thus the famous Ballas jars of Upper Egypt have no added filler, but rely on their natural porosity to cool the water. Overfired examples of these jars are much less desirable as water coolers, and the vitrification of the effloresced surface layer makes them much more suitable for the storage of other liquids.

Finer fabrics, whether marl or silt, are not well-suited to use as cooking vessels, and it is notable that marl clay vessels, particularly in the New Kingdom, are usually made for specialist storage on a large scale as in the case of the meat jars or amphorae (Rose 1984, groups 13 and 21). They might also be used for containers for precious commodities as in the case of the 'pilgrim flasks'. They also appear as fine tableware (for a review of New Kingdom marl forms and fabrics, see Bourriau and Nicholson 1992). This finer fabric is less tolerant of rapid firing and so, in untempered form, is usually fired in a kiln rather than in an open firing. Firings tend to be much more controlled than for coarser silt wares (Nicholson and Patterson 1989; Nicholson 1995a) and to take longer to reach high temperatures, so steam can be released from the vessels more gradually and without any bloating or blistering of the walls.

It is not true to say that marl clays are always fine and without filler whilst silt wares are coarse and contain much filler material (the Marl C fabric group of the Middle Kingdom is only one obvious exception), but as a general rule finer fabrics tend to be in marl clays and coarser ones in silt. The more localised occurrence of marl clays, combined with the need for more carefully controlled firing, helped to develop a more specialised industry, manufacturing a more limited range of vessel forms than that encountered amongst silt clay potters. This seems to be as true in antiquity as it is today.

The relationship between forming technology and fabric should also be noted. In the past it has been widely held that wheel-thrown wares must always be fine fabrics, because the inclusion of coarse aplastics would damage the potters' hands. As a result one or other of the hand forming techniques (see p. 125) must, it is argued, have been utilised for coarse fabrics. In fact this cannot be held to be an invariable rule, and contemporary Egyptian potters confirm that it is possible to throw clay which contains substantial quantities of aplastic material, if the clay is soft enough and the wheel speed slow enough.

Secondary processing

Once clay has been prepared so as to be suitable for the forming of vessels the potter has a range of options open to him (see for what follows Arnold 1993 or more generally Rice 1987).

The earliest Egyptian pottery is handmade, i.e. formed without the aid of the potter's wheel. A whole range of techniques is covered within the term 'handmade' and several of these may be combined in a single vessel. The simplest method of pottery-making is modelling: using the fingers to produce a so-called 'thumb-pot'. Examples of this type never entirely die out, although they are commonest in the early periods (Arnold 1976). Brunton (1948: 18) records an example from Matmar, dating to Naqada II (see also Bourriau 1981a: 21). A development of this technique is to use tools to extend the height of the walls beyond the reach of the potter's arms. This can be done by scraping the walls upward with a spatula-like implement, or more usually by the 'paddle and anvil' method.

The solid anvil (usually a round stone or specially shaped clay object – Nicholson 1995a) is placed inside the vessel whilst the clay is beaten against it using a wooden paddle. This has the effect of thinning the walls and by working upward from the base of the vessel the potter is able to increase its height. Egyptian potters today use it in the manufacture of water cooling vessels, and it was probably the technique used in making 'pan grave' pottery of the late Middle Kingdom and Second Intermediate period. It is particularly well-suited to the making of globular shapes, especially if the clay is coarse. Whilst fabrics which contain large aplastic inclusions can be thrown on the wheel (see above), if very large quantities of such inclusions are required then hand forming is preferable.

Another common hand-forming technique is that of coil or ring building. As the name implies, rings or short coils of clay are made and then luted together. The joints between the coils may be simple butt joints or take a more complicated form akin to tongue and groove joints in woodwork (Stevenson 1953). This may be accompanied by the use of paddle and anvil to help smooth the walls and so disguise the coils. The best coil built pottery can be hard to distinguish from paddle and anvil or even wheel-thrown wares. Probably the most carefully executed coil-built vessels are the black-topped wares of the Predynastic (e.g. Bourriau 1981a: 18). In some cases these seem to have been built on a turntable, sometimes misleadingly referred to as a 'slow wheel' by archaeologists. Such a device helps to make the vessel shape more regular, and in some cases the turntable may have served as a true potter's wheel by being spun sufficiently rapidly to build up centrifugal force and so 'throw' parts of the vessel such as the rim. Alternatively, the rim may have been 'turned' on a turntable to make it more even. Turning should not be confused with throwing. The first is a process akin to lathe turning whereby clay is removed from a partly dry ('green' or 'leather hard') vessel, whilst the second is the forming of a vessel using pressure and centrifugal force. In the pottery from the 'Ayn Asil workshops in the Dakhla Oasis in the First Intermediate period, a variety of hand-forming techniques can be observed: modelling with the fingers, coiling and the use of a turntable. Marl clay imports from the Nile Valley, in contrast, show unequivocal evidence of throwing.

Vessels can also be moulded, either by pressing the clay into a hollow 'open face' mould or by pressing it over a 'form' known as a *patrix*. It is this latter type of moulding which is best known from Egypt. It is used from as early as the Old Kingdom to produce the specialised vessels known as bread moulds. These are low fired, coarse clay vessels in which bread was baked, and which would be broken and discarded after use. It was desirable that they should have a smooth interior in order to prevent the contents adhering too closely to the vessel walls (Jacquet-Gordon 1981: 11–24). Occasionally open face moulds were used, for example in making the faces on the lids of canopic jars, for figure vases (Bourriau 1987) and for the bases of Eighteenth Dynasty marl clay amphorae (Hope 1989: 93).

The potter's wheel is known from representations as early as the Fifth Dynasty (tomb of Ty, Saqqara, Fig. 5.3) and perhaps as early as the Fourth (tomb of Nebemakhet, Giza

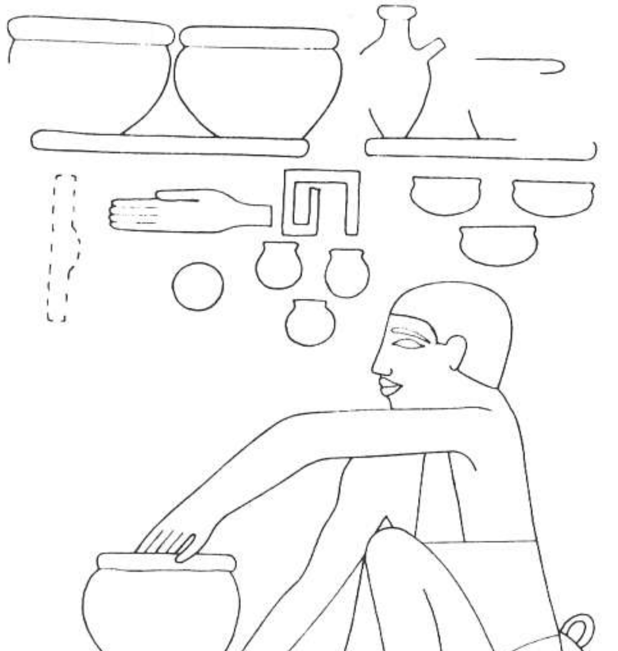


Figure 5.3 Potter from the Fifth-Dynasty tomb of Ty at Saqqara.

– though this could be a turntable). Wheel-thrown pottery is certainly known from this time onwards and it rapidly becomes the predominant technique of vessel fabrication (Arnold 1993: 41–79).

There has been much debate as to the nature of the earliest potter's wheels and Hope (1981) considered those in the form of a pivot made from two stones to be nothing more than a turntable. However, recent work by Powell (1995) has convincingly demonstrated that these were capable of producing true thrown pottery, and that furthermore it is possible to throw some forms using only one hand, the other being employed to keep the wheel moving, a technique illustrated in the scenes in the tomb of Amenemhat at Beni Hasan (BH2) (see Arnold 1993: 48, fig. 50) and elsewhere. The wheel-head has a greater diameter than the uppermost stone (as the tomb representations suggest) through the attachment of a large clay bat to this stone, which serves as a flywheel and wheel-head combination. As well as representational evidence, what is believed to be an actual Old Kingdom wheel-head has been recovered during the Czechoslovakian excavations at Abusir (Verner 1992: 55–9). In passing, it should be noted that smaller clay bats are regulary used in potting and are placed on the wheel-head so that vessels can be thrown on them and then lifted off without damage to the newly thrown pot. A fragment of what is believed to be a bat has been discovered from excavations at site 045.1 at Amarna.

As well as the throwing of pottery it is known that th wheel was used in the turning process. This is evident no only from the spiral incisions found on the bases of som vessels, but also from actual shavings of clay produced as a result of the turning process and, characteristically, thrown into a clay preparation pit for re-cycling at Amarna site O45.1.

The kick-wheel (or 'combined wheel'), in which the power is provided by the potter kicking a flywheel mounted below the wheel-head, is first seen on representations from the temple of Hibis at Kharga, and dates to the time of Darius (521–486 BC) (Holthoer 1977: 24; Arnold, 1993: 79–83).

It should be borne in mind that vessels are not necessarily produced in a single operation (see Fig. 5.4). Large pots might be made in several sections which were then luted together. A vessel with a round base might have its shoulders and neck made in one operation and then be inverted in a specially modified wheel-head before the base is shaped (Nicholson and Patterson 1985a). Handles, and/or applied or incised decoration might also be added.

Once a vessel has been formed, by whatever means, it must be allowed to dry. In Egypt it is usually sufficient to allow vessels to dry in the sun, although at times it may be necessary to shade them to prevent over-rapid or differential drying which might lead to cracking. Early in the year, when nights are cold, vessels might even be covered with straw or some similar material to help prevent frost damage.

It is during this drying stage that the effloresced surface forms on some of the marl clays, such as those from the Ballas region. Where a vessel is in contact with the ground efflorescence may be incomplete and a patch is left on the base of the vessel, which becomes a permanent feature once the vessel is fired. Similar marks may be left on the upper parts of vessels where handles have touched during the drying process.

Once vessels have dried they are commonly subject to some form of inspection, however cursory. Those which have dried so badly as to have major cracks, or which are damaged during the drying process, will be thrown into the clay preparation pit for recycling, a process known from antiquity (Nicholson 1995b: 14) as well as among modern potters. Those vessels with only minor damage might be repaired by the insertion of a little wet clay (Nicholson 1995a: 284). It is also at this time that slip can be added to the vessels.

A slip is a suspension of fine clay, often with the addition of a pigment to produce a colour different from that of the clay body itself. It may be applied to change the surface colour, or simply to give a clean, even finish to a vessel. It is allowed to dry and will be fixed by firing. Any painted decoration is almost always added at this stage, before firing. An exception is the polychrome painted funerary

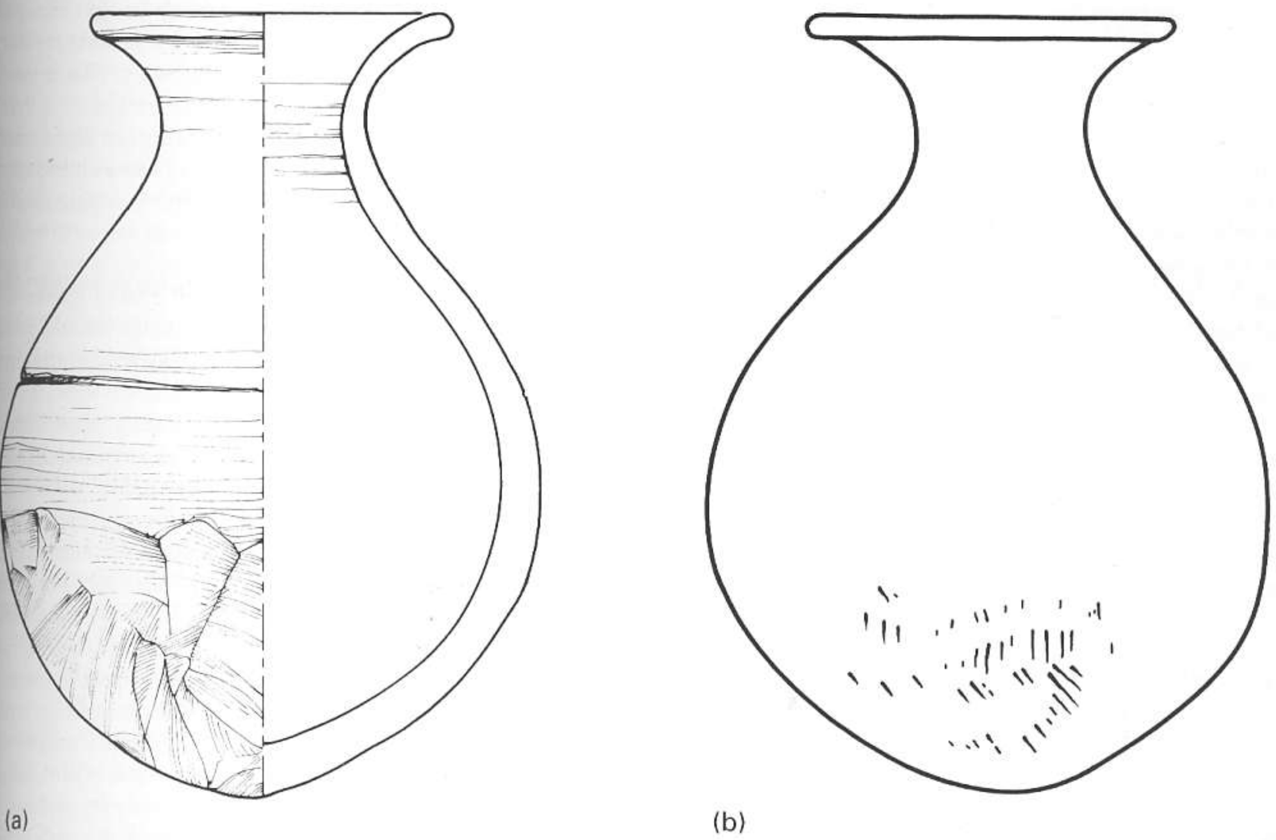


Figure 5.4 Middle Kingdom flask from Diospolis Parva (Fitzwilliam Museum, E.83.1899). (a) Drawing by W. Schenck with the original published drawing, (b), for comparison. The new drawing shows that the vessel was thrown on the wheel and, after drying, was trimmed with a knife to remove the excess clay. Rim diameter 8.1 cm.

pottery of the New Kingdom (Bell 1987). The pigments used have been studied, particularly by Noll (1981a and b), who re-examined some of Lucas' data as well as by Riederer (1974) and Bachmann, Everts and Hope (1980) (see also Chapter 4, this volume).

When dry, slip may be burnished by polishing with a hard, rounded object such as a pebble. An unslipped vessel surface can also be burnished in this way. The effect of burnishing is to compact the clay at the surface of the vessel, which helps to make it not only less permeable to liquids, but also shinier. It is likely that the purpose of much burnishing is purely decorative rather than functional, and the effect is such that it has sometimes been erroneously described as a 'glaze' by Egyptologists. Glaze is 'a glassy coating melted onto the surface of a ceramic article' (Rice 1987: 476) and although applied to faience (see Chapter 7, this volume) it is not known from Egyptian pottery before Roman and more especially Islamic times.

Tertiary processing: firing

Pottery firing causes a change in state from a plastic to an aplastic material (Nicholson 1993). Until this point it is possible to add water to a vessel and so return it to its plastic clay state for recycling. After firing, badly damaged vessels – generally known as 'wasters' – are virtually useless, although they may occasionally be ground up for use as the type of filler known as grog. It should, however, be noted that the discovery of a vessel showing firing cracks or similar deformities on a site need not mean that it is a waster and was therefore made at the site of its discovery. Potters frequently disguise what they regard as minor faults in their work by filling them with unfired clay, dough or a fugitive slip paste (Nicholson 1995a: 288, 297).

The simplest form of firing is the 'open', 'bonfire' or 'clamp' type. Vessels to be fired are heaped up and fuel is piled over and amongst them. They may be surrounded by a low wall of stones or turf, or simply piled up on the ground surface. Occasionally they are fired in a shallow pit or depression. Whatever the case, there is relatively little control over the firing and temperatures usually rise quite quickly. Tobert (1984: 148) provides data on the temperature ranges of various bonfire firings and from these and other data it has been possible to calculate a mean maximum temperature for open firings of 860 °C (Nicholson 1989b: 128). Debono and Mortensen (1990) have suggested temperatures as high as 900 °C. This is higher than is often assumed, but it should not be forgotten that firing is a function of time *and* temperature, and that the absolute peak temperature is therefore less important than the time for which a particular temperature is maintained. Temperatures over *c.* 600 °C are generally sufficient to sinter clay and render it ceramic.

Skilled potters may attempt to manipulate open firings by placing those vessels which they require to be fired for longest at a point in the stack where they are subject to the most sustained heating, such as on the downwind side. This will also allow them to be heated more gradually than those where the fire is first lit, and whose temperature gradient may be most severe. It is to be expected that the coarsest fabrics would be placed at the point of steepest temperature gradient.

Vessels are sometimes removed from open firings whilst they are still hot, and after quite short periods of time, so that they can be coated with something to help render them less permeable. This is one way in which potters can counteract the permeability of coarse fabrics needed for open firing. Milk or resin may be used by modern potters on the inside of the hot vessel to block the pores so that once cooled it has a much reduced porosity. The possibility that such practices may have been used in antiquity must be borne in mind when considering the investigation of vessel contents by scientific means.

Although bonfire firings can reach high temperatures they cannot readily maintain them. As a result a more sophisticated construction, the updraught kiln, is commonly used (Holthoer 1977: 34–7; Soukiassian, *et al.* 1990: vii–xii; Nicholson 1993: 106–17). This comprises a chimney-like structure whose upper part is separated from the lower by a gridded floor or 'chequer'. The vessels to be fired are stacked in the upper part, with their open ends facing downward, and a fire is lit in the lower part of the kiln. The hot gases rising through the chequer into the stack not only pass between the vessels, but circulate inside them, thus firing the clay (Soukiassian, *et al.* 1990: 49ff.).

Such updraught kilns are commonly built into a bank or partly sunk into the ground (Nicholson 1989c; Soukiassian *et al.* 1990: 9) and this, combined with the wall of the structure, gives them a greater degree of insulation, and therefore thermal efficiency, than is possible in an open firing. It also allows a greater number of vessels to be fired in a relatively small space. The fire can be fuelled continuously, and the atmosphere controlled so that a reducing fire can be produced if desired.

Studies of modern Egyptian potters (e.g. Nicholson and Patterson 1989, Nicholson 1995a; Brissaud 1982) suggest that although the temperatures achieved in kiln firings may not be higher than the maximum possible from some bonfire firings, the degree of control is very much greater and the time for which high temperatures can be maintained is also greater. Temperatures of 1000 °C can be reached relatively easily with a simple updraught kiln, and the examination of Egyptian pottery by various re-firing techniques suggests that most firing temperatures were well below this (Soukiassian *et al.* 1990: 67ff.).

Firing atmosphere, 'redox conditions', can also be important in firing. A clean fire, with clear flames and relatively little smoke, is one where there is ample oxygen, and is thus known as an oxidising fire. The result will be to oxidise iron rich clays so that they fire red or reddish brown. A fire where there is little oxygen and a great deal of smoke will reduce iron to its ferric state yielding black vessels. Most ancient Egyptian pottery is the result of an oxidising firing, although this needs some qualification, since most firings actually comprise a series of oxidation and reduction events. The red colour of most Nile clays suggests that the firing was concluded with an oxidation phase.

The manipulation of firing conditions is responsible for the production of the black-topped red ware so characteristic of the Predynastic period. Although produced without the aid of a kiln, this is some of the finest pottery known from ancient Egypt. The exact method of its manufacture is unknown, but one simple method would be to fire the vessel in a reducing atmosphere in an open firing, and then invert it in sawdust or some similar medium whilst it was still very hot at the end of the firing. The fresh sawdust would draw oxygen away from the clay thus reducing the iron to give the black topped effect (Adams 1988: 20; Makundi *et al.* 1989).

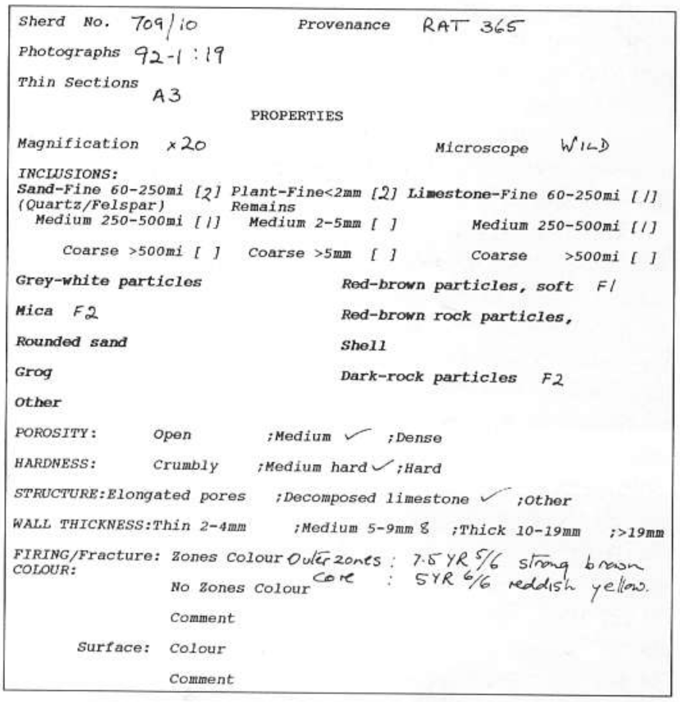
After a vessel is fired it is possible to apply a non-permanent slip, known as a fugitive slip, to it (French 1992: 89). However, these rarely survive archaeologically, and are commonly used to conceal faults resulting from firing, such as discoloration or minor cracking. Such cracks are filled with clay which, after drying in the sun, is disguised by the slip (see p. 127).

The composition of Egyptian pottery

Knowledge of pottery composition, understood in its broadest sense, to include the composition of fillers, slips and decorative pigments (see below) as well as clay, is a powerful tool in understanding cultural process. It takes archaeologists to a fundamental question: was the pottery locally made or imported to the site and if the latter, from how far away? In conjunction with other properties of ceramic – shape, technology, function, and decoration – composition helps to characterise a pottery industry and so to define the culture which produced it. After over 100 years of excavation in the Nile Valley, we are only now beginning to understand the materials used in pottery making. One reason is that only within the last thirty years has the fabric of a vessel (defined as the potter's paste after firing) been recorded systematically for all pottery. Much early reporting defined fabric by a single property such as surface colour, texture, filler or hardness rather than by a combination of properties observed in a freshly broken cross section. In such cases the route back from the fired vessel to the raw material of the potter's paste is tortuous if not blocked. Even with modern recording it still remains difficult to trace, as all ceramicists agree (Rice 1987: 417–19), and particularly so in Egypt where so few centres of production have been found, especially for the Dynastic period.

The relation of pottery fabric to clay

To characterise fabrics, archaeologists have taken over some of the terms used by geologists to describe clays, but this practice should not disguise how different the two materials are. Between the raw clay and the fabric, changes have taken place due, in chronological order, to: the potter's processing, which may involve removal of matter (cleaning), separation of size fractions (levigation) or addition of solid matter (filler), as well as addition of water; the shaping process, which may orientate the inclusions in a particular direction; and firing, which produces complex chemical changes in composition. Even after manufacture, further changes may occur to alter the composition of a vessel fabric: during use, vessel contents may be absorbed into the pores; after deposition, material from the environment may similarly become absorbed; and finally excavation and post-excavation processes such as exposure to light, washing, acid soaking (not usually practised in Egypt), and storage in plastic bags may modify it.



Sherd No. 709/10 Provenance RAT 365
Photographs 92-1 : 19
Thin Sections A3

PROPERTIES

Magnification x20 Microscope WILD

INCLUSIONS:
Sand-Fine 60-250mi [2] (Quartz/Felspar) Plant-Fine<2mm [2] Remains Limestone-Fine 60-250mi [1]
Medium 250-500mi [1] Medium 2-5mm [ ] Medium 250-500mi [1]
Coarse >500mi [ ] Coarse >5mm [ ] Coarse >500mi [ ]
Grey-white particles Red-brown particles, soft F1
Mica F2 Red-brown rock particles,
Rounded sand Shell
Grog Dark-rock particles F2
Other

POROSITY: Open ;Medium ✓ ;Dense
HARDNESS: Crumbly ;Medium hard ✓ ;Hard
STRUCTURE: Elongated pores ;Decomposed limestone ✓ ;Other
WALL THICKNESS: Thin 2-4mm ;Medium 5-9mm 8 ;Thick 10-19mm ;>19mm
FIRING/Fracture: COLOUR: Zones Colour Outer zones : 7.5YR 5/6 strong brown
No Zones Colour Core : 5YR 6/6 reddish yellow.
Comment
Surface: Colour
Comment

Figure 5.5 Fabric description sheet, filled in for the example of Nile B2 (photographed in Figure 5.6a). Eighteenth Dynasty, from Memphis.

Properties of fabric

Fabric, like raw clay, consists of a fine matrix, made up of particles in the silt and clay size fraction (i.e. >0.060 millimetres), together with varying quantities and types of larger inclusions. Sorting is a term used to describe the size distribution of particles, so that well-sorted means an even distribution of size fractions. The inclusions may have been deliberately added as filler or be naturally occurring, and our ability to determine the clay source of the fabric depends largely on our being able to decide which they are (Porat and Seeher 1988).

The significant properties of a fabric are texture, i.e. number, size and shape of inclusions and their distribution through the matrix (Nordström and Bourriau 1993, figs. 1 and 2); colour of the exterior surface and fracture; mineral inclusions (most commonly limestone, ochre, mica, feldspar, quartz, shell and ash); organic inclusions (commonly plant remains represented as rectangular voids or rod-shaped impressions with or without the silica skeleton of the plant fibres remaining); porosity (which may be defined by the percentage of voids to total volume within a fabric); and hardness (defined as degree of resistance to scratching).

Since these properties were partly acquired during the secondary processing and firing of clay, if we can understand their character we may be able to infer the existence of certain processes and firing temperatures. To take a site-specific case: it has been argued that the Plum Red Ware of Hierakonpolis was made from a levigated clay, because of its uniformly fine texture determined by grain-size analysis (Allen *et al.* 1989: 55). To take a more generally applicable example: limestone inclusions begin to decompose in firing temperatures of about 850 °C and the resulting reaction rims are visible, sometimes even to the naked eye (Bourriau 1981a: no. 148).

Recording the properties of a fabric

The recording of the properties of a fabric may be considered as having four levels, ideally linked by a statistically valid sample of the same material passing through all. The first level is the recording in the field, museum or storeroom of all the pottery, using a × 10 hand lens. The second is the collection and recording in greater detail of a representative series of sherds which illustrate the criteria used for the first level classification. Here the essential tools are a binocular microscope and a camera (Arnold, 1981, see Fig. 5.6). The third level is petrographic analysis using thin-sections, which allows most of the inclusions in the sand-size fraction and larger to be identified, and creates more accurate data for measuring texture and porosity, whilst serving as a bridge between the lowest level analysis (1 and 2) and the highest (4) (see Hamroush and Zeid 1990). This fourth level, confined to the laboratory, is detailed compositional

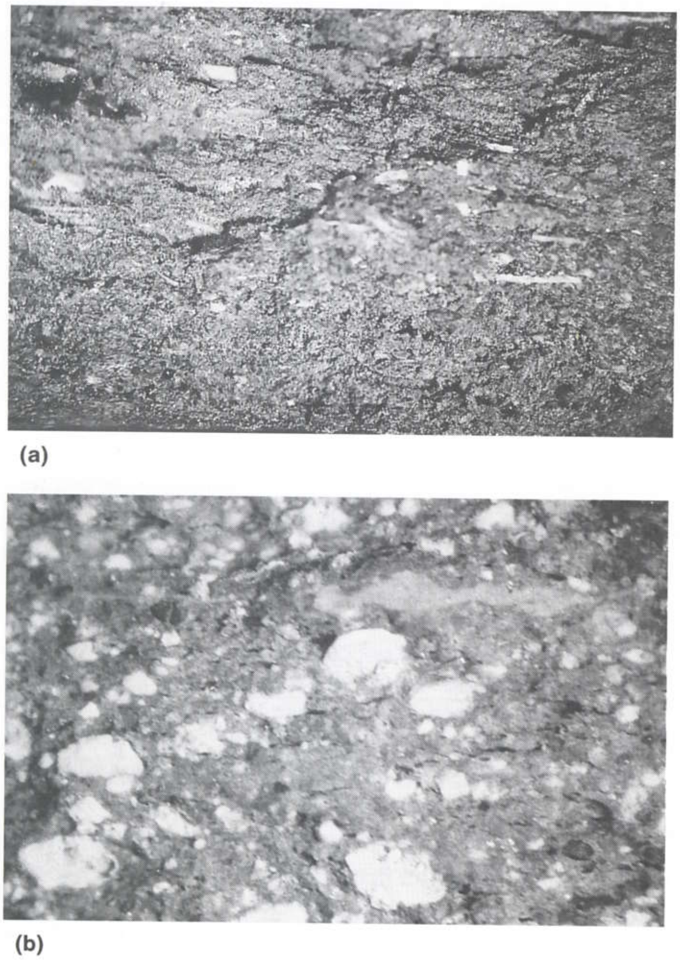


Figure 5.6 Sherd breaks photographed through the microscope: (a) Nile B2 × 20 magnification, described in Figure 5.5. (b) Marl D × 30 magnification. Both from Memphis.

analysis of both matrix and inclusions, using a variety of chemical and mineralogical techniques and quantitative data analysis packages to group the samples on the basis of the results (Pollard and Heron 1996: 20–80, 104–48).

Levels 1 and 2: visual classification of pottery fabric

There are several model systems for fabric description in European, American and Mediterranean archaeology (for the first named see Peacock 1977: 29–33). The one employed for illustration here (slightly modified) was used in devising the Vienna System, which offers a framework for classifying the most common fabric groups found in Egypt between the Old Kingdom and the end of the New Kingdom. It is non-site specific so inter-site comparisons are made easier. That it is usually not applicable to the Predynastic and post-New Kingdom ceramic industries reflects both the uncertain state of (published) research and the great differences in technology, distribution and raw materials which both periods show.

The Vienna system

The reader is referred to Nordström and Bourriau (1993: 168–82) for full descriptions, illustrations, suggested date range and source (based upon distribution) for each group. The criteria used to define fabric properties are shown in Figure 5.5. This method is used in the Egypt Exploration Society's current excavations at Memphis. The sheet has been completed for an example of Nile B2 fabric of New Kingdom date. The quantity of a particular inclusion present is indicated by numerals 1, 2, 3. Number 1 means the particles are scarce and scattered thinly through the matrix; 2 that they are conspicuous and common throughout; 3 that they are so abundant as to be touching each other. How easy it is to differentiate between or subdivide these fabric groups in a given assemblage depends not only on how well and consistently the properties are identified but also on whether and how they link to shape, function, decoration and shaping process. Figure 5.5 includes an entry for wall thickness, which is not a fabric property but profoundly influences porosity, hardness, colour and texture and provides a link to other properties of shape, function and manufacture. Fabric groups themselves often form a continuum rather than possessing sharply defined boundaries (Nordström and Bourriau 1993: 170, fig. 7).

The Nile fabrics

These are divided into five groups A–E, differentiated by the quantity and size of their most common inclusions, *viz.* sand, plant remains and limestone. Sand is an awkward term. Correctly defined it means all aplastic mineral inclusions in the size fraction between 0.060 and 2.0 mm, but is commonly used by the archaeologist, as here, to apply only to the quartz and feldspar components.

Nile A

This fabric group contains a large amount of fine sand, but no plant remains, except for an occasional particle picked up accidentally. The regular gradation in size among the particles of the matrix and the fine sand inclusions suggests that the sand is a natural constituent and not an added filler. The fracture colour is usually brown or greyish-brown without strongly defined zones, indicating a well-controlled firing of relatively long duration. Porosity is moderate or dense, hardness is medium.

Nile B

This fabric group contains varying amounts of fine to coarse sand and fine to medium straw. It is subdivided into Nile B1, which has a fine texture with only scattered fine plant remains, and Nile B2 which shows conspicuous plant remains used as filler. Nile B2 is common in all periods and regions and so shows great variability (see Fig. 5.6a), especially in properties closely related to firing-colour, hardness and porosity. For example, the colour of the fracture is usually brown but it may show a black core, or a red core with violet outer zones. Nile B1, however, is much more restricted in all its properties, and is linked to vessels with a particular function, most notably the drinking cups of the Middle Kingdom (Arnold, 1988: 140–1).

Nile C

This fabric group contains a large quantity of medium to coarse plant remains, and is characteristically the most poorly sorted and porous of all the Nile fabrics. It shows the widest range of inclusions, and in addition to plant remains it may include ash, bone, shell, limestone and sand. Like Nile B2 it is widespread and potentially embraces several variants. It is often used for large, heavy containers with very thick walls, such as vats for beer-making. The colour of the fracture varies between grey-brown and reddish-brown and there is almost always a black core. There are often signs of uneven firing and hardness ranges between medium and soft. The shaping is often carried out by hand, using a variety of methods (see p. 125).

Nile D

This group contains the range of fabrics in groups Nile A–C with the addition of numerous limestone inclusions. It cannot be assumed that the limestone is a filler unless the number and angularity of the particles indicate it, since there are naturally occuring lime-rich Nile sediments. Alternatively the potter may have mixed his major clay with one which was lime-rich. The porosity varies, in part due to variation in the quantity and size of the plant remains, but the fabric is usually very hard and highly fired, showing zones of red and even violet in the fracture.

Nile E

This fabric group is characterised by abundant fine to coarse, rounded sand inclusions. It otherwise shares the properties of Nile groups A–C and can be subdivided accordingly. The fabric is soft and crumbly with an open texture and only medium hardness. Such fabrics have an obvious advantage for cooking pots (see p. 124) and appear as such during the Middle Kingdom, but at this time and later they are also common in the eastern Delta in a wide range of vessels, as a result of potters' using the local *gezira* sands as a filler. This property is useful archaeologically in the identification of eastern Delta products in other regions (Bourriau 1996: 26).

The marl fabrics

Again divided into five groups A–E, these calcareous fabrics are much more heterogeneous than the Nile fabrics, and easier to distinguish from one another by eye, even supported only by a hand lens. However, the precise sources of their raw material must for the present mainly be inferred from the results of distribution studies (Arnold 1981). Analysis, even at the fourth level, has succeeded in characterising, rather than in provenancing, them (see p. 135–5), except in the case of el-Omari, ʿAyn Asil and Hierakonpolis.

Marl A

This fabric group is defined by its dense, homogeneous matrix, containing fine- to medium-sized mineral inclusions and little organic matter. It also has a consistently fine texture, low porosity and extreme hardness. It fires from pink to pale grey or olive. It occurs in four variants. Marl A1 is distinguished by conspicuous fine- to medium-sized angular particles of limestone added to the paste as a filler (Nordström 1972: 54–5 Fabric IVA). The limestone usually shows little sign of decomposition – an indication of firing at a low temperature, below *c.* 800 °C. Marl A2 has numerous fine mineral inclusions but no one type dominates. It seems to be very well sorted, suggesting cleaning or levigation by the potter. Distribution strongly suggests an Upper Egyptian origin (Bourriau 1981b), probably in the Theban area. Marl A3 appears to the eye to be closest to a modern Qena clay and its source seems to have been in the same region. The texture is exceptionally fine and there are very few inclusions of any kind. No filler has been added but the clay may have been levigated. Distinctive elongated air holes are present. The fabric seems to be consistently fired to high temperatures, *c.* 1000 °C, producing a characteristic pale green colour on the surface and in section. Marl A4 has the coarsest texture of all the Marl A variants, due to the large amount of sand and, in some examples, conspicuous plant remains. Fine particles of red ochre are characteristic. The fracture varies between light red and greenish-grey and is often zoned. It shows a considerable range of porosity and a hardness from medium to crumbly.

Marl B

The matrix is homogeneous but the texture extremely coarse due to abundant fine to coarse angular sand, added as a filler. Porosity is low and the fabric is hard except for highly fired examples. The fracture often shows a pink core with grey-green outer zones. Its distribution strongly suggests an Upper Egyptian origin.

Marl C

The matrix is fine and the abundant, more or less decomposed fine to coarse limestone particles give the fabric group a characteristic speckled appearance and coarse texture. Sand, added as a filler, is always present, as are pellets of the clay matrix. The latter are probably the result of poor mixing but may have been deliberately added to improve resistance to thermal shock, since cooking vessels are common in this fabric (Whitbread 1986). Most vessels have a grey-white firing surface and the fracture shows a dark core with red outer zones. Porosity is usually low and hardness always very great. This fabric group, which contains three subdivisions, Marl C1, C2 and Compact, certainly derives from sources in Lower Egypt (Arnold 1981; 1988). It is the most common marl clay in Lower Egypt throughout the Middle Kingdom and Second Intermediate Period.

Marl D

The matrix is fine and homogeneous and the distinctive characteristic is the abundant fine to coarse angular limestone inclusions, which seem to have been added as filler. They are usually smaller than those in Marl C and constitute a smaller percentage (up to 25 per cent) of the fabric. There is also sand and rock equal in quantity to the limestone (see Fig. 5.6b). Porosity is low and the fabric extremely hard. The texture varies considerably. The surface fires light grey to green and the fracture is pale reddish brown. The fabric is used mainly for closed forms, especially amphorae, and is found all over Egypt during the Eighteenth Dynasty. Of special interest are vessels which carry dockets in hieratic giving date, contents and place of origin, sometimes in addition to stamps and sealings with royal names. At present, distribution patterns favour a Lower Egyptian source.

Marl E

This fabric should perhaps be considered rather as a variant of Marl B than as a separate fabric group. It is distinct from Marl B only in having medium to coarse straw added as a filler. It is most common at Ballas in the early Eighteenth Dynasty and occurs elsewhere in a small, specialised range of forms. Marl fabrics with straw filler also occur sporadically at other periods e.g. the Late Roman, where Bourriau has noted it at Saqqara.

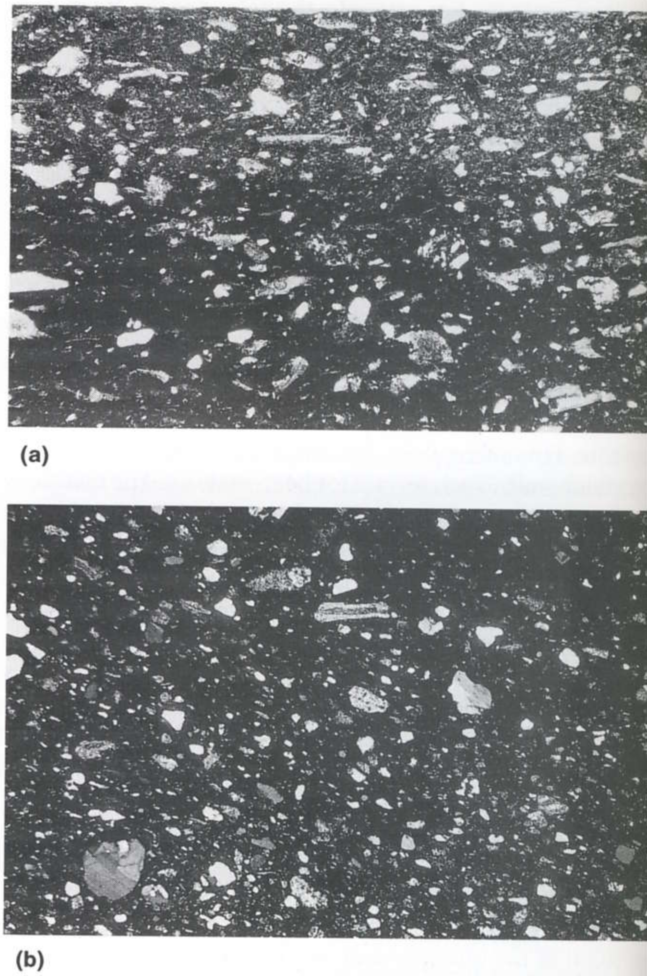


Figure 5.7 Photographs of thin-sections: (a) Nile B2 from Memphis The boundary between the core and outer zones is just visible. The silic skeletons from burnt out plant remains are visible; white grains ar quartz and feldspars; black grains are iron oxide. Taken under PPL (b) Marl D from Memphis. The fabric is rich in quartz and limestone fragments. Taken under XPL.

Level 3: Petrographic analysis of pottery fabrics

This technique, which consists of examining thin sections of the fabric or extracted mineral inclusions in the sand-sized fraction, in transmitted light using a petrological microscope, is becoming increasingly useful as a complement to what is visible to the eye assisted by a hand lens or low power microscope. It can be a source of confusion if too few samples are examined and/or they are not related to fabrics already recognised and described in detail at level 2 (see Figs. 5.7a and b). Thin-section analysis allows many of the mineral and organic inclusions present to be identified. The silt/clay matrix is usually too fine for thin-section analysis to be useful but its general character can be described (Porat and Seeher 1988: 219; Hamroush and Zeid 1990: 119). Petrological analysis introduces greater precision into estimates of texture and porosity since it allows accurate measurement of inclusions or voids and their expression as a percentage of total volume. It can also be used, with or without refiring experiments, to indicate original firing temperatures, by study of the condition of certain aplastic inclusions (Porat and Seeher 1988: 219). Theoretically, the improved detail and precision can be used to subdivide an existing fabric classification, but if the new sub-classes were to rely upon criteria visible only in thin-section, then they could not be applied with confidence to the assemblage as a whole. A different approach (Nicholson and Rose 1985; Fieller and Nicholson 1991: 71–85) is to use the method to quantify the fabric properties. For example, how far do classes represent different potters' pastes and how far are they a creation of the firing process? The next step, whether such variations be considered 'accidental' or not, is for the archaeologist to decide, based upon his knowledge of the potter's processing methods and on their relationship to vessel shape and function.

Grain size and shape analysis, as well as the specific identity of inclusions, may help with the difficult problem of deciding which inclusions are present as filler and which occur naturally in the clay. As a general rule, where numer-

Sayre 1974; Hancock *et al.* 1986), to those where the important questions were archaeological and grew out of a current excavation (Allen, *et al.* 1989; Hamroush and Zeid 1990; Ballet and Picon 1990; de Paepe *et al.* 1992). A similar evolution can be seen from a single method to a multi-method approach and towards more careful sampling and less reliance on inherited data-sets (Redmount and Morgenstein 1996; Bourriau 1998). In forming compositional groups, there is still no consensus as to whether it is better to employ multi-variant analysis which uses all the reliable compositional data, see Fig. 5.8 (Bellido *et al.* forthcoming) or discriminant analysis which selects significant elements or ratios of elements (Hancock *et al.* 1986; Redmount and Morgenstein 1996).

It is essential to understand that the groupings arrived at, if taken from samples of both fired pottery and raw clay, are not directly comparable. The primary and secondary processing which the pottery alone has undergone will have radically changed its elemental and mineralogical composition. A well-known effect is the dilution factor which results from the addition of quantities of sand or limestone to the paste. Sand and limestone contain smaller amounts of trace elements than the clay matrix, and adding them has the effect of lowering the trace element composition overall. If this factor is recognised it can be taken into account at the data analysis stage. This is why compositional analyses need to be used after other methods have been applied to determine what changes the potter has made in his raw material. Some studies, although not of Egyptian clays, have tried to predict them by examining the effect of levigation and firing on raw clays (Allen *et al.* 1982). Some forms of discriminant analysis set out to avoid the problem by utilising elements such as rare earths which are present mainly in the clay matrix of the fabric.

With this *caveat*, how successful have studies been so far in characterising pottery fabrics? Enough compositional data have been published by now for any sherd to be assigned to one of three groups: Nile alluvium; Marl clay; and kaolinite clay (see Figs. 5.8 and 5.9). Using accessible but as yet unpublished data (Bellido *et al.* forthcoming) it is possible to differentiate three sub-groups among the Marl clays corresponding to Marl B, Marl C and Marl D in the Vienna System. It is even easier to distinguish Egyptian from Palestinian pottery by using the large data-sets available. However, it has to be said that an experienced ceramicist using a microscope on a fresh break can do as much (and often very much more). A filler such as fine straw is easy to see, sometimes even by the naked eye, but does not always show up in chemical analysis (by XRF – Ballet and Picon 1990 and NAA – in the study referred to above, Bellido *et al.* forthcoming).

Elemental mean concentrations and deviations for Marls and Niles

Element	MARLS		NILES	
	Mean	S.D.	Mean	S.D.
Na	0.830	0.33	1.11	0.36
Al	7.37	1.6	7.42	1.2
Ca	9.54	3.7	3.84	2.3
Sc	16.6	2.5	21.8	2.7
Ti	0.553	0.12	0.873	0.16
V	120	26	149	24
Cr	137	62	156	67
Mn	668	420	1214	660
Fe	4.62	0.62	6.43	0.89
Co	18.7	3.4	29.74	6.2
Rb	42.5	9.9	45.3	14
Cs	2.03	0.75	1.59	0.76
La	33.5	8.0	28.5	9.3
Ce	67.7	11	67.6	18
Sm	6.02	1.3	6.40	1.6
Eu	1.40	0.28	1.82	0.49
Dy	3.93	0.68	4.67	0.88
Lu	0.386	0.072	0.448	0.14
Hf	6.59	1.7	8.18	7.32
Ta	1.36	0.31	1.59	0.38
Th	8.21	1.7	6.94	3.08
U	2.66	0.80	2.18	1.06

`Analytical information`

Element	Podmore Concentration	Gamma Energy (KeV)	Counting Regime
Al	11.44 %	1779	Short
Ca	1.824 %	3085	Short
Ti	0.6987 %	320	Short
V	152.0 ppm	1434	Short
Mn	404.9 ppm	1811	Short
Dy	6.13 ppm	95	Short
Na	0.0686 %	1368	Inter
Sc	26.0 ppm	889	Long
Cr	121.4 ppm	321	Long
Fe	5.482 %	1099	Long
Co	20.0 ppm	1333	Long
Rb	84.54 ppm	1076	Long
Cs	7.87 ppm	796	Long
La	41.91 ppm	488	Inter
Ce	80.1 ppm	145	Long
Sm	7.35 ppm	103	Long
Eu	1.55 ppm	344	Long
Lu	0.527 ppm	208	Long
Hf	5.484 ppm	482	Long
Ta	1.294 ppm	1221	Long
Th	14.01 ppm	312	Long
U	3.05 ppm	278	Long

Figure 5.8 Compositional data: twenty-two elemental concentrati for 150 samples of Nile silt fabrics and 193 samples of Marl clay fabri

How successful have studies been in identifying the clay sources used by ancient potters? Three studies have succeeded, in relation to Hierakonpolis (Allen *et al.* 1989), el-Omari (Hamroush and Zeid 1990), and ʿAyn Asil (Ballet

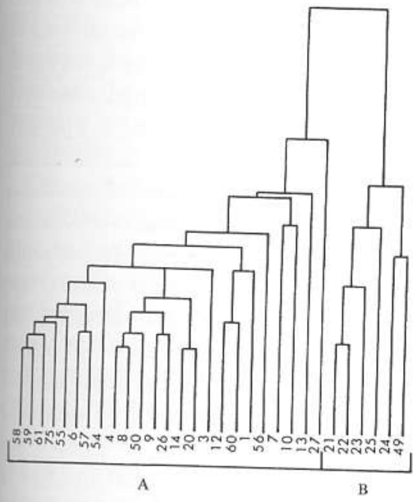


Figure 5.9 Dendrogram showing results of XRF analysis of pottery from ʿAyn Asil. A and B groups were arrived at using seventeen elements. Group A contained samples of a single fabric, in both fine and coarse variants and with/without a filler of plant ash. Group B contained only samples of a different fabric, visually distinguished by the presence of argillaceous inclusions, and used primarily for cooking pots.

and Picon 1990) (see Fig. 5.9), but each study looked at the products of a localised industry and two of the sites (Hierakonpolis and ʿAyn Asil) were production centres, so that the search area was already fairly clearly delineated. Other results have been ambiguous or negative (de Paepe *et al.* 1992) and all have quoted Tobia and Sayre's finding (1974) that chemical analysis alone could not indicate a provenance for pottery made of Nile alluvium, Pliocene clays or mixtures of the two. Tobia and Sayre's ancient pottery sample was too small and unrepresentative to be relied upon (Bourriau 1998); however, their evidence for the homogeneity (in chemical terms) of raw Nile sediments was supported by Hamroush's study (1985) of the distribution of rare earth elements in old and modern Nile sediments, in which he suggested that Nile sediment forming processes had produced an even pattern of distribution for these elements throughout the Nile Valley.

Three subsequent studies, two of modern clays (Hancock *et al.* 1986/1987; Redmount and Morgenstein 1996) and one of ancient pottery (Bourriau 1998) have challenged this view. If further work confirms these three studies, which appear to demonstrate that the differences between samples from different sites are greater than the variation within any single group or the margin allowed for analytical error, then further possibilities for the sourcing of clays are opened up. Even where kilns have not been located, it is usually possible on an archaeological site to identify some Nile silt pottery which must have been locally made, generally because it is too heavy, coarse and fragile to have been worth transporting. Analysis of such pottery groups may eventually allow compositional fingerprints to be established for different regions, periods and classes of pottery.

There have been strenuous appeals for another approach to this same goal, which is to make systematic analyses of all possible sources of raw material (Redmount and Morgenstein 1996: 761; Hamroush 1992: 51). If this is to be done then the initiative must come from archaeologists, since it will not come from scientists in the present research climate. Moreover, in our view, it is only worthwhile if investigations into ancient and modern processing methods are conducted at the same time. In any case, as a first step, efforts should be made towards standardising existing reference sets of data.

The social and economic context of the pottery industry

The place of the pottery industry in the wider social and economic context of ancient Egyptian society is a subject which has received only cursory attention from ceramic specialists (Holthoer 1977: 27–8; Hope 1987a: 7–9), although an increasing interest in the organisation of labour and the economy has touched upon the role of the pottery industry (Eyre 1987a: 27, 30; 1987b: 193; Kemp 1989, 56–63). In this section, the various sources of evidence, literary, artistic and archaeological, are considered in the light of possible modes of production.

Artistic and textual evidence

Scenes of pottery manufacture feature occasionally in tomb representations and models from the Old Kingdom to the New Kingdom (collected by Holthoer, 1977: 5–23; it is not clear that all show pottery manufacture, and the sources cited for the Late Period are not useful in this context). Such scenes have proved invaluable for the understanding of technological developments, but they reveal less about the context in which production took place, in terms either of the organisation of the workshops or their economic circumstances. Such texts as accompany the scenes provide terse and sometimes uninterpretable descriptions of the particular acts depicted, but do not contribute to the wider understanding of the activity. As one would expect from the funerary context in which they occur, they represent assets of the tomb owner, dedicated to his maintenance in the after-life. Consequently, they permit no scope for studying activities which went on outside this framework, such as, for example, any form of centralised or state-controlled industry.

Unambiguous scenes of Old Kingdom pottery manufacture are found in close association with scenes of brewing and baking, and show a very limited repertoire of vessels, usually jars (Holthoer 1977: 6–10, OKA 2, 5 and 9). More doubtful representations, where it is not clear that pottery manufacture is the practice depicted, relate the putative scenes to other industrial processes, such as metal- and leather-working (Holthoer 1977: 6–10, OKA1, 3, 4 and 10). Representations showing the integral association of pottery with the staple provisions, bread and beer, continue to occur into the New Kingdom, but at all periods, baking and brewing scenes are found without accompanying pottery manufacture. This is probably best understood as indicating that pottery production was such an obvious part of the process that it is implicit within the representations of food preparation. After all, the tomb owner required food and drink in the after-life, not the 'empties'.

Models of pottery workshops, from the First Intermediate Period and the Middle Kingdom (Holthoer 1977: 10–11, 15–16, FIB1, 2 and 4; Arnold 1993) are of interest in that they give some indication of where the activity took place. In all cases, potting apparently was carried out outdoors, although sometimes in an enclosed courtyard. The activity is depicted in close proximity to carpentry, metal-working, and in one case stone vase manufacture. In each case only two individuals are at work.

The association of pottery with other craft activities continued into the Middle Kingdom. Only at Deir el-Bersha are potters explicitly associated with bakers and brewers (Newberry 1895: pls. XXIV and XXV). The detailed scenes in three tombs at the nearby site of Beni Hasan place production squarely in an industrial context. The tomb of Amenemhat (BH2) incorporates them amongst depictions of processes such as the manufacture of linen (Newberry 1893a: pl. XI). In the tomb of Bakt III (BH15), the potters are situated below registers showing stock-taking of cattle, and above metal-working (Newberry 1893b: pl. VII). Here, scenes of baking occur at some remove from pottery-making. In the tomb of Khnumhotep III (BH3), the potters are again associated with textile preparation, and also carpentry; bread- and beer-making are pictured several registers below (Newberry 1893a: pl. XXIX). Whether the association with craft activities rather than food production is significant, reflecting different circumstances of production at Beni Hasan (the 'independence' of the pottery-makers suggesting perhaps that pottery is seen here as a commodity in its own right), or merely showing a different lay-out of working space (or indeed a different artistic convention), is impossible to tell, but again it is clear that the manufacturing is part of the activities associated with the tomb owner's maintenance in the after-life, with the same limitations of interpretation.

The tomb of Kenamun (TT93) at Thebes contains the only known New Kingdom scene of pottery manufacture (Davies 1930: pl. LIX). Like many of its precursors, it occurs in association with the preparation of food and drink, but here is an isolated, uninscribed scene, in an obscure position on the rear of a pillar in the outer hall. Its relegation to such an insignificant location prefigures the abandonment of the depiction of potters throughout the rest of the New Kingdom and beyond: although scenes of food production are not uncommon, and other forms of craft activity as part of the work of temple and state institutions are well-attested, the manufacture of ceramic containers is not depicted. The only other representations are informal: a model of the period showing a woman doing something to a pot (UC 15706; Hope 1987a: fig. 2; he suggests she is adding handles, although this is unlikely since handled pots at this period were almost all the result of specialist production, see p. 139–40), and an ostracon from Deir el-Medina which appears to show two children working on a vessel (Hope 1987a: Fig. 1), but Arnold (1993; fig. 15A) identifies the workers as Nubians. Whilst they demonstrate that pottery manufacture was in fact part of daily life, their isolated nature tells us nothing about the framework in which the activity took place.

The representations available suggest that the size of pottery-making workshops was small at all times. The models show only one or two men working in the establishments; the tomb-reliefs are more problematic to interpret, since the actions depicted could be performed at different times by the same or different persons. In most cases the workshops seem to have been situated outside, but close to other industries, and had some recognisable equipment: a turntable or wheel, a kiln or oven. Almost all the representations show the potters to be male, although very limited evidence from the Old Kingdom suggests women may have participated, tending kilns, perhaps as a result of the intimate association at that period with brewing and baking which could also be carried out by women. The New Kingdom depictions of women and, perhaps, children apparently at work on pots also suggest that in fact some modes of production were open to, or made use of, all available labour sources. We can say very little more about the individuals who worked in pottery workshops, but that they had a low social status is clear from texts (for example, P. Sallier II, quoted in Holthoer 1977: 18). To what extent this applied to those working in specialist production centres is unknown. That they did not form part of the recognised social hierarchy is clear from the absence of references to them in the varied inscriptional sources. Holthoer (1977: 17, MKD1) noted only a single stele dedicated by a potter, who had no other titles, at Abydos in the Middle Kingdom.

There is a little further information concerning potters and pottery production, mostly of New Kingdom date, from which one can begin to throw light on the economic context in which some potters worked. By far the most interesting source is the body of texts relating to the supplying of, and the transactions between, members of the community of state-employed craftsmen at Deir el-Medina (Janssen 1975: 485–8). Here, potters were part of the supply staff for the community, although based outside it, and made regular deliveries of vessels. There is little indication of significant ceramic production at the village itself: excavation revealed the remains of a single potter's workshop below house SE1, at the foot of the enclosure wall and outside the village when in use, but no more details are known (Bruyère 1939: 264). It is impossible to say whether the installation belonged to those living in the village, or to their suppliers. Certainly the isolated desert location of Deir el-Medina makes it eminently unsuitable for regular or large-scale production, and there is no other indication of such activity.

The craftsmen also received supplementary goods on top of their basic grain allocation, including vessels of beer, and other commodities which were supplied and/or were measured in *mnt*-jars, including oils and fats, beer, and honey. The *mnt*-jar was a type of pottery vessel particularly associated with wine, and is probably to be understood as a two-handled amphora (Bruyère 1939: 353; for the type and its changes in form over the New Kingdom see Hope 1989: 87–118). The type appears to have been the product of specialist manufacture in a restricted number of centres, and its 'élite' nature, albeit only as a container, is reflected in the nature of goods supplied in it and their expense. However, in general, the many texts which relate the value of commodities arriving at the village fail to attribute values to pottery apart, it seems, from that of the vessel contents, emphasising the cheapness and availability of the product.

The very ubiquity of pottery as an essential means of holding goods probably accounts for the lack of reference to it. One exception is a stele of Rameses II, recounting the commissioning of a group of professional quarrymen to make a statue (Eyre 1987b: 183). On it, the king stipulates that, *amongst the abundant supplies he has ordered for* them were 'pots made on the wheel, as vessels to cool water for you in the hot(?) season'. These vessels would presumably have been manufactured by potters associated with the great state institutions of the New Kingdom.

Finally, we should give brief consideration to the possibilities that existed for private trade in such commodities as pottery. Small-scale transactions in foodstuffs, as well as in simple manufactured items, are known from the Old Kingdom onwards, and although pottery has not been explicitly recognised as a commodity for exchange, it is likely that it changed hands both as containers and in its own right (Eyre 1987a: 31–2, 1987b: 199–200). Who the sellers were is unclear; as a means of marketing it seems most suitable for small-scale 'domestic' and local production, intended for the local community, rather than state- or estate-based establishments. These would presumably have had the capacity to store excess production until required, especially in view of the apparent lack of value of the product. By the New Kingdom, it is clear that some goods were made for the market; indeed temples employed professional traders on their staff. Considered in the light of the far greater complexity of ceramic production by this time, such traders may well have formed the means by which some types of vessel, not only commodity containers but also vessels clearly not intended for that purpose, spread from their centres of manufacture.

The archaeological evidence

The most commonly recognised features on archaeological sites which reflect the presence of a pottery-making industry are kilns (see Nicholson 1993 and Hope 1993 for a review of the current evidence), which, although it is not always clear whether for pottery or some other industrial process, are often more readily identifiable than other features. The identification of production areas apart from those associated with kilns is rare (although difficult to identify in the archaeological record, Nicholson and Patterson 1985a and 1985b), and the opportunity to examine the installation in a wider context is rarely available.

Taking the evidence of production as manifested by the identification of kilns, pottery manufacture is known from the length and breadth of the Nile valley in Egypt and Nubia, and outside it in the Delta, the western oases and Sinai. Even in the Predynastic period, production at the Upper Egyptian site of Hierakonpolis reached 'staggering proportions' between c. 3800–3500 BC (Hoffman 1982: 142). Here fifteen kiln complexes have so far been identified, and an excavated example is associated with scattered domestic occupation; the potter's house seems to have burnt down on one occasion. The excavated kilns are unsophisticated, but produced at least three different ware types in many different forms, catering for the needs both of the settlement and the nearby cemeteries. It seems that some kilns were used to fire more than one ware, although *the coarse ware was intended primarily for the settlement,* and the red burnished ware for the cemeteries; one may tentatively suggest that a fully-developed funerary ceramics industry had not developed by this stage. This is borne out at the Delta site of Buto (which, however, fell within a different, lower Egyptian cultural milieu for much of the period), where cemetery and domestic pottery seems to be the same, differing only in quantitative rather than qualitative terms (Köhler 1992: 10).

Examination of the vessels of this period have led to the suggestion that already there was specialised production (i.e. the output of a limited range of wares and forms, often for a specific purpose, and in demand because of it) as far back as Naqada II for certain marl vessels (Mond and Myers 1937: 50; Bourriau 1981a: 44). Painted decoration has also been used as a basis for identifying centres of production and the trade networks emanating therefrom (Aksamit 1992; Finkelstaedt 1980, 1981).

In the late Fifth or early Sixth Dynasty, pottery was manufactured in the mortuary temple of Khentkaus at Abusir (Verner 1992). Here a small workshop was established at a date somewhat after the original foundation, within the funerary temple, apparently in an area of the internal courtyard screened off with matting. The workshop had a preparation and storage area with a wheel and other essentials, and a kiln nearby, also within the temple. The types produced, as deduced from wasters, were beer jugs, bread moulds, stands and miniature vessels, which types were presumably to serve the cult. All of the vessel types were probably of siltware, although this is not explicitly stated; this is the fabric group usually used for these forms. The excavator equated this establishment with a reference in the Abusir papyri (documents from the temple archives of Neferirkara, Posener-Kriéger 1976: 45–6) to a room with potter's wheel. It seems, then, that here the needs of the cult were met from its own resources (although interestingly there is no mention of food production in the same area).

Unfortunately, there is no evidence for similar establishments within other royal funerary complexes, but these may have been served by separate establishments, such as those identified near the north pyramid of Sneferu at Dahshur (Stadelmann 1983), and at Giza near the funerary temple of Menkaura (Saleh 1974, 1996). At Dahshur, firing structures were found in a thin-walled building some distance in front of the pyramid. Nicholson (1993: 112) accepts them as kilns, although the excavator thought they were more likely to be for cooking and the provisioning of the élite personnel associated with the functioning of the complex, since the pottery found therein was said to be of 'household' type, and (apparently) no evidence for pottery manufacture was found. At Giza, part of a large industrial area was excavated which included kilns; the excavator interpreted the whole establishment as dealing with the preparation of food offerings for the cult, which required 'ovens, water jars, bins for grain and ordinary reservoirs of pottery for keeping the goods required'. However, Lehner (1985: 157) has identified what may be installations for levigating clay amongst the structures, suggesting that pottery manufacture was in fact taking place there. Given the intimate association between the preparation of the staples of the diet and pottery-making in the private tombs, it would seem extremely probable that the same association was maintained in state-controlled establishments.

Archaeological examples of pottery production not associated with funerary establishments in the Old Kingdom come from Elephantine (Kaiser *et al.* 1982: 296–9), and Dakhla (Hope 1987b: 33–4). At Elephantine, kilns have been located outside the walled Old Kingdom town, and date from about the mid-Fourth to Fifth Dynasties. They perhaps formed part of a larger industrial area. Although few details are available, it appears that both marl and silt clays were worked there. The Dakhla kilns, which may well have formed part of a potter's workshop, were badly eroded, and little more can be said about this material, apart from the fact that the Old Kingdom pottery from the oasis was closely comparable to the contemporary repertoire in the Nile valley (Hope 1987b: 25).

This homogeneity in form and fabric is a striking feature of the pottery of the period, and extends beyond the Nile valley out to the western oases. The explanation for this is not clear: O'Connor (1974–5: 27) has suggested that the homogeneity of storage jars was due to either restricted production at only a few major centres and/or to a widespread trade in commodities that extended throughout the country. Centralised production could perhaps be cited as a reason for the standardisation of other types. However, what little evidence we have suggests that 'standardised' types were produced in various parts of Egypt (as, for example, at ʿAyn Asil where Old Kingdom forms continued to be made into the First Intermediate Period). Whether there was a high degree of control by the state on potters, who were thereby constrained in what they could manufacture, or whether the homogeneity derived from widespread trade and copying remains to be discovered.

The best example of a town-based workshop complex, of slightly later date, comes from ʿAyn Asil in the Dakhla oasis (Soukiassian *et al.* 1990; see Fig. 5.2). This produced pottery from the end of the Old Kingdom into the First Intermediate Period. Like the workshop at Elephantine, it was situated outside the enclosure wall of the settlement. Whilst of relatively modest size, with a suggested working team of five to ten people, it had the capacity to produce a wide range of forms, and exploit a variety of clays from the area, some of which seem to have been chosen because of their specific properties. The forms included characteristic bread moulds of a type well-known throughout Egypt in the Old Kingdom (Jacquet-Gordon 1981: type A), as well as carinated bowls and cups. The manufacture of bread moulds led the excavators to suggest that there was no 'domestic' production at this time, since, they hypothesised, this would be the type most probably produced by individual households for their own use. These workshops do not seem to have supplied the entire needs of the local population, since there was little evidence in them of the ceramic types found in the town's cemeteries (Soukiassian *et al.* 1990: 164; Minault-Gout and Deleuze 1992: 193–4).

In the Nile valley, the evidence suggests that the apparent centralisation of production or distribution of at least some types of Old Kingdom pottery broke down with the political fragmentation of the First Intermediate Period, and that regional styles developed, which appear to correspond to known political boundaries of the period (Bourriau 1981a: 51; O'Connor 1974–5: 27–8; the evidence he cites for this can be interpreted as showing limited trade across these boundaries). Collapse of state control did not, however, prevent trade outside the frontiers of Egypt; storage jars (presumably commodity containers) continued to arrive in Nubia after Egyptian political control had been lost there (O'Connor 1974–5: 29). Only in the Twelfth Dynasty were the regional styles subsumed back into a more homogenous style which incorporated Egypt and Nubia (except the eastern Delta, where foreign settlements greatly influenced the local repertoire).

Archaeological evidence for pottery production in the Middle Kingdom is slight. Kilns were discovered in the open town at Mirgissa in Nubia, on the periphery of the settlement, but nothing further is known of the workshops (Vercoutter 1970: 79–81 and fig. 23). The open town appears to be the earliest established part of the site, preceding the fort, but it is not clear if this was an Egyptian state-controlled workshop serving state needs, or one serving an 'ordinary' population.

Also in Nubia, an isolated potter's workshop was discovered at Nag el-Baba, in Ashkeit district, dating from the Twelfth Dynasty into the Second Intermediate Period (Site 228: Säve-Söderbergh 1989, 265–7; Holthoer 1977: 16–17). This was a multiple-roomed complex which included clay preparation areas, and had an adjacent kiln of unsophisticated type. Pottery-making tools were identified, including pebbles suggested to be for compacting the surfaces of vessels; the 'palette' from the site, not noted by Holthoer, could well be a rocker stamp for the decoration of vessels, a rare but attested technique in the C Group (for example Wenig 1978: 138, cat. 34). Holthoer also drew attention to a socketed stone set in a low protruding wall in one room, which was coated with an unidentified black substance. This may have been a door pivot, but could also have been for some sort of turntable. No wasters or unfired sherds were mentioned amongst the finds; the fired pottery recovered is a mix of Nubian handmade C-Group, and wheelmade wares, the latter said 'generally' to be imported from Egypt. The question of whether the putative turntable, which does not seem to have been used in the manufacture of C-Group pottery, indicates the manufacture of 'wheelmade' wares here on Egyptian lines (or even by Egyptians) is unanswerable, although the illustrated 'wheelmade' pieces from the site are, unusually, open forms, rather than the usual closed forms required for the import of commodities. There is a certain amount of confusion in that the spouted bowls from the site, illustrated and described under the heading wheelmade, are described in the text as possibly deriving from Old Kingdom Egyptian vessels, which may have 'served as prototypes for contemporary *handmade* pottery, e.g. in the Kerma culture and in C-Group (habitation site no. 228 [i.e.the Nag el-Baba workshop]) and Pangrave context' (my italics, Holthoer 1991: 69). Other finds in the workshop, such as bits of molten copper and mud loom weights suggest that it also manufactured other items.

Specialist funerary production has been posited for some centres in the Middle Kingdom and the Second Intermediate Period, including Beni Hasan and Ballas (Bourriau 1981a: 60; 1986–7). At Beni Hasan, this material is distinguished by its distinctive forms and fabrics, its crude manufacturing technique, and the lack of change in the types used in contrast to the rate of alteration of domestic types. At Ballas, a detailed comparison of the pottery from the settlement and cemeteries identified three ware groups found only in the settlement, and wares common in the cemetery that were under-represented in the settlement (but never exclusively present in the cemetery). Although there is not sufficient evidence to suggest this was the pattern across the whole of Egypt, it seems likely that this was the case.

In the New Kingdom, more evidence is available. At Amarna, several kilns have been identified within the residential areas of the city (Nicholson 1989c), both as part of industrial and private estates. Only one of these, Q48.4, has produced evidence of an associated production area, (Rose 1989). Here the potters worked primarily in siltwares, producing vessels, mainly bowls, of types found in abundance throughout the city. There were, however, also a few unfired marl sherds from closed-form jars. Further evidence for production can be found in surface finds of elements of the bearings of potter's wheels.

Five such bearings have been found (Rose 1989; Powell 1995): one from Q48.4, two from the surface of the South Suburb, a mainly residential area, one of uncertain provenance, and one (Ashmolean 1929.417) from house T36.11 in the North Suburb. In passing, it is worth noting the number of fragments of wheel-bearings identified by Powell in the British Museum and on display in the Cairo museum, most, unfortunately, unprovenanced. It is likely that many others lie, misidentified as door sockets, grinders, or not identified at all, in other museums; a full listing, and their correct identification as surface finds on archaeological sites where their size and weight make them likely to survive well, would probably give a better overview of the widespread nature of pottery making in Egypt than anything else.

More or less contemporary with the Amarna workshop is one found in North Sinai at Haruba, site A-345 (Oren 1987: 97–106). It included preparation areas and kilns, and was situated to east of an area which was apparently not residential, but included magazines used for storing grain. The types produced were mostly made in locally available clay, but the forms were drawn from the Nile valley repertoire, and included 'various types of bowls and kraters; the whole range of drop-shaped vessels', tall 'offering stands', and 'flower pots with heavy, frequently perforated bases bearing deep thumb indentations'. The workshop apparently served as an adjunct of the nearby fortress and produced for the garrisons stationed therein, and perhaps for other fortresses across Sinai, as well as for official convoys passing across the area. The official nature of the establishment is reflected both in its proximity to the fortress and in the occurrence of beer jars stamped with cartouches of Seti I at a nearby site, A-343. The practice of stamping utilitarian vessels, in this case breadcones, has also been noted at Amarna, in the bakeries associated with the temple complex at Kom el-Nana.

Some slight evidence for production comes from the west bank at Thebes. The Deir el-Medina remains have already been mentioned; and kilns seem to have been found behind the mortuary temple of Amenhotep son of Hapu, but no descriptions are available (Varille and Robichon 1935: fig. 1). The latter may have formed part of a

New Kingdom industrial area serving the funerary temples, which ran under the temple.

The evidence from the pottery of the period indicates a greater diversity in production than seen previously, in terms of wares, forms, and surface finishes, and in certain cases specialisation of production can be confidently suggested. The uniformity of fabrics used for wine jars (almost certainly the *mnt*-jars of the Deir el-Medina texts already mentioned, see p. 136) and meat jars, and the standardised features, dimensions and capacities of the vessels, present powerful evidence for specialist manufacture in a very limited number of centres, probably in Lower Egypt because of the clay used. These centres had the capacity to turn out vessels in huge numbers (Hope 1982). Specialist production in centres associated with the major palace complexes has also been suggested for New Kingdom blue-painted pottery, both on stylistic grounds and because of the use of relatively rare pigment in the vessels' decoration (Bachmann *et al.* 1980; Hope 1982), and also for polychrome painted amphorae (Bell 1987) and modelled and sculpted vessels (Bourriau 1982). Certainly in the case of the blue-painted vessels it would seem that they were traded in their own right, since many forms are not suitable as commodity containers, but even so, what is known of their distribution suggests they only reached rural and outlying areas very rarely (for example, very few examples are known from Nubia). This implies that blue-painted vessels imparted a certain status to their owners. At Amarna, where excavations have sampled all classes of dwelling in the city, blue-painted vessels are found everywhere, including the apparently 'poorer' areas; the main differences between areas lies in the quality of the decoration. However, poorly and carelessly decorated specimens still occurred in what would otherwise be thought of as élite areas of the city.

The localisation of certain marl wares into Upper and Lower Egyptian types in the New Kingdom enables the distribution of other vessel types to be examined, and results in the impression that marl pottery was travelling further, and as a commodity in its own right (Nordström and Bourriau 1993: 175–82). An example is the category of 'spinning bowls' at Amarna, a distinctive open vessel with handles affixed to the base or wall on the inside (Nagel 1938: 183–8). The bowls were used in the preparation of flax for plying, and were most commonly made in Upper Egyptian marl (Marl A2). This in itself is unusual; marl clays were usually used for closed forms, to serve as commodity containers, and very rarely for bowls. A property of the clay must have made them particularly desirable for their purpose, perhaps their lack of porosity, since flax fibres are best plied when wet. Siltware examples of the type are rare in comparison with the marl examples. How do the Upper Egyptian vessels come to be at Amarna? Their association with a particular craft may, perhaps, indicate that they were state-supplied, but this seems unlikely, given their widespread distribution over the site; and since weaving was carried on as part of household activities, it seems most logical that the bowls were directly obtained by each household, as required, from traders.

Siltwares are less easy to consider in terms of regional production because of their less distinctive composition, but it may be that examination of prevailing modes of surface treatment by area as applied to similar forms may suggest different areas of production. For example, the commonest type at Amarna, a flat-based bowl with a simple contour and rounded rim, is there invariably red-slipped. At Malkata, an almost contemporary site on the west bank at Thebes, the same form occurs unslipped as well as red-slipped (Hope 1989: 10, fig. 1h). As well as demonstrating more localised production, it also serves to suggest that regional variation is not to be sought only at times of political instability.

A further traceable example of localised production which was traded into the Nile valley is to be found in certain vessels produced in the Dakhla oasis, the fabrics which are distinctive (Aston 1996: 9; Hope 1987b). From the New Kingdom onwards, a limited range of vessel forms from this source were imported into the Nile valley, amphorae and gourds in the New Kingdom, and cigar-shaped vessels thereafter. The vessel shapes indicate clearly that commodities were the items being transferred, but as yet, no synthesis has been undertaken to look at the wares' distribution. However, work on the ceramics of the Third Intermediate Period has identified the pattern familiar from earlier periods of political instability, the development of regional styles (Aston 1996).

Specialist funerary production has been posited for some centres in the New Kingdom, such as Thebes (Rose 1996: 170). Here pots imitating stone and glass were made in a distinctive marl clay that is only used for one other vessel type, the definitively funerary canopic jars. These vessel types do not occur either on non-funerary sites in the region, or in tombs outside the Theban region.

There is less information regarding the pottery industry of the Third Intermediate and Late Periods. A kiln discovered at East Karnak, dated from about the seventh to the late fifth centuries BC, lay in an open space or courtyard in an industrial quarter, not far from a residential area (Redford 1981: 14). No pottery types are mentioned as associated with the use of the kiln. A complex of kilns at Memphis were built over the forecourt of a Ramesside temple adjacent to the enclosure of the main temple, but this had gone out of use and dwellings had been built in the area (Jacquet 1965: 46–50). There were, apparently, some unfired sherds but no information is available on the types.

A final, if uninterpretable, source of evidence which may have some bearing on ceramic production may be found in potters' and painters' marks. The former were made before firing in the leather-hard clay, and may consist of hieroglyphs or simple designs or symbols (marks made after firing may have a separate significance associated with ownership rather than manufacture). Their meaning in most cases is obscure; they could, for example, represent batch marks, the output of an individual potter or workshop, or a commissioned output. In some cases they represent the vessel's capacity (Bourriau 1981a: 68, no. 123). However, it is clear that not all vessels were marked, and even when marks appear common on a particular type (as for example Old Kingdom bread moulds, or New Kingdom meat jars), not every example had them. It is to be hoped that future synthesis will identify particular associations between marks, forms and fabrics, and perhaps assist in interpretation. Painters' marks, hieroglyphs or designs, have been noted on some blue-painted vessels in the unpainted band between registers of decoration, but again their meaning is unknown (Hope 1991: 35).

Discussion

Modes of pottery production have been the subject of considerable study, both in the ancient world and in modern societies (Rice 1987: 183–91; Peacock 1982: 8–10), and certain of the models outlined are useful guides against which to consider what we know of the industry in pharaonic Egypt. A constraining factor is that many of the proposed modes of production operated within a monetary economy, and are viewed against this backdrop; this, of course, does not apply to the Egyptian state, and here other factors may be of importance. That having been said, the following modes can be extracted from Rice's list as possibly having relevance to the Egyptian situation:

- household-based or 'domestic' production, in which the needs of the household are met from its own resources, often by women, without utilising specialised equipment. The makers are non-professional and carry out the activity when necessary.
- household industry: still a 'domestic' industry, but the potters manufacture with a view to trading their wares. Manufacture is not necessarily vital to the household's subsistence. The potters make use of basic equipment.
- individual workshops: here pottery manufacture, usually by men, is a vital source of subsistence even if it is not a full-time activity, that is, it is economically essential to the group undertaking the activity. These industries are usually small and isolated, but use specialised equipment and the workers and workspace have designated functions. They serve the local community, and do not have well-developed marketing systems.
- nucleated workshops: individual workshops are grouped together to form an industrial complex, in which manufacture is vital to subsistence. They produce a standardised range of high quality products using highly developed technology.
- 'attached' specialist producers: pottery (and other supplies) are produced for interest groups who can manipulate production and demand. This might include control by state authorities or élite individuals. These workshops can have a commercial role, selling surplus production by trading.

A major problem is that not every mode of production is equally visible from the available sources: for example, at no time is there unequivocal evidence for domestic production, i.e. by the household for its own consumption, although this is often assumed to have been of major importance. If one takes lack of specialised equipment as a marker for this mode of production, the fact that simple handmade vessels only constitute a significant part of the ceramic output of the Old Kingdom, it may be justifiable to suggest that it is only at this time, and earlier, that one could posit this type of production. It may be significant in this context that a common type of crudely formed handmade jar, found in abundance in soundings at ʿAyn Asil, were not made or fired in the excavated ceramic workshops (Soukiassian *et al.* 1990: 144). This may mean that there were other 'professional' suppliers of this type, but it may instead be an indication of true domestic production. The preponderance of wheel-finished or turned products thereafter indicates non-domestic, professional, manufacture, obtained by the general population through obscure means, but presumably including trade.

Pottery 'industries' are attested from the earliest periods considered here. They may constitute 'household industries' and/or 'individual workshops', as for example Hierakonpolis and Nag el-Baba. The latter model would seem to apply to the town-based industries of ʿAyn Asil and Elephantine, although we have no idea whether the surviving kilns were the sole providers of ceramics to their towns (apart from any funerary production), how they stood in relation to the official administration of the towns they served, or how the goods that they produced were marketed or acquired.

The most easily identifiable mode of production is that by 'attached specialists', which existed from the Old Kingdom onwards. Small pottery workshops – probably 'individual workshops' in scale – formed part of the estates of élite members of society, although we cannot say if such workshops provided for all of the estate's needs: the evidence tends to show pottery mainly as an adjunct to provisioning, and too little is known about centralisation of production to discuss further. Similarly, the establishments at Abusir and Dahshur represent individual workshops in scale, but were under state control, and therefore are also to be recognised as 'attached specialists'. The same applies to the establishments located at Giza, although the current lack of information gives no idea of the scale of production.

Whether the New Kingdom representation in the tomb of Kenamun (TT93) shows his private estate, or is in fact an aspect of his administrative duties is less clear (he was, for example, overseer of the magazine (*šnʿ*) of Amun, Davies 1930: 13). However, the evidence from Amarna demonstrates that pottery-making (of a modest scale that could still be described as an 'individual workshop') went on on the large private estates of the city, and also in 'industrial complexes'. The latter included pottery-making amongst other types of manufacture, and were separate from dwellings. Kemp (1989: 60–3) suggested that they could be understood as rewards given to state officials, who thereby reaped the benefits of their output, whilst passing it into wider circulation by various means. These establishments, which he equated with the *šnʿw* of the texts, were therefore not exactly private resources of the individual, but administered through such, and their output could be used for state projects: the pottery supplies for the Workmen's Village seem to have included material from such an establishment. The extent to which trading took place from surplus production of any of these workshops is unknown.

Another clear example of 'attached specialist' production is seen at Deir el-Medina. Here the craftsmen may have been regularly supplied with pottery, but there is no reason to think that this came from more than a single workshop, or perhaps several 'individual workshops' (the texts refer to 'the potter', without any qualification). It is not clear where these attached specialists would have been based, but it is likely that the workshops were under the auspices of the state institution(s) which supplied the village's payments. The same model probably applies to the pottery-making establishments around the Sinai forts.

Specialisation, as manifested in 'nucleated workshops', remains a matter of some uncertainty. Marl clay wares have been considered the most likely candidates for production under these conditions, due to the localised nature of the clay sources and their suitability for specific purposes, as in vessels from Ballas or Fustat today. However, the evidence from Elephantine and Amarna, where both marls and silts were exploited in the same workshops, indicates that this was not always the case, and Bourriau (1985: 32) has pointed out some areas where marl clays were readily available and the whole repertoire of forms at certain periods were made in that material. Only in the New Kingdom can specialisation of this type be confidently suggested on the basis of the pottery itself, and it is unfortunate that no production sites have been found. Whether specialisation is connected with the growth of urban markets deserves investigation (Peacock 1982: 99).

A different sphere of specialisation is that of manufacture specifically for funerary use. It seems that, to a considerable extent, the pottery incorporated in burials was the result of manufacture separate from that of ordinary domestic wares. Apart from noting the existence of this aspect of the industry, we know nothing of how it was organised.

As a general point, it is of interest to note that, according to our present state of knowledge, the emergence of regional styles seem to coincide with periods of the collapse of central control, and disappear at time of strong state control (that changes in pottery styles do not always seemingly fit neatly with political change has however, been demonstrated by Adams 1979). Whether this can be sustained remains to be studied; however, certain major changes in ceramic production, such as those in the mid-Eighteenth Dynasty (Bourriau 1981a: 72), clearly take place at a time of profound stability. In summary, the evidence available suggests that pottery-making was an ubiquitous part of Egyptian life from the earliest periods. Manufacture was not entirely, or even mostly, domestically-based, although the bulk of pottery in use was supplied from local sources. Trade in ceramics, although usually as containers for goods, can also be demonstrated from the Predynastic period onwards. The identification of regional patterning in ceramic styles, particularly at periods of political instability in the Egyptian state, bears out this contention. Most production, however, remained small-scale and scattered, and economies of scale do not seem to have been important; the existence of large-scale specialised industries was a phenomenon of the New Kingdom.

Vessel usage

The products of the ceramic workshops encompassed a wide range of vessels over time. The vast majority certainly served domestic purposes, associated with storage, preparation and consumption of food. Some contained precious commodities, of food and other materials, and were designed for transportation. Other types served 'ritual' purposes of varying sorts. Overlapping these are questions of any prestige conferred by the possession of certain pottery types, a matter which has been touched on above.

Identifying the functions for which vessels were made, and the uses to which they were put (which clearly need not be the same) is a matter of some difficulty. Documentary sources are of little assistance: ancient Egyptian terminology with regard to vessels is too poorly understood to be of much assistance (Mesnil du Buisson 1935; Janssen 1975: 407–35), and representations in tombs are often schematically drawn, making identifications with actual pots difficult, even at the level of identifying the material depicted. However, in a few cases, information from tomb images has provided the evidence from which the function of certain types has been recognised. These include bread moulds (Jacquet-Gordon 1981), spinning bowls (Nagel 1938: 183–8), and, more circuitously in reasoning, beer jars (Holthoer 1977: 86–8); although in the case of the latter the stele of Anymen from Amarna shows a libation of wine being poured from what appears to be a beer jar (Davies 1908: pl. XXII; see also Chapter 22, this volume).

Jar labels identifying the contents are not uncommon in the New Kingdom (for example, Leahy 1985). They are usually found on marl clay vessels, and it is from the regular association of certain forms with certain commodities that wine jars and meat jars have been identified (although 'wine jars' were also used for other commodities, such as oil and honey). However, the question remains as to what a label actually signifies: is it an indication of what the vessel usually held, or is it labelled because on this occasion it was not used for its usual purpose?

The vessels themselves give some clues as to their usage. Certain fundamental deductions can be made on the basis of the clay, surface treatment and form. The type of clay chosen affects a vessel's thermal properties and its ability to withstand heating. Porosity may be desirable or not, depending on intended usage: modern water storage vessels, *zirs*, allow water to seep through the walls, thus cooling the contents by evaporation. *Gullas*, modern water jars of marl clay, do the same. In other cases, where transport of liquids is a factor, permeability can be minimised by the choice of clay, the application of a slip, and polishing or burnishing to compact the surface (see pp. 126 and 127). The archaeological correlates that can be predicted for certain categories of vessel function, storage, cooking, food preparation without heat, serving and transport, have been summarised by Rice (1987: 238). Egyptian ceramics generally fit into these categories, which need not be mutually exclusive, and other issues may cross-cut that of usage, such as status or prestige associated with the ownership of certain types.

There are a number of vessels which lie outside the range of household and transport functions. These include vessels of 'ritual' purpose, such as canopic jars, and less obvious vessel types such as the tall offering stands of the New Kingdom, which are found in chapels, and (perhaps) the moulded and sculpted vessels of the same period. Furthermore, some blue-painted vessels seem to have included display as part of their function, since their main decoration is concentrated on one side of the vessel. This may not have been their sole or even principal purpose: an example came from the immediate vicinity of the entrance to the Workmen's Village at Amarna, a spot for which some sort of ritual connotation is conceivable. Other vessels seem to have served industrial purposes: spinning bowls have already been mentioned, and the mysterious 'firedogs' of the Middle and New Kingdoms (Aston 1989b; Nibbi 1987) remain to be convincingly interpreted. It should be added that although many vessels have been found in tombs used as commodity containers, it is doubtful whether this can always be taken to indicate the vessel's use in life. The specialist manufacture of funerary pottery, already noted, militates against this.

Secondary modifications to the vessels also give some clue as to usage. Blackening and burning on the exterior may indicate use for cooking, but the question remains whether most examples of the type show the same feature. Cooking pots from Amarna appear, on the basis of burning, to occur in two very different forms, although both in siltware, one a wide-mouthed carinated bowl, and the other a restricted short-necked globular jar; at Malkata the forms used are the same carinated bowl and another type of bowl which at Amarna is never burnt (Hope 1989: 14). By contrast, burning on the interior may indicate use as lamps or for the burning of incense (the latter being a further case where the evidence of tomb representations can be correlated with actual vessel types). At Amarna, a frequently noted feature is the wearing away of the slip on the interior of a common type of bowl. The type usually comes from domestic contexts, and a possible explanation for the trait is that the wear represents the scouring of vessels after use. The fabric seems too soft for the vessels to be used for grinding and anyway stone mortars are common at the site.

Finally, analysis of visible residues, and of invisible traces trapped within the structure of the vessel provide some understanding of uses to which individual pieces were put. However, without a large number of examples, it will not prove possible to generalise as to the usual range of uses to which types could be put.

A key to understanding usage lies in study of assemblages within their archaeological context. On settlement sites, this means the identification of area function through the usual archaeological means, and the assessment of the occurrence of pottery types within that framework (Rose 1984, 1986, 1987), or between contemporary sites (Goren *et al.* 1995: 113–16). Not only may this identify the specific function of some vessel types, but also indicates what 'typical' ceramic repertoires were in certain contexts. However, this can be complicated by the fact that a vessel's useful life did not necessarily end once it was broken or had fulfilled its original function. Large chunks of vessels were used for structural purposes, as, for example drains, sumps, or even to contain child burials. In modern times, whole vessels are sometimes built into houses to provide insulation against heat and cold. In the case of transport wares, these could clearly serve secondary purposes after the contents had been removed, including as containers for different commodities (with concomitant relabelling). Thus, for example, meat jars have commonly been found buried in floors where they served as underground storage chambers.

Sherds were reused for a multitude of purposes. They were incorporated into buildings through their presence in mud bricks. In part, this may have been the fortuitous result of where the raw material for the brick was gathered, but in some cases the size of the sherds included make this appear deliberate. They were used in the late Roman period as chinking in mud-brick vaulting; and a modern usage, which may have been practised anciently, is to scatter them on the roof to absorb rainfall. All these practices may lead to the incorporation of sherd material into the archaeological record which does not play a part in the interpretation of pottery as related to site function, although it plays a key role in the understanding of the taphonomy of the site. Sherds (ostraca) were also reused as a material on which to write throughout Egyptian history, and were used for anything from casual scribbling, to letters, contracts and diaries, some of which were undoubtedly later transferred to a more easily storable medium such as papyrus. Sherds could also be used as convenient tools. A feature of many habitation and tomb sites are sherds of which one or more edges have been worn smooth, and are generally of a size that fits conveniently into the hand. They seem to have been used for digging, particularly of the kind associated with 'treasure hunting'.

The future of pottery studies

Since Lucas wrote, there has been a vast diversification in pottery studies, which now encompasses both scientific investigation of the ceramics themselves and their wider interpretation. It is widely realised that ceramics, by virtue of the quantity in which they are found (no other material approaches pottery in terms of volume), and their ubiquity on sites of all periods and types, are capable of reflecting economic and social conditions in a way no other aspect of material culture of sites can.

This aspect of study is as yet in its infancy for ancient Egypt, and it is worth stating here the sorts of questions which may be addressed. Firstly, the matter of chronology. This is the most fundamental use to which pottery has been put in Egypt. Vessels can, on the whole, now be reasonably well dated, usually by the association of complete vessels from tombs with inscriptional material. Scientific dating methods such as thermoluminescence are irrelevant in this context, since the error rate (currently *c.* ±10 per cent) is greater than would be useful for dating in Egyptology (cf. Rice 1987: 440–3). However, refining of the system is necessary, and this is most likely to take place by means of quantified analysis of large quantities of material, recording detailed changes in attributes over time through the stratigraphic record (for example, Hummel and Schubert 1994), or by applying seriation techniques to cemetery evidence (for the technique, see Rice 1987, 436–7; for an example of its application in Egypt, Wilkinson 1996). When closely contemporaneous bodies of material are available, comparison may highlight features that indicate differences in function, production area, or status. Once regional or specialised production can be identified, mechanisms of trade can more easily be assessed.

A different way to approach the problem is by looking at changes in the same sorts of vessels or wares over time. Jacquet-Gordon (1981) has documented bread moulds from the Predynastic to the Late Period and beyond, and from this it is clear that there is a radical change at the end of the Old Kingdom. What is the explanation of that change? Is it a matter of social change, or a difference in economic conditions? Is it a response to technological innovation, or merely a matter of fashion? Or, again, what explains the resurgence of interest in sculpted and decorated pottery in the early New Kingdom, an interest last manifested in the Predynastic period? Or, does change or innovation in production of other types of material (for example, faience), influence ceramic production? Can fall-off patterns from production areas demonstrate status associated with certain wares?

In short, one strand of future work must be to pull the ever-increasing amounts of information together and construct mechanisms for its interpretation. An essential for this is the production of properly quantified data based on substantial assemblages from well-excavated contexts, which allow for comparison within and between sites. A number of methods of quantification are currently in use in the field of ceramic studies (Orton 1975; Orton *et al.* 1993). The most commonly used are:

Sherd counts: the results of this method are influenced by the differential breakage rate of certain ware types. For example, fine-walled vessels will break into more sherds than coarse wares. Also, the type of context may influence the results, in that, for example, a surface on which traffic passes regularly may have more broken sherds.

Sherd weights: again, the results are influenced by the types of wares involved; in this case heavy ware types will be over-represented (both techniques can be combined to give an average sherd size, which may assist in interpreting site formation processes, for example that smaller sherds may indicate more wear and hence longer exposure).

Estimated vessel equivalents: this uses rims or bases to form a measure of how many vessels of a given type are represented in a deposit, and has the advantage that it enables comparison between vessel types in an assemblage without the same degree of bias as weights and counts. In it the percentage of the extant diameter is recorded for each rim or base of the type. The percentages of individual rim sherds are added together for each type and, divided by 100, giving a figure for the type which can be used for comparison with that of other types.

References

Adams, B. 1988. *Predynastic Egypt*. Aylesbury: Shire Egyptology.

Adams, W.Y. 1979. On the argument from ceramics to history: a challenge based on evidence from medieval Nubia. *Current Anthropology*, 20: 727–44.

1986. *Ceramic Industries of Medieval Nubia*. Lexington, KY: Kentucky University Press.

Aksamit, J. 1992. Petrie's type D46D and remarks on the production and decoration of predynastic decorated pottery. *CCE*, 3: 17–22.

Allen, R.O., Rogers, M.S., Mitchell, R.S. and Hoffman, M.A. 1982. A geochemical approach to the understanding of ceramic technology in Predynastic Egypt. *Archaeometry*, 24: 199–212.

Allen, R.O., Hamroush, H. and Hoffman, M.A. 1989. Archaeological implications of differences in the composition of Nile sediments. In *Archaeological Chemistry IV*, (ed. R.O. Allen). Washington: American Chemical Society, pp. 33–56.

Arnold, D. 1976. Wandbild und Scherbenbefund. Zur Töpfertechnik der alten Ägypter vom Beginn der pharaonischen Zeit bis zu den Hyksos. *MDAIK*, 32: 1–34.

1981. Ägyptische Mergeltone ('Wüstentone') und die Herkunft einer Mergeltonware des Mittleren Reiches aus der Gegend von Memphis. In *SAK* (ed. D.Arnold). Mainz: von Zabern, pp. 167–91.

1982. Keramikbearbeitung in Dahschur 1976–1981. *MDAIK*, 38: 25–65.

1988. Pottery. In *The Pyramid of Senwosret I.* (ed. D. Arnold). New York: Metropolitan Museum of Art, pp. 106–46.

1993. Techniques and traditions of manufacture in the pottery of ancient Egypt. In *An Introduction Ancient Egyptian Pottery.* (eds. D. Arnold and J.D. Bourriau). Mainz: von Zabern, pp. 11–102.

Arnold, D. and Bourriau, J.D. (eds.) 1993. *An Introduction to Ancient Egyptian Pottery. Fascicle I.* Mainz: von Zabern.

Arnold, D.E. 1985. *Ceramic Theory and Cultural Process.* Cambridge: CUP.

Aston, D.A. 1989a. Qantir/Piramesse-Nord – Pottery Report 1988. *Göttinger Miszellen*, 113, 7–24.

1989b. Ancient Egyptian fire dogs – a new interpretation. *MDAIK*, 45: 27–32.

1996. *Egyptian Pottery of the Late New Kingdom and Third Intermediate Period.* Studien zur Archäologie und Geschichte altägyptens 13. Heidelberg: Heidelberger Orientverlag.

Bachmann, H.G., Everts, H. and Hope, C.A. 1980. Cobalt-blue pigment on 18th Dynasty pottery. *MDAIK*, 36: 33–7.

Ballet, P. and Picon, M. 1990. Étude de la céramique. In *Balat III. Les Ateliers de Potiers d'Ayn-Asil* (eds. G. Soukiassian, M. Wuttmann and L. Pantalacci). Cairo: IFAO, pp. 75–165.

Ballet, P. and Vichy, M. 1992. Artisanat de la Céramique dans l'Égypte Hellénistique et Romaine. *CCE*, 3: 109–19.

Bell, M. 1987. Regional variation in polychrome pottery of the 19th Dynasty. *CCE*, 1: 49–76.

Bellido, A., Bourriau, J.D., Bryan, N. and Robinson, V. Forthcoming. Chemical fingerprinting of Egyptian pottery fabrics: a comparison between NAA groupings and the Vienna System.

Bietak, M. 1968. *Studien zur Chronologie der nubischen C-Gruppe: Ein Beitrage zur Frühgeschichte Unternubiens zwischen 2200 und 1500 vor Ch.* Vienna: Böhlaus.

Blackman, W. 1927. *The Fellahin Of Upper Egypt.* London: Harrap.

Bourriau, J.D. 1981a. *Umm el-Ga'ab: Pottery From the Nile Valley Before The Arab Conquest.* Cambridge: CUP.

1981b. Nubians in Egypt during the Second Intermediate Period. An interpretation based on the Egyptian ceramic evidence. In *Studien zur altägyptischen Keramik* (ed. D. Arnold). Mainz: von Zabern, pp. 25–41.

1982. Clay figure vases. In *Egypt's Golden Age: The art of living in the New Kingdom 1558–1085 B.C.* (eds. E. Brovarski, S.K. Doll and R.E. Freed) Boston: Museum of Fine Arts, pp. 101–6.

1985. Technology and typology of Egyptian ceramics. In *Ceramics and Civilization Vol. 1: Ancient Technology to Modern Science* (ed. W.D. Kingery). Columbus, Ohio: The American Ceramic Society, pp. 27–42.

1986/7 Cemetery and settlement pottery of the second intermediate period to early New Kingdom. *BES*, 8: 47–59.

1987. Pottery figure vases of the New Kingdom. *CCE*,1: 81–96.

1996. Observations on the pottery from Serabit el-Khadim. *CRIPEL*, 18: 19–32.

1998 The role of chemical analysis in the study of Egyptian pottery. In *Proceedings of the Seventh International Congress of Egyptologists Cambridge 1995.* (ed. C. Eyre). Leuven: Peeters, pp. 189–99.

Bourriau, J.D. and Nicholson, P.T. 1992. Marl clay pottery fabrics of the New Kingdom from Memphis, Saqqara and Amarna. *JEA*, 78: 29–91.

Bourriau, J.D., Smith, L.M.V. and Nicholson, P.T. in press. *New Kingdom Pottery Fabrics: Nile Clay and Mixed Nile/Marl Clay Fabrics from Memphis and Amarna.* London: EES.

Brissaud, P. 1982. *Les Ateliers de Potiers de la region de Louqsor.* Cairo: IFAO.

Brooks, D., Bieber jr., A.M., Harbottle, G. and Sayre, E.V. 1974. Biblical studies through activation analysis of ancient pottery. In *Archaeological Chemistry* (ed. C.W. Beck). Washington: American Chemical Society, pp. 48–80.

Brunton, G. 1948. *Matmar.* London: Quaritch.

Bruyère, B. 1939. Rapport sur les fouilles à Deir el Médineh (1934–1935). III. Cairo: IFAO.

Butzer, K.W. 1974. Modern Egyptian pottery clay and Predynastic buff ware. *JNES*, 33: 377–82.

Cardew, M. 1952. Nigerian traditional pottery. *Nigeria*, 39: 188–201.

Davies, N. de G. 1908. *The Rock Tombs of El Amarna. Part V – Smaller Tombs and Boundary Stelae.* Archaeological Survey of Egypt. Seventeenth Memoir. London: EEF.

1930. *The Tomb of Ken-amun at Thebes.* The Metropolitan Museum of Art Egyptian Expedition, Vol. V. New York: MMA.

Debono, F. and Mortensen, B. 1990. *El Omari.* MMA.

Eyre, C. 1987a. Work and organisation of work in the Old Kingdom. In *Labor in the Ancient Near East* (ed. M.A. Powell). American Oriental Series 68. New Haven, CT: American Oriental Society, pp. 5–48.

1987b. Work and organisation of work in the New Kingdom. In *Labor in the Ancient Near East* (ed. M.A. Powell). American Oriental Series 68. New Haven, Conneticut: American Oriental Society 68, pp. 167–222.

Fieller, N.R.J. and Nicholson, P.T. 1991. Grain size analysis of archaeological pottery: the use of statistical models. In *Recent Developments in Ceramic Petrology* (eds. A. Middleton and I. Freestone). London: British Museum Research Laboratory, pp. 71–111.

Finkelstaedt E. 1980. Regional painting style in prehistoric Egypt. *ZAS*, 107:116–20.

1981. The location of styles in painting: white cross-lined ware at Nagada. *JARCE*, 18: 7–10.

French, P. 1992. A preliminary study of pottery in Lower Egypt in the Late Dynastic and Ptolemaic periods. *CCE*, 3: 83–93.

Goren, Y., Oren, E. and Feinstein, R. 1995. The archaeological and ethnoarchaeological interpretation of a ceramological enigma: pottery production in Sinai (Egypt) during the New Kingdom period. *KVHAA Konferenser*, 34. Stockholm, 101–20.

Hamroush, H. 1992. Pottery analysis and problems in the indentification of the geological origins of ancient ceramics. *CCE*, 3: 39–51.

Hamroush, H. and Zeid, H.A. 1990. Petrological and chemical analyses of some neolithic ceramics from el Omari, Egypt. In *El Omari* (F. Debono, and B. Mortensen). Mainz: von Zabern, pp. 117–28.

Hancock, R.G., Aufreiter, S. and Elsokkari, I. 1986/87. Nile Alluvium: Soil and Ceramics. *BES*, 8: 61–71.

Hancock, R.G.V., Millet, N.B. and Mills, A.J. 1986. A rapid INAA method to characterize Egyptian ceramics. *JAS*, 13: 107–17.

Harbottle, G. 1982. Provenience studies using Neutron Activation Analysis: the role of standardization. In *Archaeological Ceramics* (eds. J.S. Olin and A.D. Franklin). Washington: Smithsonian Institution, pp. 67–77.

Hennessy, J.B. and Millet, A. 1963. Spectographic analysis of the foreign pottery from the royal tombs of Abydos and Early Bronze Age pottery of Palestine. *Archaeometry*, 6: 10–17.

Hodges, H. 1989. *Artifacts*. London: Duckworth.

Hoffman, M. 1982. *The Predynastic of Hierakonpolis – An Interim Report*. Egyptian Studies Association Publication 1. Cairo and Macomb, Ill.: University Herbarium, Cairo and Department of Sociology and Anthropology, Western Illinois University.

Holmen, K. 1990. Indentification of some plant remains in the el Omari pottery. In *El Omari* (F. Debono and B. Mortensen). Mainz: von Zabern, pp. 129–30.

Holthoer, R. 1977. *New Kingdom Pharaonic Sites: The Pottery*. Scandinavian Joint Expedition to Sudanese Nubia Vol. 5:1. Stockholm: Scandinavian University Books.

1991. The wheelmade pottery in Middle Nubian cortex. In *Middle Nubian Sites* (ed. T. Säve-Söderbergh). The Scandinavian Joint Expedition to Sudanese Nubia publications Vol. 4: 1, 59–74. Partille: Paul Åström Editions.

Hope, C. 1981. Two ancient Egyptian potter's wheels. *JSSEA*, 11: 127–33.

1982. Aspects of ceramic specialisation and standardisation in the New Kingdom. *BL*, VII: 39–41.

1987a. *Egyptian Pottery*. Aylesbury: Shire Egyptology.

1987b. Dakhleh Oasis project – report on the study of the pottery and kilns. In *Ceramics From The Dakhleh Oasis (second season 1979)* (eds. W. Edwards, C. Hope and E. Segnit). Victoria College Archaeology Research Unit Occasional Paper No. 1. Burwood: Victoria College Press, pp. 25–52.

1989. *Pottery of the Egyptian New Kingdom: Three Studies*. Victoria College Archaeology Research Unit, Occasional Paper No. 2. Burwood: Victoria College Press.

1991. Blue-painted and polychrome decorated pottery from Amarna: a preliminary corpus. *CCE*, 2: 17–92.

1993. Pottery kilns from the oasis of el-Dakhla. In *An Introduction To Ancient Egyptian Pottery* (eds. D. Arnold and J. Bourriau). Mainz: von Zabern, pp. 121–7.

Hummel, M and Schubert, S. 1994. Kom el-Ahmar: Ceramic typology. In *The Akhenaten Temple Project 3: The Excavations of Kom el-Ahmar and Environs* (ed. D. Redford). Aegypti Texta Propositaque II. Toronto: Akhenaten Temple Project, pp. 30–82.

Jacquet, J. 1965. The architect's report. In *Mit Rahineh 1956* (ed. R. Anthes). Philadelphia: The University Museum, University of Pennsylvania, pp. 46–59.

Jacquet-Gordon, H. 1981. A tentative typology of Egyptian bread moulds. In *Studien zur altägyptischen Keramik* (ed. D. Arnold). Mainz: von Zabern, pp. 11–24.

Janssen, J.J. 1975. *Commodity Prices From The Ramessid Period*. Leiden: E.J. Brill.

Kaiser, W., Avila, R., Dreyer, G., Jaritz, H., Seidlmayer, F. and S. 1982. Stadt und Tempel von Elephantine. *MDAIK*, 38: 271–345.

Kaplan, M.F., Harbottle, G. and Sayre, E.V. 1982. Multi-disciplinary analysis of Tell el-Yahudiyeh Ware. *Archaeometry*, 24: 127–42.

Kemp, B.J. 1989. *Amarna Reports V*. London: EES.

1995. *Amarna Reports VI*. London: EES.

Kirby, C. 1989. Report on the 1987 excavations: The excavation of Q48.4. In *Amarna Reports V* (ed. B.J. Kemp). London: EES, pp. 15–63.

Köhler, K. 1992. Problems and priorities in the study of Pre- and Early Dynastic pottery. *CCE*, 3: 7–16.

Kroeper, K. (1992) Shape + Matrix = Workshop. Ceramic from Minshat Abu Omar. *CCE*, 3: 23–31.

Leahy, M.A. 1985. The hieratic labels, 1979–82. In *Amarna Reports II* (ed. B.J. Kemp). London: EES, pp. 65–109.

Lehner, M. 1985. Giza. A contextual approach to the Pyramids. *Archiv für Orientforschung*, 32: 136–58.

Makundi, I.N., Waern-Sperber, A. and Ericsson, T. 1989. A Mössbauer study of the black colour in Early Cypriote and Nubian C-group Black Topped pottery. *Archaeometry*, 31: 54–65.

Mesnil du Buisson, Compte du. 1935. *Les noms et signes Égyptiens désignant des vases ou objets similaires*. Thèse complementaire pour le Doctorat des Lettres, Faculté des Lettres de l'Université de Paris.

Minault-Gout, A. and Deleuze, P. 1992. *La mastaba d'Ima-Pépi*. FIFAO XXXIII. Cairo: IFAO.

Mond, R. and Myers, O. 1937. *Cemeteries of Armant I*. London: EES.

Nagel, G. 1938. *La Céramique du Nouvel Empire à Deir el Médineh*. Cairo: IFAO.

Newberry P. 1893a. *Beni Hasan I*. Archaeological Survey of Egypt. First Memoir. London: EEF.

1893b. Beni Hasan II. Archaeological Survey of Egypt. Second Memoir. London: EEF.

1895. *El Bersheh I*. Archaeological Survey of Egypt. Third Memoir. London: EEF.

Nibbi A. 1987. *Ancient Egyptian Pot Bellows and the Oxhide Ingot Shape*. Oxford: DE Publications.

Nicholson, P.T. 1989a. Experimental determination of the purpose of a 'box oven'. In *Amarna Reports V* (ed. B.J. Kemp). London: EES, pp. 241–52.

1989b. *Iron Age Pottery Production in the Hunsrück-Eifel-Kultur of Germany: A World-System Perspective*. Oxford: BAR S-501.

1989c. Report on the 1987 excavations: the pottery kilns in building Q48.4. In *Amarna Reports V* (ed. B.J. Kemp). London: EES, pp. 64–81.

1993. The firing of pottery. In *An Introduction to Ancient Egyptian Pottery* (eds. D. Arnold and J. Bourriau). Mainz: von Zabern, pp. 103–20.

1995a. The potters of Deir Mawas, an ethnoarchaeological study. In *Amarna Reports VI* (ed. B.J. Kemp). London: EES, pp. 279–308.

1995b. Glassmaking and glassworking at Amarna: some new work. *Journal of Glass Studies*, 37: 11–19.

Nicholson, P.T. and Patterson, H.L. 1985a. Pottery making in Upper Egypt: an ethnoarchaeological study. *WA*, 17 (2): 222–39.

1985b. The potters of Deir el-Gharbi. *Popular Archaeology*, February 1985: 5–10.

1989. Ceramic technology in Upper Egypt: a study of pottery firing. *WA*, 21 (1): 71–86.

Nicholson, P. and Rose, P. 1985. Pottery fabrics and ware groups at el-Amarna. In *Amarna Reports II* (ed. B.Kemp). London: EES, pp. 133–74.

Noll, W. 1981a. Bemalte Keramiken Altägyptens: Material, Rohstoffe und Herstellungstechnik. In *Studien zur altägyptischen Keramik* (ed. D. Arnold). Mainz: von Zabern, pp. 103–38.

1981b. Mineralogy and technology of the painted ceramics of Ancient Egypt. In *Scientific Studies in Ancient Ceramics* (ed. M. Hughes). London: BMP, pp. 143–54.

Nordström, H-Å. 1972. *Neolithic and A-group Sites*. Scandinavian Joint Expedition to Sudanese Nubia, Vol. 3:1. Stockholm:

Scandinavian University Books.

Nordström, H-Å. and Bourriau, J. 1993. Ceramic technology: clays and fabrics. In *An Introduction to Ancient Egyptian Pottery* (eds. D. Arnold and J. Bourriau). Mainz: von Zabern, pp. 147–90.

O'Connor, D. 1974–75. Political systems and archaeological data in Egypt: 2600–1780 BC. *WA*, 6: 15–38.

Oren, E.D. 1987. The 'Ways of Horus' in North Sinai. In *Egypt, Israel, Sinai. Archaeological And Historical Relationships In The Biblical Period* (ed. A.F. Rainey). Tel Aviv: Tel Aviv University, pp. 69–120.

Orton, C. 1975. Quantitative pottery studies: some progress, problems and prospects. *Science and Archaeology*, 16: 30–5.

Orton, C., Tyers, P. and Vince, A. 1993. *Pottery in Archaeology*. Cambridge: CUP.

de Paepe, P. 1986. Étude mineralogique et chimique de la céramique néolithic d'el Kadada et ses implications archéologiques. *Archéologie du Nil Moyen* 1: 113–40.

de Paepe, P., Gratien, B. and Privati, B. 1992. Étude Comparative de Céramiques Kerma. *CRIPEL*: 63–81.

Payne, J. 1966. Spectrographic analysis of some Egyptian pottery of the Eighteenth dynasty. *JEA*, 52: 176–8.

Peacock, D.P.S. 1977. Ceramics in Roman and Medieval archaeology. In *Pottery and Early Commerce* (ed. D.P.S.Peacock). London: Academic Press, pp. 21–33.

1982. *Pottery in The Roman World: An Ethnoarchaeological Approach*. London: Longman.

Perlman, I. and Asaro, F. 1969. Pottery analysis by neutron activation. *Archaeometry*, 11: 21–53.

Pollard, A.M. and Heron, C. 1996. *Archaeological Chemistry* Cambridge: The Royal Society of Chemistry.

Porat, N. and Seeher, J. 1988. Petrographic analyses of pottery and basalt from Predynastic Maadi. *MDAIK*, 44: 215–28.

Posener-Kriéger, P. 1976. *Les archives du temple Funéraire de Néferirkarí Kakaô (Les papyrus d'Abousir)*. Cairo: IFAO.

Powell, C. 1995. The nature and use of ancient Egyptian potter's wheels. In *Amarna Reports VI* (ed. B.J. Kemp). London: EES, pp. 309–35.

Redford, D. 1981. Interim report on the excavations at East Karnak, 1977–78. *JARCE*, 18: 11–41.

Redmount, C.A. and Morgenstein, M.E. 1996. Major and trace element analysis of modern Egyptian pottery. *JAS*, 23: 741–62.

Reisner, G.A. 1923. *Excavations at Kerma*. Cambridge, MA: Peabody Museum of Harvard University.

Rice, P.M. 1987. *Pottery Analysis: A Sourcebook*. Chicago: University of Chicago Press.

Riederer, J. 1974. Recently identified Egyptian pigments. *Archaeometry*, 16: 102–9.

1988. The microscopic analysis of Egyptian pottery from the Old Kingdom. In *Akten des vierten internationalen Ägyptologenkongresses München 1985* (ed. S. Schoske). Beihefte Studien zur altägyptischen Kultur, I. Hamburg: Helmut Buske Verlag. Band I: pp. 221–30.

1992. The microscopic analysis of calcite tempered pottery from Minshat Abu Omar. *CCE*, 3: 33–7.

Rose, P. 1984. The pottery distribution analysis. In *Amarna Reports I* (ed. B.J. Kemp). London: EES, pp. 133–53.

1986. Pottery from the Main Chapel. In *Amarna Reports III* (ed. B.J. Kemp). London: EES, pp. 99–117.

1987. Pottery from Gate Street 8. In *Amarna Reports IV* (ed. B.J. Kemp). London: EES, pp. 132–43.

1989. Report on the 1987 excavations: The evidence for pottery-making at Q48.4. In *Amarna Reports V*, (ed. B.J. Kemp). London: EES, 82–101.

1996. The pottery. In *The Tombs Of Amenhotep, Khnummose and Amenmose at Thebes* (ed. N. Strudwick). Oxford: Griffith Institute, pp. 166–81.

Rye, O.S. 1976. Keeping your temper under control: materials and the manufacture of Papuan pottery. *Archaeology and Physical Anthropology in Oceania*, 11 (2): 106–37.

Saleh, A.A. 1974. Excavations around the Mycerinus pyramid complex. *MDAIK*, 30: 131–54.

1996. Ancient Egyptian house and palace at Giza and Heliopolis. In *House and Palace in Ancient Egypt* (ed. M. Bietak). Vienna: Österreichische Akademie der Wissenschaften, pp. 185–94.

Säve-Söderbergh, T. 1989. *Middle Nubian Sites*. Scandinavian Joint Expedition to Sudanese Nubia, Vols. 4:1 and 4:2. Partille: Paul Åstrom Editions.

Soukiassian, G., Wuttmann M., Pantalacci, L., Ballet, P. and Picon, M. 1990. *Balat III. Les Ateliers de Potiers d'Ayn-Asil*. Cairo: IFAO.

Stadelmann, R. 1983. Die Pyramiden des Snofru in Daschur. Zweiter Bericht über die Ausgrabungen an der nordlichen Steinpyramide. *MDAIK*, 39: 228–30.

Stevenson, R.B.K. 1953. Prehistoric pot-building in Europe. *Man*, 53: 65–8.

Strouhal, E., Urbanec, Z., Čejka, J. and Cejkova, I. 1988. Elemental analysis of pottery from the temple of Queen Khentkaus at Abusir. In *Akten des vierten internationalen Ägyptologenkongresses. München 1985* (ed. S. Schoske). Band I. Beihefte Studien zur altägyptischen Kultur 1. Hamburg: Helmut Buske Verlag, pp. 247–55.

Tobert, N. 1984. Ethno-archaeology of pottery firing in Darfur, Sudan: implications for ceramic technology studies. *Oxford Journal of Archaeology*, 3 (2): 141–56.

Tobia, S.K. and Sayre, E.V. 1974. An analytical comparison of various Egyptian soils, clays, shales and some ancient pottery by neutron activation. In *Recent Advances in Science and Technology of Materials*, Vol. 3 (ed. A. Bishay). New York: Plenum, pp. 99–128.

Varille, A. and Robichon, C. 1935. Quatre nouveaux temples Thebains. *CdE*, 10: 237–42.

Vercoutter, J. 1970. *Mirgissa I*. Paris: CNRS.

Verner, M. 1992. Discovery of a potter's workshop in the pyramid complex of Khentkaus at Abusir. *CCE*, 3: 55–60.

Wenig, S. 1978. *Africa In Antiquity: The Arts Of Ancient Nubia And The Sudan*. 2 vols. New York: Brooklyn Museum.

Whitbread, I. K. 1986. The characterisation of argillaceous inclusions in ceramic thin sections. *Archaeometry*, 28: 79–88.

Wilkinson, T.A.H. 1996. *State Formation in Egypt: Chronology And Society*. Cambridge monographs in African archaeology 40. BAR International Series 651. Oxford: Tempus Reperatum.

Williams, D.F. 1983. Petrology of ceramics. In *The Petrology of Archaeological Artefacts* (eds. D.R.C. Kempe and A.P. Harvey). Oxford: Clarendon Press, pp. 301–29.

Woods, A.J. 1986. Form and function: some observations on the cooking pot in antiquity. In *Ceramics and Civilization*, Vol. 2. (ed. W.D. Kingery). Columbus, Ohio: American Ceramic Society, pp. 157–72.

6. Metals

JACK OGDEN

Introduction

The importance of metallurgy throughout history is underlined by our habit of dividing the past into Bronze and Iron ages, with various subdivisions of these. Such convenient chronological nomenclatures imply a greater segmentation of metal use in the past than is strictly true. The periods of usage of different metals and alloys overlapped and there was often a long delay between the first exploitation of a new technology and its adoption by society at large. Egyptian peasants were still harvesting grain with flint-edged sickles 1,000 years after the pharaoh Pepi I had been immortalised in an over life-size copper statue found at Hierakonpolis (Cairo JE33034).

We know little of the prospecting habits of the Egyptians, but they were thorough and perhaps systematic in their discovery of metalliferous deposits employing a combination of large-scale state expeditions and smaller prospecting/surveying groups. A graffito by Thuthotep, a 'reckoner of gold' around 2000 BC has been found at the remote Abrak well some 240 kilometres southeast of Aswan (de Bruyn 1955). The prospectors might have lacked geochemical knowledge in the modern sense, but they had a practical understanding of nature. No doubt they could recognise the land formations, rock colours and even flora associated with metal deposits. For example, it has been noted that the pine *Pinus halepensis* grows particularly abundantly over the copper gossans on Cyprus (Constantinou 1982), while the presence of acacia trees can reflect the presence of copper and lead ores. Possibly, the association of the goddess Hathor with both mines, as at Timna, and with acacia trees is not coincidental. Acacia wood also served as pit props in some Egyptian gold mines – a function which devotees of Hathor might have found reassuring.

In the ancient Near East, ores were generally treated at or near the mines; it is easier to transport and keep a tally of ingots than bulkier raw materials. Nevertheless, the availability of fuel would dictate the best option for treatment locality. The urban craftsmen were probably far better acquainted with associated craft activities such as faience and glass manufacture than ore recovery and mining processes. However we do not know the economic or other factors that decided which ores should be locally treated near the mines to produce metals or which if any might be transported for use in the pigment and glaze industries.

Our understanding of ancient Egyptian metals comes from the careful study of surviving examples using, increasingly, the analysis and internal study made possible by technological advances. To date, thousands of analyses of Egyptian metals have been published (e.g. Riederer 1978b, 1981, 1982, 1983, 1984, 1988; Lucas 1962; Fleming and Crowfoot-Payne 1979). A good summary of earlier analyses is given by Riederer (1982) and an overall summary of results is provided by Kaczmarczyk and Hedges (1983). There are also numerous other analyses scattered in the conservation and scientific literature, while a huge number undertaken by museums around the world remain unpublished. Most of these analyses have been carried out on supposed Late Period copper alloy objects. Garland noted that

> Amongst archaeologists it is the practice to assign any non-ferrous metal object not found under known and convincing circumstances or not bearing marks by which they may be dated . . . to the Saitic period, generally the 26th Dynasty. (Garland and Bannister 1927: 83)

This tradition is still alive and well. Firm chronological distinction will not be possible until analysis of metal finds becomes as standard a practice in Egyptology as it is in some other archaeological fields. Analysis is now an integral and useful part of archaeology and art history. For example, Riederer, on the basis of his various analyses of over 1,200 Egyptian copper alloy objects, noted that composition sometimes seemed to vary with subject (Riederer 1978b, 1981, 1982, 1983, 1984, 1988). This ties in with Roeder's earlier observation that forms or poses of deity figures tended to differ from place to place within Egypt (Roeder 1956). This is understandable. If the statuettes were usually made at the local temples, their attributes and poses might be expected to replicate those of the cult statues then in use there, while their compositions would reflect the traditions of, and constraints on, the local metalworkers as well as aesthetic and colour considerations.

Our knowledge of ancient sources of ores and other natural products is helped by the published geological studies of Egypt, including much undertaken since the Second World War on metal ore distribution and geochemistry. The reader is thus directed to the specialist geological literature, starting with el-Baz's annotated bibliography (el-Baz 1984). John Harris' 1962 revision of Alfred Lucas' fundamental work *Ancient Egyptian Materials Industries* is, of course, still invaluable and the reader is directed to the older works referenced there, in particular to those relating to excavation reports and ancient documentary sources (Lucas 1962).

Antimony

Antimony is a light, bright, white metal, not unlike silver in appearance, but it is brittle and better suited to casting, not mechanical working. The use of metallic antimony in ancient Egypt has been reported, but such instances were largely discredited by Lucas on the basis of visual study and, where feasible, analysis (Lucas 1962: 195–9). Thus we can now exclude such supposed examples as the 'antimony powder' said to have been found in Tutankhamun's tomb and the 'antimony plating' on an Old Kingdom vessel. Readers are directed to Lucas' comments and can also note that Meyers' more recent re-analysis of the 'antimony plated' vessel confirmed that the surface layer was indeed actually arsenic due, almost certainly, to natural surface enrichment (Lucas 1962: 198; Smith 1970: 102, n. 5).

The only confirmed examples of metallic antimony from ancient Egypt published to date are the small beads, probably of native antimony, of Third Intermediate Period date which were found by Petrie at Lahun and analysed by Gladstone (Lucas 1962; Garland and Bannister 1927: 32). The identification is supported by the existence of occasional excavated (and analysed) finds of metallic antimony outside Egypt – in Western Asia, Transcaucasia and Italy (Caley 1964: 135–6; Moorey 1994: 241–2). The Egyptian beads were probably imports since antimony ores occur as little more than minute traces in Egypt.

Some Iron-Age beads from Tell el-Fara in Israel are described by Dayton (1978: 450) as tin:antimony alloys with about 66 per cent tin and 33 per cent antimony. Although antimony has not yet been found as a principal component in any ancient Egyptian alloys, we might well expect other examples of metallic antimony and antimony-rich alloys to be identified as analysis becomes more routine. As a *caveat*, however, we can note that objects made of antimony alloys occasionally appear in collections that are modern fakes made of easy-to-cast 'type-metal'.

Antimony is common in small amounts in ancient copper alloy objects (usually under about 1 per cent) and as a trace element in lead. It is also found as an ingredient in Egyptian faience from the time of Thutmose III and in glass from about the Amarna period onwards (Kaczmarczyk and Hedges 1983: 98). An antimony compound was also used as an occasional eye-paint in Egypt from the Amarna period onwards, but this was far less common than has generally been supposed – a state of affairs seemingly also true in Mesopotamia (Lucas 1962: 196–9; Moorey 1994: 241). The evidence suggests that antimony, as ore or native metal, was reaching Egypt from the New Kingdom onwards, and was perhaps sometimes confused with tin.

Bronze *see* copper and copper alloys

Electrum *see* gold and electrum

Copper and copper alloys

Copper is a pinkish-yellow metal that occurs native – that is in metallic form – or, far more commonly, as copper-containing ores from which the copper can be extracted by procedures termed smelting. Copper-bearing deposits can contain copper ores of varying complexity and purity and some native copper. Apart from metallurgy, there were a myriad of uses for copper and copper ores in ancient Egypt: in medicines (Weser 1987: 189–94), as pigments (see pp. 153, 154, 156 and Chapter 4, this volume) and as colouring agents in glazes and glass (see p. 156–7 and Chapters 7 and 8, this volume).

Occurrence and retrieval

The main copper-producing regions accessible to the ancient Egyptians were the Eastern Desert and the Sinai, including the Serabit el-Khadim region in the southwest and Timna in the Wadi Arabah, now part of Israel. The epigraphic evidence only refers to the turquoise found at Serabit el-Khadim, but the reported remains of *tuyères*, moulds, crucibles and casting installations suggest local ore treatment (Beit-Arieh 1985: 89–116). Copper slags, ores, crucibles, ingot moulds and other working detritus of Old and Middle Kingdom date have also been found at Wadi Magharah, some twenty kilometres southwest of Serabit el-Khadim. However, it is possible that this was more a treatment centre for ores from the surrounding region than a major mining area (Petrie 1906: 51–2; Lucas 1962: 202–4; Beit-Arieh 1981: 95–127). In view of the turquoise-biased epigraphic material, it is difficult to determine the relative extents to which mining in the Serabit el-Khadim/Magharah area was directed at the turquoise (see Chapter 2, this volume, for discussion of the implications of the term *mfk3t*) or at the copper. However, we can note that the scale of imperial turquoise exploitation in Sinai in the New Kingdom contrasts with the sparse surviving examples of its use in Egyptian jewellery. It is difficult to believe that jewellery was its primary employment. The use of ground turquoise in glaze-making had been suggested by Petrie but rejected by Lucas. Turquoise is an aluminium phosphate. Aluminium is commonly found in glazes due to its presence in sand. However, traces of phosphorus are also found in some Egyptian glazes but have not so far been satisfactorily explained (Lucas 1962: 186–7). Representations of turquoise at the mining sites in the form of cones, apparently of powder, not nuggets or blocks, tend to suggest non-jewellery use.

Our best evidence of ancient copper exploitation in Sinai comes from the Timna mines and smelting sites which have now been excavated and studied in considerable detail. This mining area reveals the recovery and local smelting of copper ores from the fourth millennium BC onwards and the gradual development of the metallurgical processes employed. Traces of manganese in a Predynastic axe and protodynastic copper bands have been taken as evidence that the copper came from Sinai (Lucas 1962: 209). There is little evidence for continued exploitation of the Sinai mines during the First Intermediate Period, but mining was re-started in the Eleventh Dynasty and became extensive in the Twelfth Dynasty, with an increasing documentary record (Mellado 1995). Copper-mining activity at Timna appears to have reached its peak during the Nineteenth and Twentieth Dynasties and represents the largest-scale Egyptian copper-mining enterprise so far discovered (Shaw 1998). The Timna mines were essentially a series of cylindrical shafts which linked underground galleries. According to Craddock:

> The mines were small, shallow and, although linked underground, display little evidence of any overall mining strategy, or of any knowledge of the possibilities of ventilation or drainage. (Craddock 1995: 69)

Timna has been associated with the New Kingdom copper mines at Atika mentioned in Papyrus Harris (Levene 1998). Workings at Timna appear to have ceased abruptly in the time of Rameses V. Strangely, there is no evidence so far for any exploitation of the Timna mines in the Late Period – the period when the production of copper statuettes and the like in Egypt increased exponentially. For a general survey of the Timna mines see Rothenberg (1972).

In Egypt itself, copper ores occur along almost the entire length of the Eastern Desert into Nubia. There is a cluster of copper deposits in the Eastern Desert inland from Safaga, and between Safaga and Quseir there are copper ores with various lead, zinc and nickel associations (Nassim 1949: 143–50). The extent of ancient workings is still largely unknown, but the lead and zinc contents of some of the ores might suggest an origin for the high lead levels in copper glazes from Elkab in the Old and Middle Kingdoms (Kaczmarczyk and Hedges 1983: 235). Copper mines of ancient but uncertain date at el-Atawi/Wadi Sitra (due east of Luxor) might have supplied workshops within the temple complexes at Thebes, where workers carried out such ambitious commissions as the casting of the doors for the temple of Amun at Karnak (as represented in the Eighteenth-Dynasty Theban tomb of Rekhmira, TT100; Davies 1943; see Fig. 6.1). The Ptolemaic bronze foundry recently found at the funerary temple of Seti I at Thebes might well come at the end of a long tradition of temple-based metalworking in the area (Scheel 1989: 41).

The Hammash area, north east of Aswan, has chacopyrite (copper/iron sulphide) ores with some associated gold. The ancient gold and copper workings in this region include some which date back to the Middle Kingdom, if not earlier (Klemm and Klemm 1994).

On the basis of analyses of copper-containing glazes, Kaczmarczyk and Hedges (1983) have recently suggested that the southern Eastern Desert was already being exploited in the Middle Kingdom, and perhaps even as early as the First Dynasty. Simple ores such as malachite, cuprite and atacamite (with the deeper deposits of sulphides with zinc, lead and silver admixtures) also occur at Samiuki in the Eastern Desert, not far from Ras Banas (Anwar 1964: 89–94). Lucas, following Hume, called the mines in this area 'the most important deposits of copper yet discovered in Egypt', and describes the extensive underground workings and the general copper recovery detritus such as ore crushers and slag. According to Lucas (1962: 206–8), the mine at Abu Seyal was 'worked extensively' in ancient

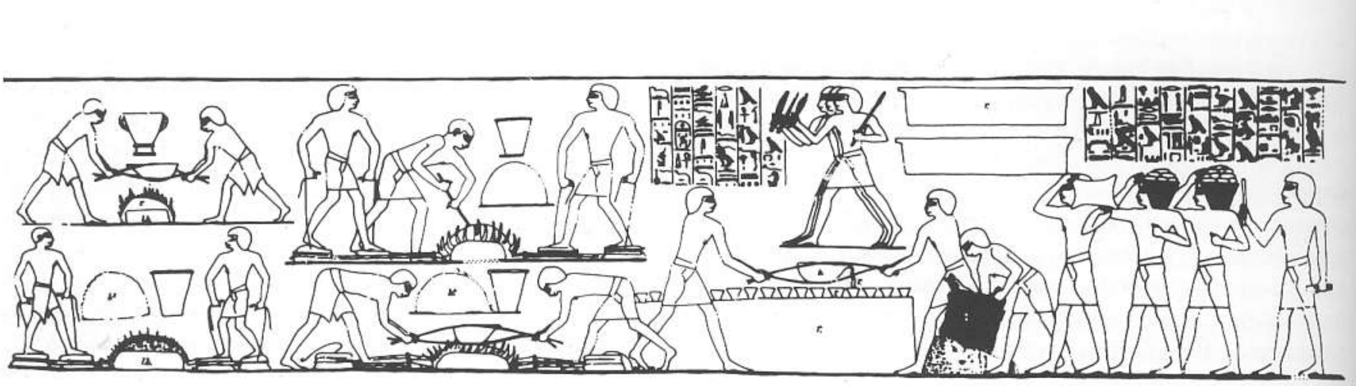


Figure 6.1 Scenes from the Theban tomb of the Eighteenth-Dynasty vizier Rekhmira (TT100), showing metalworking, including the casting of two bronze doors.

times. It has been suggested that at least some of the ore from this area was treated at Quban, where there is abundant slag. A stele from southeast of Aswan refers to the official Hor who had been instructed to collect 'copper from the land of Nubia' during the Twelfth Dynasty (Lucas 1962: 209).

The association of gold and copper ores is not unusual in the Eastern Desert and Nubia. The ore samples found at the Old Kingdom smelting site at Buhen are primarily malachite with a low iron content, but they have been reported to have a remarkably high gold content (el-Gayar and Jones 1989b). The copper derived from these ores is also reported to have included gold particles, but – in view of the ready solubility of gold in copper – these results have been questioned (Craddock and Giumlia-Mair 1993). The Abu Seyal ore, however, appears to be different from that smelted at Buhen and a more southern source for the latter is likely (el-Gayar and Jones 1989a: 31–40).

Literary references to the import of copper into Egypt from the north seem to occur first during the New Kingdom (Lucas 1962: 209), and some of this copper undoubtedly originated in Cyprus. Oxhide ingots – a form characteristic of (but not unique to) Cypriot copper exports – are depicted in the tomb of the Eighteenth-Dynasty vizier Rekhmira at Thebes (TT100). In addition, the famous wreck from Ulu Burun (Turkey) contained copper which is assumed to have been traded from Cyprus to Egypt in the fourteenth century BC (Bass 1986: 269).

Copper and its alloys

Neither native copper nor the copper produced by smelting ores are 100 per cent pure copper. They always contain a variety of other metallic impurities, the nature and amounts of which can reflect the geochemistry of the deposit, the metallurgical processes used in extraction and smelting, and the nature and purity of any intentional alloying metals. The major and minor elemental composition of copper or copper-alloy objects can thus provide potential chronological and geographical information, including evidence for authenticity.

The term 'copper alloy' as used here covers a wide range of alloys in which the predominant metal is copper. In the past the term 'bronze' was often used indiscriminately to cover all copper alloys and even copper alone, but the term 'bronze' is more correctly limited to those alloys which are predominantly copper and tin.

Copper

Some of the earliest examples of copper objects from Egypt – simple, flimsy ornaments and implements from as early as the Badarian period – might possibly have been made from native copper, i.e. copper found in nature in metallic form, not as ores. However the availability of native copper in early Egypt might well have been overstated in the past. For example an Early Dynastic copper chisel found in Nubia has a small silver and gold content which led to its identification as native copper. Lucas, however, felt that it was highly unlikely that such a comparatively large object could be of native copper. He proposed the use of copper ore with a small precious metal association (Lucas 1962: 200–1) – a view now supported by the proved association of copper and gold in some ores as noted above.

The simple 'oxide' copper ore minerals, such as malachite and azurite (both copper carbonates), have bright colours that would attract prospectors and require only fairly elementary smelting procedures. Although even for the simplest ores some pre-treatment, such as hand sorting and crushing 'benefication', would have been important to maximise the yield (Doonan 1994: 84–97). Relatively low temperatures and initially simple crucibles with blowpipes, later small furnaces, would suffice. Experiments have shown that copper can be smelted in clay crucibles with a bank of three or more blowpipes. Up to 90 per cent recovery is possible with simple oxide ores such a malachite and no slag is produced (Craddock 1995: 126–7). The large quantities of crucible fragments, malachite and atacamite and copper prills at Buhen, but no slag, have been taken to indicate crucible smelting of copper here in the Early Dynastic Period (el-Gayar and Jones 1989a, 1989b; Craddock 1995: 130–1).

If we accept that some impurities in the copper, such as arsenic or nickel, are indicative of smelted copper ores, not native copper, the introduction of smelted copper, albeit fairly impure, must have occurred in Egypt by about 4000 BC. In Egypt the low iron levels (average 0.03 per cent) that we see in some of the earlier Predynastic and First Dynasty Egyptian copper alloy objects probably reflect the use of primitive smelting operations using crucible furnaces.

More efficient production, and the ability to exploit more complex and lower grade ores, required higher temperatures and a procedure termed 'fluxing' – the presence or addition of materials to aid the melting and separation of the copper. Iron oxide was the general flux. The smelting of oxide copper ores with iron oxide results in the formation of a mass of mainly iron-minerals, the 'slag', and the reduced copper. This copper is either produced as small prills which are retrieved by crushing the mixed mass of cinders and slag, or, if higher temperatures over longer periods are obtainable, will form a puddle in the base of the furnace which will cool to give a plano-convex or bun ingot. Craddock and Meeks (1987: 187–204) have described the simplest type of early copper-smelting shaft furnace as 'probably the size and shape of a small upturned bucket but lacking its bottom.' We might assume that bag bellows superceded blowpipes for copper-smelting. However, there is little certain evidence for bellows from Egypt until pot bellows appear in the Middle Kingdom (see p. 157). Tylecote calculated that the plano-convex ingots produced at Timna in the more sophisticated shaft furnaces of the New Kingdom weighed between about three or four kilograms a slightly higher estimate than Merkel (1995: 22).

Simple fluxing with slag production was in use at Timna in Sinai by the end of the fourth millennium BC and was soon fairly universal in the Eastern Mediterranean world. Its introduction into Egypt, as evidenced by a sharp rise in iron levels (to an average of about 0.33 per cent) seems to have occurred during the Second Dynasty (Craddock 1985; Craddock and Meeks 1987: 187–204; Cowell 1987; Craddock 1995: 137–40). Recent investigation of slags from Bir Nasib in Sinai show the production of unfluxed copper in Predynastic times and the use of iron ore fluxes by some unspecified time during the Old Kingdom (el-Gayar and Rothenberg 1998; Craddock 1995: 130–1).

The copper produced at the Old Kingdom smelting site at Buhen has an average iron content around 0.5 per cent (el-Gayar and Jones 1989b) and the over-life-size Sixth-Dynasty statue of Pepi I is, according to what is probably the most reliable analysis to date (Desch 1928), almost pure copper with 0.7 per cent iron, enough to indicate a true fluxing process, and 1.1 per cent nickel. Gladstone and Lucas also analysed samples of the Pepi statue and both reported high purity copper and no tin (Lucas 1962: 214).

More efficient copper production was possible when the slag could be run off while molten. 'Tapped-slag' furnaces of this type can probably be dated in the Sinai to the time of the middle to late New Kingdom. It is noteworthy that the average iron levels in Egyptian copper alloy objects drops to around 0.14 per cent by the Late New Kingdom. There are various possible explanations for this. It could reflect the introduction of tapped slag furnaces, the switch to sulphide rather than oxide ores, or, possibly, the employment of manganese rather than iron fluxes utilising the extensive manganese mineral deposits in those areas (Rothenberg 1972: 232; Bachmann 1980: 103–34).

The introduction of more efficient copper-production methods could help explain the exponential increase in cast copper alloy objects during the Third Intermediate Period and Late Period. Sulphide ores were undoubtedly smelted by this time, although the oxide ores, when available, were also still utilised. The smelting of sulphide ores will produce copper with, in theory, lesser amounts of trace elements such as arsenic, antimony and bismuth. For sulphide ores, prior roasting is required and silica, not simply iron oxide, usually has to be present as a flux. The fact that concertina bellows appear to have been introduced in the Near East in the first millennium BC might have aided copper as well as iron production (Craddock 1995: 181–3).

Pure, or near-pure, copper is not easy to cast because it is prone to gas bubbles and tends to shrink, thus producing poor-definition, porous castings. Nevertheless, some surviving Egyptian objects of high purity copper dating right up to the New Kingdom show that the smiths were able to cope with consummate skill.

When first smelted some of the iron from the flux will enter the copper which will thus contain several per cent of iron – as seen in Late Bronze Age copper finds from Timna. Levels of iron up to 1 or 2 per cent are not uncommon in Egyptian copper alloy objects, but higher iron levels – up to 10 per cent or so can enter during smelting – make the copper almost impossible to cast or hammer. The copper has to be refined to remove at least the majority of the iron. It is quite easy to bring the iron contents down to around 0.5 per cent by simply melting the copper and scooping off the oxidised impurities from the surface of the melt. An ingot found in the Wadi Araba, some way from Timna, shows that ingots left the smelting sites in unrefined state.

Copper objects with several per cent iron occur sporadically right through Egyptian history. Examples include a Fifth-Dynasty amulet (Brunton *et al.* 1927: 69) with around 6.5 per cent iron, and a fine, hollow-cast head from a statuette of a Ramesside pharaoh with around 95 per cent copper, 2 per cent lead and 2 per cent iron (Schoske and Wildung 1992: 221–2). We can probably assume such iron contents are fortuitous. A copper cat in Hamburg has been reported to contain almost 12 per cent iron (Riederer 1988: 7). Such an alloy would be extremely difficult to cast and perhaps needs verification – the possibility of contamination of iron from another object or iron wire core supports (see p. 159) should be borne in mind. However, we can note the intentional copper alloys with up to 20 per cent or more iron met with in Iron-Age Italy and elsewhere (Craddock and Meeks 1987: 187–204).

Nickel is a common impurity in ancient copper alloy objects but usually under about 1 per cent. Higher nickel contents are most typically found in zinc-containing copper and thus seldom encountered in Dynastic Egyptian objects. Other trace elements in ancient Egyptian copper and copper alloys include bismuth and cobalt.

Copper–arsenic alloys

Arsenic is present in many ore types and there are at least traces of arsenic in most ancient Egyptian copper and copper alloy objects. Arsenic presence results in the production of wrought copper of far greater hardness – a vital property for implements and weapons – and also greatly facilitates casting by causing the molten metal to flow more easily. The convention is that copper objects with more than about 1 per cent arsenic are regarded as representing the deliberate use of arsenic-rich copper ores or the intentional combining of arsenic and copper ores (Moorey 1994: 242). Almost certainly the higher arsenic levels which appear during the Old Kingdom were not fortuitous (Kaczmarczyk and Hedges 1983: 73). Up to 7 per cent was found in axes in the British Museum (Cowell 1987). Analysis of blue copper-based pigments from more than 110 well-dated Egyptian tombs not only confirms the view that this pigment was made from scrap or by-product copper – as Vitruvius (*De Architectura* VII, Ch. XI, 1; see Morgan 1914) later states – but also provides corroborating chronological information. Arsenic is found first in copper-based pigments in the Fifth Dynasty (el-Goresy *et al.* 1998).

The frequent association of high arsenic with low levels of other impurities is an argument in favour of intentional additions rather than the use of an enriched ore type. We might expect intentional use of arsenic-rich copper ores from an early period followed in time by deliberate additions of arsenic ores to copper or copper ores. However, there is no way to make a definite distinction using current analytical methods.

Analyses have seldom revealed any definite discernible difference between arsenic content and intended use – we would expect low arsenic levels in objects that would benefit from a soft rather than a hard alloy in manufacture. On the other hand, the attractive silver colour of arsenic-rich copper was one motive for its use, regardless of the function or mode of manufacture of the object.

Arsenic is still present in noticeable amounts in a handful of Egyptian copper and copper alloys in the New Kingdom. It is found in copper-based pigments up to the time of Hatshepsut (el-Goresy *et al.* 1998). Arsenic levels in post-New Kingdom copper alloy are typically less than about 1 per cent. When higher levels occur they are presumably, in the main, fortuitous. However, Riederer's analyses (Riederer 1978b, 1981, 1982, 1983, 1984, 1988) show that Late Period cat figurines and cat heads appear to have high arsenic contents more often than might be expected by pure chance. Schorsch (1988) has also referred to a Late Period cat head with a noticeable arsenic content. The two highest arsenic levels recorded by Riederer in post-New Kingdom objects (4.13 per cent and 6.39 per cent) are both in figures of the young god Harpocrates and an intentional colour choice seems possible, given that children were rendered with paler skin than adults in Egyptian art.

It is perhaps relevant that arsenic-based pigment (orpiment – arsenic sulphide) only seems to have come into use in Egypt during the Amarna Period, the very time at which the use of arsenic in copper alloys began to wane. There is no evidence that the ancient Egyptians knew arsenic in metallic form – a state of affairs paralleled in Mesopotamia (Moorey 1994: 240), although supposed examples have been cited from the ancient world.

Antimony is a frequent associate of arsenic and also appears as a trace element in most Egyptian copper alloy objects. Antimony has a similar hardening effect to that of arsenic on copper, but the intentional addition of antimony is unlikely in Egypt until the New Kingdom, after which it might have been used on occasion – perhaps confused with tin. Ancient Egyptian copper or copper alloy objects with over about 1 per cent antimony are unusual, but occasional levels up to almost 4 per cent occur even in the Late Period. Interestingly, Riederer's analyses include only five examples with over 2.5 per cent antimony – two of these are the high-arsenic Harpocrates figures mentioned above.

Copper–tin alloys

When copper is alloyed with tin there is a noticeable increase in the hardness and potential sharpness of copper alloy tools and weapons. The melting temperature drops from 1,083 °C (pure copper) to 1,005 °C for copper with 10 per cent tin. Tin also greatly increases the fluidity of the molten metal, thus facilitating casting. The effects are not dissimilar to those produced by arsenic additions, but are more dramatic and without the very real toxicity hazards. Arsenic additions, intentional or not, permit better casting than pure copper, but the large-scale production of fine-quality castings might have had to await the introduction of copper–tin alloys.

As with arsenic, around 1 per cent tin is usually taken to be the dividing line between accidental and deliberate presence. The deliberate addition of tin (though presumably in the form of an ore, not metallic tin) to copper had occurred in some parts of the Near East by 3000 BC. Tin levels of over 1 per cent have been found in several Early Dynastic objects with the highest reported levels to date being 7 per cent and 9 per cent respectively in a ewer and basin from the tomb of the Second-Dynasty king Khasekhemwy (Cowell 1987; Kaczmarczyk and Hedges 1983: 78). We can also note that Berthelot (1895) found almost 6 per cent tin in a Sixth-Dynasty vessel. Deliberate copper–tin alloys (true 'bronzes') were still the minority in the Middle Kingdom. Examples include the superb Middle Kingdom hollow-cast figure of a man, now in the Louvre (E27153), which contains around 5 per cent tin and about 1 per cent arsenic (Delange 1987). Berthelot noted just over 16 per cent tin in a Twelfth-Dynasty bracelet fragment from the Dahshur treasure (Berthelot 1895).

Copper–tin alloys still had to share the stage with copper and copper–arsenic alloys in the New Kingdom. A Thutmose IV statuette in the British Museum (BM EA64564) is almost pure copper (Craddock 1985), and Lucas remarked that there was still more copper than bronze in the tomb of Tutankhamun (Lucas 1962: 220). We can also note that tin first occurs in copper-based pigments during the reign of Thutmose III (el-Goresy *et al.* 1995: 31). From the Rameside period onwards, tin is present in the majority of copper alloy objects. Interestingly, the arsenic content of copper alloy objects drops dramatically from the New Kingdom on, and is rare after that time. The way in which tin (and lead – see p. 154) ousts arsenic at this time is matched elsewhere in the Old World and is a strong argument that earlier arsenic additions were intentional. Analyses of Egyptian glazes also show that tin became far more readily available during the New Kingdom. This agrees with the suggestion that the additions to copper alloys were now of metallic tin, not tin ores. This could also explain the appearance of other unusual tin alloys in the New Kingdom (see p. 171 under tin). The source or sources of the tin, however, are still uncertain.

The majority of Egyptian bronzes have up to around 10 per cent tin, as is generally typical in antiquity, but there are occasionally higher levels though very rarely over about 16 per cent. There are some possible chronological variations that deserve further research. For example, there appears to be a dip in average tin content in Third Intermediate Period objects, while Ptolemaic and Roman-period objects more frequently have higher tin levels than hitherto (Kaczmarczyk and Hedges 1983: 90). High tin contents will produce a copper alloy with a silvery colour, indeed a Late Period *menit* in the Fitzwilliam Museum, Cambridge (EGA.54.-1949) is of over 90 per cent copper, while its 'Electrum' inlay is actually composed of a copper–tin alloy with just over 20 per cent tin.

Correlations between object function and composition also deserve further study. It is only to be expected that there should be distinctions between, say, weapons and decorative objects due to working properties of the alloys (i.e. some alloys forming better castings, and some able to be hammered and worked to provide sharper, more durable edges). However, we can also suspect a far wider range of less obvious distinctions, some perhaps based on colour or susceptibility to surface treatments, others due to 'symbolic' reasons. For example, the programme of analyses on tools and weapons in the British Museum revealed that model tools could match the composition of their functional counterparts, although the high purity copper of three models of agricultural tools from Tutankhamun's tomb and of eleven models of tools and weapons from the Fifth Dynasty suggest that this was not always true (Coghlan 1975: 64–7; Maddin *et al.* 1984: 33–41). The potential colour relationships are particularly interesting. For example, among Riederer's recent analysis of some 1,200 Egyptian copper alloy objects, only three statuettes have over 16 per cent tin – all three are figures of the child-god Harpocrates. This suggestion of a link between a pale alloy (see also copper arsenic and antimony alloys p. 152—3) and the rendering of a child-god's skin, raises the question about the factors involved in alloy choice. Sadly, again, far too few excavated copper alloy objects are properly studied, while those currently in collections have often undergone extensive and frequently poorly recorded cleaning and conservation treatments which will have often destroyed much of the evidence for original surface.

In this context we can note recent analyses of New Kingdom stirrup-shaped finger rings, including unpublished analyses by the present writer of examples in the Fitzwilliam Museum, which show that they are typically true bronzes with 8–10 per cent tin (see Giveon 1977: 66–70). It must be assumed that such objects were produced with, or soon obtained in use, polished metal surfaces. The electrum-like colour of the alloy would resemble that of the similarly shaped gold alloy rings. That these rings were intended for use in life is proved by the considerable degree of ancient wear on some examples.

One conundrum is the existence of copper objects containing between 0.1 per cent and 1 per cent tin. Mixed copper–tin ores are rare, and analytical evidence from Timna in Sinai from samples from various stages in the copper recovery process suggest that even such minute amounts might well have been additions. Such low levels would have no noticeable effect on the final hardness or working properties of the metal, but they might have facilitated casting by deoxidising the alloy (Craddock 1980).

Copper alloys with lead

Between 1 and 3 per cent lead in a copper alloy will facilitate casting without detracting from the strength of the alloy. Thus while up to about 2 per cent lead can be fortuitous, lead levels as low as 1 per cent might sometimes be deliberate. This is indicated by an apparent correlation of lead content with copper–tin rather than copper–arsenic alloys prior to the Late New Kingdom (Cowell 1987). Early examples include the Second-Dynasty copper–tin alloy ewer and basin mentioned above which both contain over 1 per cent lead.

Generally speaking, the addition of lead to copper alloys is rare before the Middle Kingdom and lead levels over about 2 per cent are rare prior to the late New Kingdom. The 16 per cent lead recorded long ago by Flight as being present in a Fourth-Dynasty copper alloy statuette is presumably a case of mistaken dating (see Riederer 1982: table 1). However, firstly Phillips did report 8.5 per cent lead in an Eleventh-Dynasty object (see Riederer 1982: table 1), and secondly two Eleventh-Dynasty copper alloy cylinder seals of Mentuhotep, now in the Louvre, have been analysed and shown to have a high lead content (Vandier 1968). It has been stated that an inlaid crocodile statuette in Munich (which originated with the same dealer as the Louvre/Ortiz Middle Kingdom copper alloy statues and is thus assumed to be part of the same Middle Kingdom find) is a leaded alloy (Scheel 1989: 41). However, the contrary view (Delange 1987) has now been shown to be correct (Giumlia-Mair 1996). A leaded alloy figure in the Louvre described as of Second Intermediate Period date (Delange 1987: 176–7) is perhaps, on stylistic criteria, a later archaising work.

The deliberate larger scale addition of lead to copper alloys is generally defined as marking the transition to the Late Bronze Age in archaeological terms. High lead levels – up to 25 per cent or more in some cases – lower the melting point of copper, increase the fluidity of the molten metal and reduce porosity. Around 25 per cent lead can lower the melting temperature of a copper–tin alloy to less than 800 °C. Lead thus facilitated the production of the ubiquitous cast copper alloy objects of the first half of the first millennium BC, but was an unwanted presence in alloys intended for edged tools or weapons.

There are perhaps occasional high-lead objects from the Eighteenth Dynasty, such as a vase with almost 15 per cent lead published by Craddock (1985), assuming that the dating of the object is secure. However, it can generally be assumed that the introduction of lead as a major component of copper took place in the Nineteenth Dynasty. Apparently 25 per cent lead was present in a Nineteenth-Dynasty Osiris figure analysed long ago by Rathgen (see Riederer 1982: table 1) and Craddock (1985) has published a Twentieth-Dynasty *shabti* figure containing about 5 per cent lead. We can note, as a parallel, that the deliberate use of lead compounds in glaze manufacture is a New Kingdom innovation (see Chapter 8, this volume) and, more precisely, lead only became a major component in Egyptian copper-based pigments between the time of Seti II and Tausret in the Nineteenth Dynasty (el-Goresy *et al.* 1998: 31).

In the Third Intermediate Period, copper alloy lead levels are still usually under 5 per cent and the thinner-walled, and more precise hollow castings appear to be tin-bronzes with minimal lead, although copper lead alloys, some with over 20 per cent lead, were becoming more common. However, high lead content is typically a Late Period phenomenon that continued into the Ptolemaic period, when over 20 per cent is not unusual, and over 30 per cent is reported in some instances.

A lead content in copper alloys, even if small, can permit characterisation of the lead isotopes present and thus, potentially, perhaps indicate actual sources of the lead. In recent years there has been much work carried out on lead isotopes in ancient objects in general (see under lead and silver pp. 168, 170), including Egyptian copper alloy objects (Fleming 1982: 65–9), but the validity of the technique is still under review. It should also be noted that lead in a copper alloy can possibly derive from the fluxes used in the smelting process (Rothenberg 1972: 237).

Copper–zinc alloys

Several of the Eastern Desert copper ores contain zinc (sometimes making up a considerable proportion), but these ores would seldom produce an alloy with more than 1 or 2 per cent of zinc. Early use of such mixed ores might explain such objects as a copper pin from a Predynastic grave (no. 218) at Naqada which is stated to contain around 2 per cent zinc and 1 or 2 per cent nickel (Baumgartel 1960: 18).

In Egypt the only pre-Roman use of deliberate copper–zinc alloys – what we term gun metals or brasses – might have been for some late Ptolemaic statuettes and small ornaments. Even some of these, such as some figurines in the so-called 'Alexandrine' idiom, are possibly of early Roman rather than Ptolemaic date. Supposed copper alloy objects or components from Dynastic Egypt with more than 2 or 3 per cent zinc are generally intrusive in the excavation or fake. For an example of the latter see Russmann (1981: 149–56). Here the uraeus was a modern zinc-containing alloy, the statuette itself was a leaded tin-bronze and ancient.

The manufacture of the objects

Copper working 'factories' have now been identified in various parts of Egypt. Here the ingots from the mines, scrap or imported metal were transformed into a plethora of implements, weapons and ornaments for a temple, royal, secular or dead clientele (Scheel 1989).

For example, a major copper-alloy working centre at Qantir, ancient Piramesse, in the Eastern Delta has recently been discovered (Pusch 1990). The excavations have revealed a massive late Eighteenth- to early Nineteenth-Dynasty metal working site covering over 30,000 square metres (see Figs 6.2 and 6.3). Tangible evidence includes crucibles, *tuyères*, moulds, waste, slag and other metal-working tools. This was a centre that included very large-scale copper alloy casting and, perhaps, parallel craft industries. The presence of foreign, including Hittite, armour, weaponry and tools points to foreign craftsmen. The workshop methods revealed can be compared with those depicted in tomb-paintings of the period and with further study of this remarkable site we will undoubtedly gain a far greater understanding of the Egyptian metal-working industry.

There is a wide repertoire of metal-working scenes in tombs (Scheel 1989). For example, the Fifth-Dynasty tomb of Wepemnofret (called Wep) at Giza has scenes showing copper-working (Weinstein 1974: 23–5). These include melting and pouring and, most interestingly, what is probably the earliest reference to annealing with the hieroglyphic caption 'There is no cracking (?) if it is heated excellently'. Annealing is the heating process used to soften, and make more workable, metal that has become hard and brittle due to the build up of stresses during shaping.

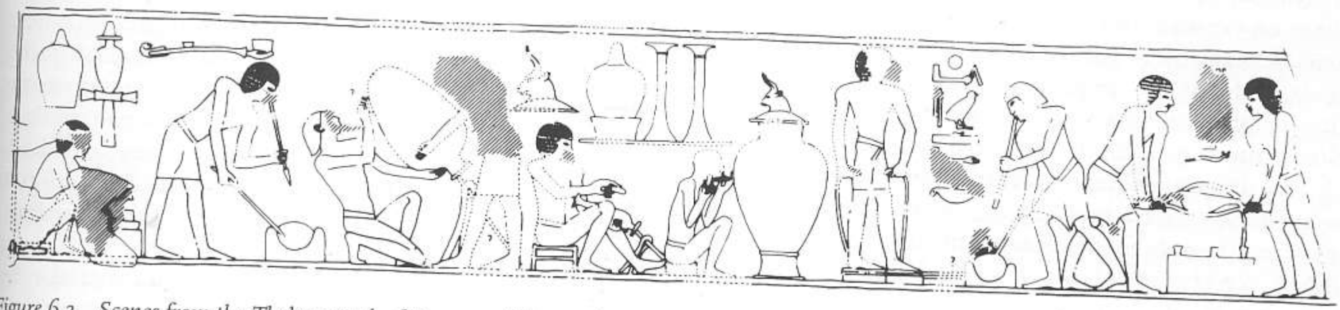


Figure 6.2 Scenes from the Theban tomb of Puyemra (TT39), showing metal-working.

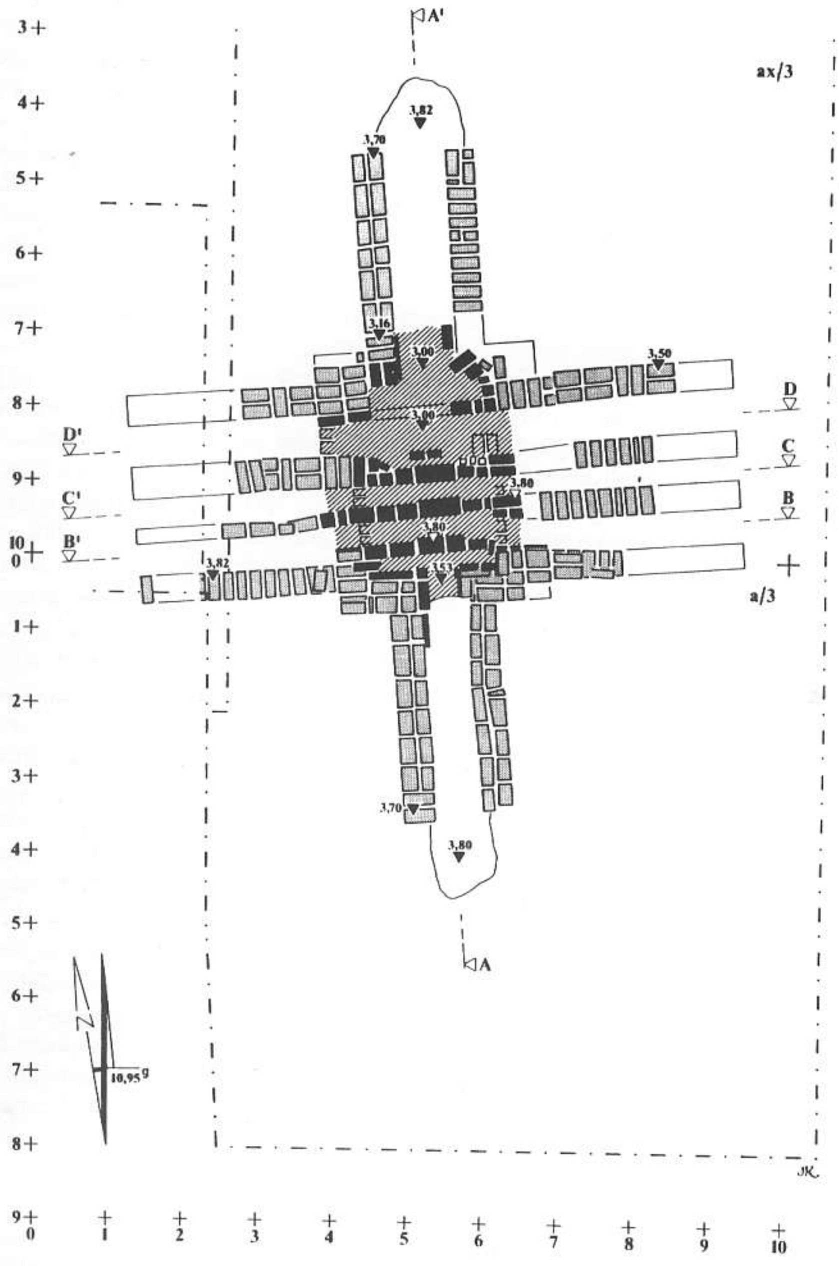


Figure 6.3 Plan of the cross-shaped smelting area at the Delta site of Qantir.

The best-known metal-working scenes are probably those on the wall of Rekhmira's Eighteenth-Dynasty tomb at Thebes (TT100). These show various stages in the large scale production of copper alloy objects – from the arrival of the ingots to the casting of a temple door (Davies 1943; Wainwright 1944: 94–8; see Fig. 6.1).

The ubiquitous copper alloy statuettes representing a near-infinite selection of Egyptian deities are almost invariably from temple not funerary contexts. Enormous quantities of such statuettes have been found: Garland and Bannister (1927: 83), for instance, noted how the draining of the Lake at Karnak 'provided almost a glut of certain varieties', and similar fortuitous finds have sometimes flooded the antiquity market since. A cache of more than 100 copper alloy figurines was excavated at North Saqqara in 1968/9 (Emery 1970). Unfortunately, despite the quantity, quality and almost pristine condition of these pieces (many examples had been wrapped in linen), a proper study of technology, material or surface has never been carried out.

Such caches (paralleled in stone sculpture) do call into question any general policy of recycling 'sacred' copper-alloy objects. This would suggest that temple workshops required a steady source of newly mined raw material. After a review of Egyptian glaze compositions, Kaczmarczyk and

Hedges stated that 'The data . . . lead to one inescapable conclusion: from the sixteenth century BC onwards arsenical copper and tin bronzes were used on a regular basis as a source of copper in the faience industry.' (Kaczmarczyk and Hedges 1983: 90) and 'from the Eighteenth Dynasty on bronze scrap was the primary source of tin in faience' (1983: 239). In consideration of what has just been said, we might suggest that by-products of metallurgy, not recycled objects, might have provided much of the raw material for glaze, glass and pigment manufacture. If so, a close association of metal-working and faience/glass (and perhaps pigment) production must be assumed.

The simplest manufacturing process would be to hammer out small ingots, prills or even bits of native copper into sheets which could then be bent and cut into the required form. The skills needed to raise complex three-dimensional vessels from sheet and to join separate components by rivets and other mechanical methods had been acquired by the First Dynasty. Fine examples include a First-Dynasty find made at north Saqqara some sixty years ago (Emery 1939). Such techniques were usual for metal vessels throughout Dynastic times in Egypt. Vessels were seldom cast, the only common exception being the ubiquitous Late Period situlae with their relief decoration. If the monumental copper figure of Pepi I is of hammered, not cast components, (see p. 158) it would represent the pinnacle of surviving Old Kingdom sheet metal-work.

With the exception of most vessels and containers, and some simple implements, Egyptian copper alloy objects were generally cast to virtually their final form, whereafter only cleaning, and perhaps the addition of details, was needed. Cast weapons and tools however, did require serious mechanical working to harden and toughen the edges enough to be serviceable.

Some sheet-like objects, such as *menits* and mirrors, might have been largely formed by hammering, but the finer, more plastically modelled, openwork *menits* and the comparably worked vase-stands of the Eighteenth Dynasty were probably cast and might indicate the introduction of new casting technology.

The ability to generate the heat to smelt copper meant that the heat necessary to melt and thus cast copper was equally achievable. The main problem lay in generating the concerted heat need to melt and cast reasonable quantities of metal. Blowpipes, sometimes in banks, were used to maximise the heat for melting copper and other metals in the earliest times – they are represented at least as early as the Fifth Dynasty (Lucas 1962: 213, Scheel 1989). Pot bellows, in which a leather top on the flared opening of a pottery nozzle is pumped up and down by hand or foot to force a jet of air out of the narrow end, appear to occur first in the Middle Kingdom (Nibbi 1987; Davey 1979; Tylecote 1981b). However, there is no representational evidence for such bellows prior to the Eighteenth Dynasty. It might be doubted whether larger masses of metal, such as that needed in the initial stages of the manufacture of the Pepi I statue, could be obtained with simple blowpipe technology. However, it has recently been demonstrated that crucible smelting of copper, and thus melting of copper, is quite feasible with a bank of three to six blowpipes (Craddock 1995: 127). There is no evidence that large-scale casting was carried out away from the Nile in the mountainous mining regions where the prevailing winds could have been harnessed.

The simplest form of casting is to pour the molten metal into open moulds carved in stone, shaped in pottery or even formed in sand. More complex, three-dimensional forms required moulds made up of two, three or more sections that could be dismantled to remove the casting. However, at least some of the surviving moulds in terracotta and stone were probably used to make the 'wax' models for use in the lost-wax casting process, not to directly cast the final object.

Objects, such as ingots, flat axes and chisels were being cast by early Predynastic times. Lucas described the earliest Egyptian casting known to him as an axe-head of middle Predynastic date found by Brunton at Matmar which, according to the report by Carpenter, was cast and then hand-worked – either hot-worked or cold-worked plus annealing (Carpenter 1932: 625–6; Lucas 1962: 213). The composition of the axe head was almost pure copper with just minor impurities including 1.28 per cent nickel and 0.15 per cent iron.

In the process of lost wax casting a model of the desired object is modelled or moulded in wax or some other material which is easy to model and has a low melting temperature. The use of beeswax *per se* should not be assumed. In more recent times, a resin/oil mixture or wax/resin has generally been employed and even lead has been used at some periods. Beeswax alone is often too soft particularly for complex or thin articles in warmer climates and today metal-casters can have separate recipes for summer and winter 'waxes'.

The wax model is coated with the 'investment' material, usually clay with an organic binder like dung or chaff, and a hole pierced down from the outer surface to the model. When the clay is fired the wax burns or flows out and molten metal can be poured in. Once cooled and solidified, the mould is broken to extract the casting. The object then typically requires the removal of any surface protrusions or flaws (not the least being the sprue – the attached metal that has solidified in the funnel-shaped pouring hole). The piece is generally given final surface details and polished. A copper alloy statuette of Harpocrates still in its investment has been published (Williams 1919: 3–7).

In practice, certain refinements to the process were required. Air escape holes through the investment would facilitate the complete filling of the mould by metal, as would links between parts of a complex shape. Garland, for example illustrates the 'runners' linking the legs of an unfinished solid cast ibis (Garland and Bannister 1927: 45).

Hollow castings are made by modelling the 'wax' around a central core. Hollow casting would not only save metal but, as Becker *et al.* (1994) have recently pointed out, it would also result in less potential shrinkage and thus less distortion in the mould. The interior core was perhaps most usually made from the same sandy clay/organic material as the investment. Such cores turn black on casting when the organic matter plus any absorbed waxes or resins burn. Blackened cores of this type are typical of Egyptian and other ancient hollow-cast copper alloy objects. There is potential for the dating of such cores by thermoluminescence techniques (Riederer 1978a). Other core materials include gypsum, (presumably plaster suggesting that such a material might also have been used for some investments), calcium carbonate in some form or other (conceivably carved limestone, see Riederer 1982: 30) and even wood (Schorsch 1988). Some cores inside animal figurines were intended to be removed after casting, in order to permit the insertion of a mummified animal (Jett *et al.* 1985).

Lost-wax casting was used for copper objects by the Old Kingdom. The use of casting for large-scale objects, such as the monumental statues of Pepi I and his son, remains unproven. Garland and Bannister (1927) suggested that the fine shaping and detail of Pepi (evident in the best photographs), together with the thickness of the metal, would make hammering a most unlikely option. Assembly of several separate castings would be the only option here, if indeed casting was used. Garland and Bannister did note the visible rivets as evidence for assembly from cast sections, but presumably hammered components would also require rivets.

Early lost-wax castings include the separately made and inserted spouts in some Old Kingdom ewers which date back at least as far as the Fourth Dynasty (Garland and Bannister 1927: 35; Lucas 1962: 215; Schorsch 1992). These, of course, are hollow and thus represent the initial stages towards the production of true hollow-cast objects (Nofal and Waly 1998).

Exceptionally fine figural hollow castings in copper-tin alloys had appeared by the Middle Kingdom – as witness the magnificent Fayum find which included the Louvre statuette mentioned above (p. 153) (Delange 1987: 211–13) and the statuettes now in the Ortiz collection (Ortiz 1994: cat. nos. 33–7). These magnificent hollow-cast statuettes show the ingenious multi-part assembly methods used even as early as the Middle Kingdom. The Louvre standing male figure has slotted-in arms and inserted lower legs and the large Ortiz figure of Amenemhat III (Ortiz 1994: cat. no. 36) has both a separate wig and arms held in place by vertical slotted grooves. This use of fine, thin-walled, hollow casting and mechanically inter-located sections shows a level of fine bronze-working skills hitherto not expected prior to the Ramesside or Third Intermediate Period. Here, as with many of the finer castings, it is difficult to gauge the extent of hand-working. The large female consort from the same group, and also in the Ortiz collection (Ortiz 1994: cat. no. 35), is just as finely hollow-cast with a core still in place (the walls of the arms being only around four millimetres thick).

Most copper alloy statuettes of the Second Intermediate Period and the early New Kingdom appear to be solid cast. Datable examples include one of the Second Intermediate Period, now in Brooklyn, depicting a squatting, nursing mother, her *uraeus* and the inscription identifying the group as a royal princess and her son. This is a consummate one-piece, solid casting, perhaps a copper-tin alloy, with plenty of negative space and with post-casting hand worked detail and inscription (Brooklyn 43.137).

The dearth of early and mid-New Kingdom copper alloy figures, either solid or hollow cast, is quite remarkable (Vassilika 1997). It is noteworthy that the majority of the surviving examples are royal – although, of course, these are the most dateable category and other non-royal examples might well reside in collections with later ascribed dates. The examples include a fine, solid-cast kneeling figure of Thutmose III in black bronze (see p. 160) with gold inlays, which has recently been acquired by the Metropolitan Museum of Art, New York (1995.21; see Hill 1995) and the British Museum statuette of Thutmose IV (BM EA64564) which also appears to be solid-cast. As with the New York piece, the arms are separate and located over square dowels projecting horizontally from the shoulders. There is also careful post-casting hand work.

Fine hollow castings, on the basis of the scanty evidence, appeared again at the end of the Eighteenth Dynasty as witnessed by a black bronze kneeling figure of Tutankhamun now in the museum of the University of Pennsylvania, Philadelphia (Fishman and Fleming 1980). In the Ramesside period, copper alloy sculpture began to become slightly more common. Three fine examples can be seen in the Metropolitan Museum of Art, New York. One is, again, a kneeling figure, perhaps solid-cast, this time of a man wearing characteristic Nineteenth-Dynasty garb (Hayes 1959: 382). The others are a standing figure of a shaven-headed priest and a late New Kingdom, hollow-cast small head with inlaid eyes (Hayes 1959: 381–3) A fragmentary, rather thick-walled, hollow-cast figure illustrated by Garland bears the cartouche of Rameses IV (Garland and Bannister 1927: 47–8).

As noted, complex objects were typically made up from separate components – sometimes part cast, part wrought – and generally joined by mechanical methods. Of these mechanical techniques, the simplest example are rivets as typically used for such purposes as attaching vessel and mirror handles.

The most common ancient joins on figurines are those connecting the arms to the trunk and, as might be expected, the types of join employed tend to mirror those found in woodwork (see Chapter 15, this volume). The simplest are just pegs or dowels, but there are also many variations on the tenon and mortise joint, often with wedge-shaped slots. Just when wedge-shaped rather than straight pegs or tenons were developed remains uncertain. A fine Middle Kingdom male figure in the Louvre has straight tenon shoulder joints (Delange 1987: 211–13), as have the Ortiz kneeling figures of Amenemhat III and his consort (Ortiz 1994: cat. nos. 35 and 37). Once assembled, joint lines could be disguised by hammering or burnishing or concealed by chased details such as arm bands and shoulder straps.

In the Late Period, one-piece castings were more often used, again. In part this was a result of the typically simpler, often cruder, forms, but it was also true that the fluidity of the now popular heavily leaded alloys permitted more complex shapes to be cast in one. When separate components were required – these were most often arms – one or both being made separately and added, depending on size and pose. An over-life-size head of a pharaoh now in Hildesheim was formerly identified as a Ramesside ruler but is in reality almost certainly a Twenty-ninth- or Thirtieth-Dynasty piece and a rare example of near-monumental hollow casting (Eggebrecht 1993: 90–1).

Soldering or braising was very seldom used on copper alloy objects in Egypt during Dynastic times and perhaps never for attaching the various components of statuettes. The use of a silver solder for copper has been reported for joining sheet copper as early as the Fourth Dynasty, when this technique was used for the copper sockets of Hetepheres' canopy supports (Lucas 1962: 216). The seam of a copper (or bronze) trumpet from the tomb of Tutankhamun is similarly assembled (Lucas 1962: 216) and the technique is sporadically reported for other times and places in the ancient world (Ogden 1983a: 67). Both silver and lead were used to plug working defects in an Eighteenth-Dynasty cow vessel – a category of object that represents the rare use of casting for New Kingdom figural objects (Winlock 1936: 147–56). The presence of solder on Egyptian copper-alloy statuettes is usually indicative of recent repair or forgery. Casting-on was sometimes used (see below) and the recent report of the feet of a Third Intermediate Period female statuette being 'welded' on might, rather, be an example of this (Raven 1992).

Roeder noted that the wax models used to cast the ubiquitous Egyptian copper alloy statuettes, both solid and hollow, could be made up from separately formed wax components – torsos, limbs, heads and so on. This would be the natural approach when the figures were being entirely hand-modelled – only the simplest forms could be created from a single initial block of wax. The improvements in precision and the possibilities of mass production permitted by moulding or casting the wax components would be a natural next step and the use of plaster moulds to produce a series of identical components (or occasionally complete figures) is probable. Recent study of copper alloy figurines in Leiden appears to confirm the use of pre-moulded wax parts in just this way (Raven 1992).

The Leiden project has also identified another casting process which is well-substantiated in antiquity in general but seldom reported from Egypt (Garland and Bannister 1927: 69; Raven 1992). This is 'casting on', a process by which a deficient or missing area of a cast is moulded in wax onto the existing metal object and then the whole area coated with the investment and new metal cast in. The apparent presence of the technique on several objects in the Leiden collection suggests that the procedure might have been relatively common. Another Egyptian example is the cast-on base (to a raised vessel) recently described by Schorsch (1992: 145–59). Care must be taken in identification. It can be difficult to differentiate between casting-on and areas where two wax components of the original casting antetype were joined, perhaps with crudely added or smeared-over wax. Metallographic study of a section taken from the area is the best guide, but for obvious reasons seldom resorted to.

Support for the cores during the production of hollow castings also needed consideration. Supports were not required when hollow castings had openings (e.g. on the underside of the bodies or at joins in multi-part objects), because the core would have been in direct contact with, and thus held in place by, the surrounding investment.

Holes cut in the wax would create contact points between core and investment and provide the necessary support. This might explain the mysterious so-called 'dowel holes' both in the Philadelphia figure of Tutankhamun mentioned above (p. 158) (Fishman and Fleming 1980) and in a figure of Min-Amun in the Fitzwilliam Museum, (E49b, 1954 Vassilika 1997), and although this cannot be proved in Egypt, such a technique was later used by Greek metal-casters (Haynes 1992: 70–1). The holes left in the final casting could be plugged or concealed under gesso and gilding.

Late Period copper alloy castings sometimes retain traces of iron wires 'chaplets' used to hold the cores in place (Garland and Bannister 1927: 39–41; Schorsch 1988). Schorsch (1988) has recently pointed out that fakes of Egyptian bronzes often have far more core supports than their ancient counterparts. The recent study of a fine large Third Intermediate Period hollow-cast female figurine in Leiden revealed, rather surprisingly, an internal iron rod support which passed through the trunk and divided down each leg to the heel (Raven 1992). The use of iron wire supports in New Kingdom copper alloy objects is unlikely, but we can note that Renaissance practice as well as recent forgeries of Egyptian copper alloy statuettes demonstrate that relatively pure copper struts can be employed to hold cores in place in leaded copper alloys.

Care had to be taken in all stages of casting and finishing. The fine, thin-walled hollow castings of the Third Intermediate Period and, less so, of the Late Period, were prone to core expansion and cracking at the time of manufacture if the core retained any moisture. As Garland noted, this means that not all cracks and distortion in such objects can be attributed to post-burial corrosion (Garland and Bannister 1927: 43). Hand-finishing of solid castings was quite practical if required. However, the fine, hollow-walled ones, perhaps most typically of Third Intermediate Period date, would be prone to damage by any serious mechanical working and there would have been sense in including as much of the fine detail as possible on the original wax model. The chased detailing of copper objects and the accurate cutting or sharpening up of inlay recesses would be an obvious use of iron tools, but the fine Middle Kingdom copper alloy statuettes show that iron tools were not mandatory.

The quality of workmanship of the Third Intermediate Period figures is, on average, far better than those of the Late Period when, we must assume, the rapid expansion of the industry led to much mass production of poor-quality goods being produced for temple offerings. What this says about changes in Egyptian religious practice at a time of foreign rule is outside the scope of this chapter.

Decorative inlays and overlays on copper alloy objects

The overlaying of all or part of a copper alloy object with gold, electrum or silver sheet is well-known from ancient Egypt. In the simplest technique the precious metal sheet is pressed and shaped over the object and held in place by adhesive, mechanical folds or overlaps. The commonest technique, probably from the late New Kingdom onwards, was to gild with extremely thin gold leaf laid over a thin layer of gesso. To facilitate the adhesion of the gesso to the copper alloy, the object was sometimes roughened by stippling or chiselling (Garland and Bannister 1927: 191; Oddy *et al.* 1988) or by glueing linen to the metal and then applying the gesso over this.

The gold leaf can be extremely thin – down to under 0.005 millimetres (Lucas 1962: 231). The present writer has seen cases where the gold leaf is thin enough to appear greenish by transmitted light. The nature of the adhesives used have not been ascertained but were presumably ordinary animal glues or albumen (see Chapter 19, this volume). In one unpublished Late Period example examined by the writer, minute particles of bird's feather were identified in the glue holding gold leaf to a lead substrate. This might represent the use of feather brushes – a suitable application implement as attested in medieval literature.

It has often been assumed that the even, black colour now seen on some Egyptian copper alloy objects, in particular inlaid examples, was deliberate (Ogden 1983a: caption to fig. 4.1; Craddock and Giumlia-Mair 1993). Recent research has shown that the effect, which is essentially the same as the more recent *shakudo* work from Japan, is due to the addition of a few per cent gold, often containing a little silver, to the alloy. After stringent cleaning and polishing, probably with a vegetable extract or juice as *per* the Japanese technique, the object is treated with an acid solution made from such ingredients as copper sulphate, alum and nitre. This results in a fine, compact and durable bluey-black copper oxide layer. This surface coloration makes an ideal background for inlay work in gold, silver (or electrum) and even copper, and, indeed, this is its most usual function.

The use of this technique in the ancient Old World was first noted on Roman objects. However, observation and analysis soon established its use on earlier Classical pieces – such as for the black inlaid strips decorating the finest Mycenaean dagger blades (Ogden 1993) – and then on Egyptian objects from the Middle Kingdom through to the Late Period (Ogden 1993; Craddock and Giumlia-Mair 1993; Craddock 1994; 1995b; Giumlia-Mair 1996). Middle Kingdom examples of 'black bronze' include the kneeling figure of Amenemhat III in the Ortiz collection (Ogden 1994; Giumlia-Mair 1996), a crocodile from the same group now in Munich (Giumlia-Mair 1996), and also a scimitar blade in Munich (Giumlia-Mair 1996). This latter has a copper alloy blade with a narrow band of black down each side inlaid with inscriptions and designs in gold wire – thus relating it closely to the well-known Mycenaean blades. In the New Kingdom we have the kneeling figures of Thutmose III and Tutankhamum noted above (p. 158). Once into the Third Intermediate Period and Late Period, examples became more plentiful.

Black bronzes tend to have up to about 5 per cent gold and, typically low lead levels, even in the Late Period. Black bronze has been equated with the *ḥsmn-km* (black copper) referred to in Egyptian inscriptions from the early Eighteenth Dynasty onwards (Giumlia-Mair 1996; Craddock 1998). The recent research on what are probably surviving examples of *ḥsmn-km* vindicates the view of Garland and Bannister three-quarters of a century ago. They noted that the supposed blue colour of some ancient bronzes 'must necessarily have been in great measure due to the composition of the bronze itself, not improbably containing gold' (Garland and Bannister 1927: 82).

Black bronzes are probably just one example of an ancient tradition of deliberately colouring or altering the surface of ancient metals. For example, the New Kingdom cow vessel in the Metropolitan Museum of Art, New York, mentioned above, has a surface which suggests deliberate chemical etching of some type prior to the attachment of the cow figure (Winlock 1936).

As noted below (p. 164), pigment has been observed on some gold and probably silver objects from Egypt and, as seen with copper–tin and copper–arsenic alloys (p. 152–3), some link between alloy and intended colour sometimes seems inescapable. However, the idea that the blackish inlay on the cheek of a Horus falcon deity in the British Museum might be due to deliberate treatment with an arsenic compound (Shearman 1988) has now been rejected (see Craddock and Giumlia-Mair 1993).

A Late Period cast copper alloy situla in the Metropolitan has an unusual surface layer of a high lead copper alloy. This appears to have been applied by dipping the situla into a molten lead-copper alloy and was 'subsequently re-chased and polished to simulate silver' (Young 1959). The present writer has noted what appears to be a similar technique on an Archaic Greek figure. Plating silver by dipping in an electrum alloy is referred to below (p. 165).

Gold and electrum

Bright yellow gold needs no introduction. Admired and desired for millennia, it was available as a native metal and required no complex or laborious smelting procedures. Perhaps the greatest puzzles are why its employment does not appear to precede that of copper or lead or why it has never been reported from a Palaeolithic occupation site.

Gold, formed deep within the earth's crust, is forced up through fissures in rocks to form veins, usually in quartzites. This vein or reef gold can be mined, but it is arduous work to break and grind up the rocks to release the particles of gold. However, nature lends a hand and over long periods of time wind, rain and frost break up the gold-bearing rocks and the grains and nuggets of gold are washed down into the streams and rivers where they congregate as alluvial or placer gold. Over further geological timespans some of this gold is incorporated into new rock formations.

The mines

The gold-mining regions in, or adjacent to, Egypt essentially stretch southwards through the Eastern Desert from roughly the level of Qena-Quseir to as far down as the present Sudan border, although there are some sources, exploited in antiquity, further north in the Eastern Desert. Since the gold mines of ancient Egypt were celebrated in Classical and in Medieval Islamic times, many travellers to Egypt in recent centuries have explored the mining areas. There was some mining of Egyptian gold in the twentieth century, with a reported production of almost seven tonnes between 1902 and 1958 (Sabet *et al.* 1976a). In recent times further geological surveys have been made, some aided by satellite photographs, and the renewed exploitation of Egyptian gold is still under consideration.

Documentary evidence shows that the Egyptians themselves defined three gold mining regions (Vercoutter 1959). The gold from mines in the Eastern Desert in the Hammamat to Abbad region was referred to as 'gold of Koptos'. Koptos was an important trading centre on the Nile which controlled much of the Eastern Desert produce. Further south, 'gold of Wawat' was obtained via the Wadis Allaqi and Gabgaba. The caravan routes started on the Nile at the fortress of Quban, a settlement that might have owed its foundation to the need to protect these routes and which was also, perhaps a processing centre for other produce of the area – such as copper ore (see p. 151). From still further south, from what is now the Sudan, even parts of Ethiopia, came the 'gold of Kush'.

Surveys undertaken between 1989 and 1993 by a combined Egyptian Geological Survey and Munich University team studied around 130 ancient gold mining sites in the Eastern Desert over an area roughly between the twenty-second and twenty-eighth parallels (Klemm and Klemm 1994). This research revealed extensive mining activity in the Eastern Desert from Predynastic time onwards and showed how the types of gold deposit exploited changed with time as recovery techniques improved.

In Predynastic and Early Dynastic times exploitation was fairly sparse, but spread over much of the Eastern Desert right down to the region between Aswan and Ras Banas. The Castiglioni brothers have reported the possibility of a Neolithic settlement at the gold-mining centre of Deraheib in the Wadi Allaqi (unpublished). This settlement was a major city in post-Pharaonic times and most of the buildings and mining detritus are late in date, but there is also Middle Kingdom and pan-grave pottery.

There is little *in situ* evidence for the direct exploitation of anything other than Koptos gold in the Old and Middle Kingdoms. However, the surviving documentary evidence indicates that the gold of Wawat, if not Kush, played a vital part in the Middle Kingdom and up to the middle to late New Kingdom. Examples of such textual evidence include several Middle Kingdom stelae, such as two in the British Museum: that of Simunt, discussed below (p. 162), and that of Sa Hathor. The latter, dating to the reign of Amenemhat II, explains how Sa Hathor went to the south to supervise the gold-mining and gold-washing.

This exploration for southerly gold sources might suggest that the more northerly Eastern Desert mines had been largely exhausted (within the capabilities of primitive mining technology) by the early days of the New Kingdom. Whether newly developed mining technologies made the Eastern Desert mines more economic again in the later New Kingdom, or whether changing political situations to the south made necessary a re-think about Eastern Desert exploitation, is uncertain, but certainly the exploitation of Kush gold subsided until Napatan times. In the late New Kingdom, the focus seems to have switched back to the Eastern Desert. The famous map of the gold mines now in the Museo Egizio, Turin (Cat. 1879), one of the oldest surviving maps in the world, dates from the Twentieth Dynasty, and might reflect a resurgence of interest in the Koptos gold at this period.

There is still much work to be done collating the geological, archaeological and documentary evidence regarding the exploitation of the various gold mines within reach of Egypt, but Greaves and Little's succinct words from 1929, quoted by Lucas, still apply: 'No workable deposits [of gold] have been discovered that they [the ancient Egyptians] overlooked' (Greaves and Little 1929: 123–7).

The gold grains and nuggets in a river bed, or in what had once been a river bed, can be recovered relatively simply. Initially hand-picking probably sufficed, but a more productive approach was panning in which the sands and fine gravels of the river bed are scooped up with water in a pan-like vessel and swirled around. The sand and water slosh out over the sides to leave the far heavier gold particles in the bottom of the pan. For larger-scale operations, the sand and water are run down over a sloping washing table which has suitable grooves, ridges or other arrangements to trap the gold grains. This process is called gold-washing and is also used in the recovery of vein gold once the gold-bearing rocks have been broken up and laboriously ground down to powder. Ancient gold-washing tables have been reported and illustrated by Vercoutter (1959)

Although we see representations of gold-workers in tomb decoration from the Old Kingdom onwards, the earliest representation of gold recovery is that in the tomb of Baqt III at Beni Hassan (BH15) which dates to *c*. 1900 BC. Here we see gold ore being sorted or washed, perhaps ground, while a vertical object is possibly some type of gravity washing table depicted in plan view (Chappaz 1983). More recently the newly excavated tomb of Khaʿy, described as 'goldwasher of the treasury of Pharaoh', at Saqqara has revealed a scene of gold-washing with what appears to be grinding (?), a sloping washing-table, and melting. This tomb dates to the time of Rameses II (Martin 1991: 131 fig. 90; see also Fig. 6.4).

Grinding stones, perhaps predominantly of Ptolemaic and Roman times, can be seen in abundance in the gold mining areas of the Eastern Desert. The backbreaking work and the division of labour depending on age and gender at Ptolemaic gold mines was graphically described by Agatharchides as recorded by Diodorus Siculus (Oldfather 1935: 121). We know that in Ptolemaic and Roman times the workforce was made up of prisoners of war, slaves and convicts. Although the descriptions of the mine workings from the Dynastic period are far less explicit, the mental images generated by Agatharchides comes to mind when we read, for example, the Twelfth-Dynasty stele of Simunt in the British Museum (BM EA828). This tells us how he went to the south to bring back gold for Amenemhat II and how he made men, women and children dig out the quartz then crush and wash it. This stele does raise the question of the extent to which vein gold, as opposed to the easier-to-exploit alluvial gold, was exploited in Dynastic times. There seems to be little evidence for the mining of vein gold prior to the Middle Kingdom and alluvial gold was still probably a major source in the New Kingdom and even later.

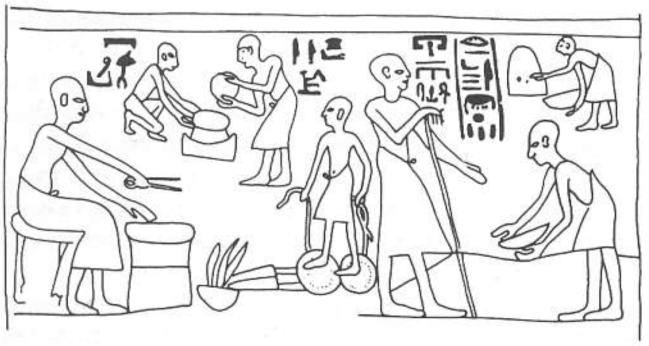


Figure 6.4 Scene of gold processing in the Ramesside tomb of Khaʿy, 'goldwasher of the treasury of Pharaoh', at Saqqara.

Once mined, the gold would have been transported to the centres where it was to be worked. For security and ease of recording, the gold would have been melted into ingots of some type, unless it was present as relatively large nuggets. We see the transport of both nuggets and ring ingots in New Kingdom wall paintings, and gold has been transported in identical forms in recent times in Ethiopia.

Some import of gold from outside Egypt, as tribute or booty, is probably likely to have occurred on a fairly minor scale throughout Egyptian history. We only have documentary evidence for imports of gold 'from the North' from the Ramesside period onwards, but tangible earlier examples might include the ten gold ingots found with the predominantly silver 'el-Tod treasure' of the Middle Kingdom (de la Roque *et al*. 1953). This possibly originated in Anatolia (see under 'silver' p. 170.

Composition and refining

Gold, as recovered from the earth (native gold), can vary greatly in composition. The predominant accompanying element is silver, which can be homogeneously alloyed with the gold in anything from mere traces up to 50 per cent or more. The copper content of 'as-mined' gold is typically under about 2 per cent, but there are exceptions, and there will generally be detectable traces of numerous other metals including iron, tin and members of the platinum family of metals.

The nature and relative proportions of the trace elements in gold potentially provide an indication of source or source type, but so far there are too few analyses of gold objects or mine samples and, besides, there can be considerable variation in the composition of native gold even within the same mining area, particularly with alluvial gold. Osman (1995: 8) has recently noted that the gold is more pure in the southerly regions exploited by the Egyptians than in the north. More precise characterisation of Egyptian gold sources might be possible in the future. For example, the presence of antimony ores in association with gold has been noted in the Eastern Desert at Wadi Ballit and Fawakhir (Hume 1937 and Azer 1966), and so we might suggest this area as a source for the gold used for the sceptre of the Second-Dynasty pharaoh Khasekhemwy with its celebrated, and previously puzzling, small antimony content (Lucas 1962: 226–7; Ogden 1976).

Traditionally gold with over 75 per cent gold present is described as gold. If it is a gold–silver alloy with under 75 per cent gold it is electrum, and, according to Gale and Stos-Gale's more recent nomenclature (1981), gold–silver alloys with 5 to 50 per cent gold should be termed aurian silver (those with less than 5 per cent gold are simply termed silver with low gold – see section on silver, pp. 170–171). Although a simple terminology for mined gold, this is, perhaps, not a good reflection on how the alloys were considered by the Egyptians, or behaved when they worked them or buried them. The traditional division between electrum and gold at 75 per cent gold level falls most inconveniently at just about the median composition for much Egyptian gold-work. Also the variable copper presence will have a major effect on colour and the effects of burial (or even deliberate post-manufacture surface treatment) can greatly 'improve' the surface colour and thus apparent purity (Ogden 1983b, 1993).

The possibility of distinguishing between natural and man-made gold–silver alloys has been raised from time to time (Weill 1951). A small lead content is usually taken to be indicative of man-made alloys, that is gold alloyed with smelted silver, but this is perhaps not an invariable rule (Ogden 1993: 39).

Iron is found in trace levels in much ancient gold. Tin, which is potentially perhaps a better indicator of source, is quite common in Egyptian gold objects (perhaps most typically in the New Kingdom, but far more analyses are needed). The tin is generally homogeneously distributed in the gold in solution, but the author has also noted what appear to be very minute inclusions of some type of hard tin mineral in Ptolemaic gold objects, and the same might well turn up in earlier Egyptian gold. Silvery-grey inclusions of the platinum-group metals are also extremely common in gold objects from Egypt (see pp. 169–70).

The composition of an ancient gold object can reflect four possible practices:

1. Gold can be used 'as found'.
2. Gold can have silver, copper, sometimes both and occasionally other metals, alloyed with it for aesthetic, practical or even fraudulent reasons.
3. Gold can be purified (refined) and employed in a pure or near-pure state.
4. Gold can be refined and then alloyed down to the desired fineness level by careful measured additions of silver, copper or other metals.

These four possibilities also represent the chronological development of gold usage. One might expect the use of gold in as-mined (or as-recycled) state to have been the norm for much of Egyptian history. However, analyses of gold objects from Predynastic times onwards show that copper is often present at levels far above those of natural impurity and a deliberate addition seems certain – a feature, also, of some contemporary Sumerian goldwork. The addition of considerable amounts of copper to produce a deliberate red colour is seemingly an Amarna-period phenomenon, as noted below (p. 164). Nevertheless, as a rule of thumb, copper levels in gold were nearly always lower than the silver levels – a fact true for most of the ancient world up to, and including, Roman and Byzantine times.

The ancient Egyptians had no way of accurately assessing the composition of gold as mined and nor would they have been able to predict or determine the eventual composition of gold deliberately alloyed with other metals. This means that standardisation and accurate assessment of value (and, outside Egypt, the possibility of developing sensible coinage) were well-nigh impossible before mined gold could be 'refined' to bring it to a pure state. Once refined gold was a reality, carefully weighed proportions of other metals could be added to provide predefined gold alloys.

The date of the introduction of gold refining is a much-debated subject. Chappaz (1983) has pointed out that in representations of metal-workers melting gold with either blowpipes or foot-bellows, we often also see one workman blowing air into the crucible with a blowpipe. For example, in the New Kingdom tomb of Puyemra at Thebes (TT39), gold is being melted with one man operating a pair of foot-bellows (see Fig. 6.2). However, a second man appears to be stirring the crucible with one hand while blowing through a blowpipe into the crucible. This would certainly help to oxidise any base metals present, particularly if extra lead or lead oxide was added (true cupellation). However, there would be no significant loss of silver and thus little if any overall increase in purity of typical as-mined Egyptian gold. This means that the oft-published Amarna letter that refers to the drop in weight when the Egyptian gold was put through Mesopotamian fires must be assumed to refer to a more efficient silver-removing refining process (EA 10; Moran 1992: 19–20), unless a batch of the gold–copper alloys typical of the Amarna period (see p. 164) had been sent overseas (Ogden 1993).

Despite this Amarna letter, the available analytical evidence suggests that refining was not used in the day-to-day jewellery industry before the Late Period, and was perhaps introduced by the Persians. The same chronology would also appear true for much of the ancient Near East and the Classical lands, and relates to the introduction of standardised coinage in Asia Minor at about that time.

On the basis of published analyses (as well as the writer's own largely unpublished analyses), it appears that Egyptian gold objects prior to the Late Period were generally unrefined and probaby simply gold as-mined (or otherwise obtained) with some addition of copper in some cases. This copper – presumably intentional – can range up to 10 per cent, with the copper levels at the upper end of this range perhaps being more typical after the middle New Kingdom. In view of the beneficial effects of copper in improving the 'gold' colour of gold–silver alloys, as noted above, it might not be coincidence if there was an increase in copper levels from a time when 'gold-coloured' gold was beginning to be valued more than the paler electrum alloys.

Ancient Egyptian gold purities can thus range from well under 50 per cent up to 90 per cent or more. Purities over about 85 per cent appear to be rare before the Late Period, and around 70 per cent to 85 per cent seem most typical of jewellery of the Middle and New Kingdoms. Berthelot (1895) notes that two examples of the gold from the Twelfth-Dynasty 'Dahshur Treasure' were around 83–6 per cent gold, the balance being silver. Copper was less than 1 per cent.

Nevertheless, some alloys are far less pure and some gold objects, perhaps often of natural alloys, have silver levels exceeding the gold (e.g. the aurian silver examples published by Gale and Stos-Gale in 1981). Other examples include a Middle Kingdom shell pendant in the Fitzwilliam Museum (E.302a, 1947) which has just over 30 per cent gold, about 66 per cent silver and around 3 per cent copper, and a similarly low level of purity was noted for some gold foil from the Twelfth-Dynasty burial of Senebtisi (unnumbered fragments; Frantz and Schorsch 1990). There was a similarly large range of compositions in the New Kingdom although, perhaps, a trend to higher average purities. There are few analyses available of Third Intermediate Period gold, but the evidence suggests much the same pattern as in the New Kingdom – including some low purities. For example a Third Intermediate Period vertical amulet case in the Fitzwilliam Museum has only about 50 per cent gold (E12.1940; see Ray 1972, unpublished analyses by Ogden).

Gold purities over 90 per cent, and often around 95 per cent, only become common in the Late Period when, as suggested above, refining perhaps began to be used on a more regular basis. For gold leaf (for use in gilding) there was an advantage in high purities – the higher the purity, the easier it is to produce thin leaves. More than 95 per cent purity seems fairly typical of later gold foils, such as on gilded Late Period copper-alloy objects. However, samples of gold leaf from Middle Kingdom wooden coffins ranged in purity from around 85 per cent or so gold right down to about 30 per cent gold (Frantz and Schorsch 1990). The recent analysis of the gold leaf on a silver plaque from the tomb of Nefertari showed it to be of high purity (99.0 per cent) gold (Markowitz *et al.* 1997). This might indicate the occasional use of refining in the Ramesside period – or if not, at least the deliberate choice of high purity gold for hammering into thin leaf. A small gold plaque from the same tomb was composed of 81.7 per cent gold (Markowitz *et al.* 1997). High purity gold has sometimes been employed for the ubiquitous fakes of Egyptian gold objects, some dating back to well before World War I; some authorities in the past have even erroneously assumed that high purity was a positive sign of antiquity.

The addition of copper, as noted, counteracts the paling effect of silver on gold and if, as usually supposed, electrum (and silver) were considered more desirable than gold prior to the New Kingdom, the early addition of copper to electrum seems counterproductive. After the New Kingdom copper might have been intentionally used to 'correct' the pale colour of as-mined gold–silver alloys. The high copper 'red golds' used for some of the gold stirrup-rings of the Amarna and immediate post-Amarna Period (and perhaps only for rings) are of some interest in studies of cultural relationships. There is enough copper – well over 50 per cent in some cases (Lucas 1962: 229; Ogden 1977) – to produce a strong red colour. Copper–gold alloys were used for deliberate, decorative purposes by the Mycenaeans at about the same period (Ogden 1993) and, interestingly, the Egyptian rings are, as a type, almost as well-known from Cyprus as Egypt. Alloying copper to gold reduces its melting temperature and makes it easier to cast. This might seem to be one explanation for these solid, and often massive, red-gold rings; the purer examples are seldom cast.

The highest copper contents in gold known to the writer from post-New Kingdom objects are in thin gold inlays in copper alloy objects and some diffusion of copper from the underlying metal might be assumed. Higher copper levels are also to be found in some gold solder alloys employed on gold objects – sometimes over 20 per cent copper.

The use of induced colours on Egyptian metals – such as the 'black bronzes' discussed above (p. 160) – is also seen in the bright blood or burgundy-red colour gold surface which was produced by small iron additions to gold. The process was discussed in depth by Lucas, who provided a bibliography of earlier work (Lucas 1962: 233–4), and it has recently been examined and replicated by Frantz and Schorsch (1990). The bright colour is only a thin surface layer and thus was not suitable for many items intended for wear. The best-known earliest examples are the beads, rosettes and 'sequins' from the tomb of Tutankhamun. The earliest instance recorded to date is from the Eighteenth-Dynasty tomb of Queen Tiye and the latest the Twentieth-Dynasty earrings of Rameses XI. The technique has so far only been encountered among royal funerary equipment.

The application of gold over copper alloys was noted briefly above (p. 160). Various plating techniques were used but all involved the application of sheet-gold as foil or leaf. The use of 'fire gilding', using mercury–gold amalgams, was unknown prior to the Ptolemaic period.

In the simplest forms, sheet gold (ranging in thickness from the extraordinarily thin to the quite substantial) could be attached to the surface of other metals and such materials as ivory and wood (see Chapters 13 and 15, this volume). Thickish gold foil could be held in place by folding or crimping it over the edges of the object or into channels deliberately formed in the object. In some cases small nails or pegs were used. For thinner foils and gold leaf the easiest procedure was to glue it to the substrate – either directly to the surface or over an intermediate gesso layer (Ogden 1983a: 80).

It seems unlikely that gold foil or leaf could be attached to copper alloys by a process involving heat and burnishing, since the copper alloys too easily develop surface oxides that would hinder adhesion, but such techniques were used to apply gold to silver in ancient times. Objects were sometimes made by fusing, by heat and hammering, gold over an electrum substrate and then hammering this out into a composite sheet from which objects could be formed (Ogden 1983a: 80–1). This technique was employed for some of the hollow annular 'hair-rings' of the New Kingdom. In one case examined by the writer, the surface layer was electrum with only a marginally higher gold level than the electrum underlying it. It seems economic nonsense to go to so much trouble to plate electrum with electrum, but an explanation might be that the surface layer was just sufficiently higher in gold to permit surface enriching (i.e. to be given a purer gold surface by chemical leaching). This technique, using various mixtures of alum, urine and other substances, has been employed until recent times. The generally accepted rule of thumb is that gold alloys with under about 55 per cent gold cannot be surface 'coloured' in this way.

The plating of silver by dipping into molten electrum, followed by chasing, was possibly used for some small amulet-like statuettes. Oddy *et al.* (1978) described a figure of the god Khons treated in this way, and the same technique appears to have been used on a similar figurine recently examined by the present writer. The use of dip-plating to provide a silver-like lead–copper alloy surface to a copper alloy situla was mentioned above (p. 160). This technique might be most typical of the Late Period, but so far few examples have been discussed.

Gold-working

The methods employed by the ancient Egyptian goldsmiths have been covered in some detail elsewhere (Aldred 1971; Ogden 1983a, 1992a), although there is still a need for a far more comprehensive study. As with copper alloys, all but the most primitive of gold objects would have passed through at least one melting state during their production history. Gold grains, dust or nuggets would be cast together into bars or rings for ease of transport and recording, and every time that gold was alloyed it would be melted with other metals. Early representations, such as that in the tomb of Mereruka at Saqqara (*c.* 2300 BC) show whole banks of workmen with blowpipes melting gold.

Nevertheless, the gold-working tradition of Egypt and the Near East was predominantly one of sheet gold, not casting. Objects were made by hammering out the gold – whether supplied as ingots, fused scrap or, later, coins – into thin sheet, which was then cut and shaped to form the individual components of the jewellery. Even components such as wires and small gold spheres were formed from sheet, the former by various cutting, hammering or twisting operations, the latter by melting small snips of sheet or wire so that surface tension would roll them up into small balls. Even the more massive, solid objects, including some fine, gold amulets were generally made by hand-working gold, not casting.

When casting was employed for gold, it was often in conjunction with hand-wrought work. For example, a gold deity figure might be cast by the lost wax process, but it might also have other components such as a rectangular sheet-gold base, attributes, hammered suspension loop and so on soldered in place. The problem was that casting was potentially wasteful of metal. There was no way to produce a mould or a wax antetype which would employ a pre-determined volume or weight of metal and every cast would have casting fins, sprues and so on which would have to be cut off.

Solid-cast gold objects, like their copper–alloy counterparts, could be made up from several separately cast components. For example the fine Twenty-second-Dynasty gold figure of Amun in the Metropolitan Museum of Art, New York (MMA 26.7.1412) was cast, with fine surface working, but the arms appear to have been made separately (by casting?) and soldered in place. The headdress plumes and base plate are of sheet-gold soldered in place.

In general the use of soldering was common for gold objects, and mechanical joints were more rare, which is exactly the opposite to the situation with copper alloy objects. In general the solders used on gold appear to have been made by adding extra silver, copper or both to some of the gold being worked. For example, one Late Period piece (private collection) was of 92 per cent gold with 7 per cent silver and 1 per cent copper, while the solder used to assemble it was 55 per cent gold, 18 per cent silver and 27 per cent copper.

For finer joints, a soldering process which in essence produced solder within the joint area by reducing a copper compound to copper (colloidal hard soldering or diffusion bonding) was probably used from an early period. A mixture of glue and ground malachite (copper carbonate) as used as a pigment, or verdigris, would have sufficed. The glue held the gold components together until the application of heat burnt the glue to carbon. In the presence of carbon the copper compound was reduced to pure copper which then alloyed with, and diffused into, the adjoining gold, thereby fusing the parts together. This type of technique was probably used for much of the granulation work in ancient times, that is the application of fine lines or patterns in minute gold spheres on a sheet-gold background. However, recent study of an example of Middle Kingdom granulation (Ogden 1992b: 52 UC6482), revealed the apparent use of a silver-based solder alloy, the mode of employment of which is not yet understood.

Granulation first appeared in Egypt during the Middle Kingdom and, particularly in view of some of the earliest examples, was almost certainly an imported idea. It reappeared in the middle to late New Kingdom and was used for some Ramesside jewellery. It is all but unknown among the Third Intermediate Period gold-work from Tanis. Granulation work never seems to have been accepted for use in the more traditional, 'iconographic' Egyptian jewellery forms and was perhaps always at least partly seen as a 'foreign' technique.

In the archetypal, traditional jewellery from Egypt, the forms were high symmetrical, laden with subtle and not-so-subtle imagery and meaning, and inlays of coloured stones were employed more as blocks of pigment than as gems. This means that stones or coloured glass were cut to fit the settings, while the settings were seldom made to employ particularly choice stones. One interesting exception to this rule is a spectacular Twentieth-Dynasty gold bracelet set with a large, irregular piece (perhaps a polished nugget) of turquoise, now in Hildesheim (Pelizaeus Museum, on loan from the Niedersächsische Sparkassenstiftung; Eggebrecht 1996: 76, fig.71).

Even pigment was sometimes applied to gold. In one case examined by the writer, a gold and silver Isis crown from a Third Intermediate or Late Period figure had part of the gold background painted red by the application of red iron oxide pigment over a very thin gesso layer (unpublished, private collection). The use of the red mercury pigment cinnabar has recently been reported on gold-work from the classical world (Williams and Ogden 1994) and in Iberio-Phoenician goldwork of about the fifth century BC (unpublished, private collection).

Enamel is glass which is ground up finely, placed in a hollow, cavity or 'cell' in the metal-work and then heated until it melts and fuses in place. Since the Egyptians were conversant with glass manufacture at least from the early New Kingdom onwards (see Chapter 8, this volume), we might well expect enamel to have been employed in Egyptian gold-work. Use of enamel in various ancient Egyptian objects has been proposed and rejected during the twentieth century (Lucas 1962: 116–17; Aldred 1971: 221 and description to plate 103; Teeter 1981: 319). The only Egyptian gold objects of Dynastic date that are known to the writer and believed likely to be decorated with true enamel are two objects found in the Third Intermediate Period tomb of Wendjebaendjed at Tanis (Ogden 1990/1). The first object is the gold bowl (Montet 1951: 83 and pl. 54; Yoyotte 1987: no. 79). Here the decoration in the centre is an inset rosette motif in the form of a complex rosette (a detail of this is shown in his figure 2). The identification is supported by the similarity in terms of both design and colour palette (white, green and a purplish colour) of a group of six enamelled gold rings found in a Mycenaean tomb at Kouklia (Maryon 1971: 170–1). The other object is one of the pectorals (Montet 1951: 77 and pl. 50; Yoyotte 1987: no. 75). The predominant use of bluish-green in this pectoral is contrary to Egyptian custom, but not surprising with enamel, where red was problematic to produce. Examination of the pectoral strongly suggest that the inlay material is fused in place, certainly it follows very precisely the contours of the cells (particularly the irregularities of the corners), and in places it seems to overlap with the cells.

Even if these two objects are enamelled – and the now-empty wire-bordered tail feathers of Rameses' famous duck bracelets (Cairo CG52575/6) are other possible candidates – enamelling was certainly the exception rather than the rule in ancient Egypt, other than in Meroitic (Ogden 1989) and Ptolemaic contexts. Over the years, various reasons have been put forward (e.g. the absence of lead in Egyptian glass, see Dillon 1907), but a simple explanation might be the close melting ranges of the ancient glasses and the ancient gold alloys used in Egypt. The types of glass used in ancient Egypt had melting temperatures that generally ranged between about 800 and 950 °C, and in practice a temperature around 900–1,000 °C would be necessary for fusing a good enamel. The majority of the gold alloys used by the ancient Egyptians would begin to melt between about 900 and 1,050 °C and some of the solders used would start to melt at well under 900 °C. In practice, Egyptian gold jewellery objects could not be enamelled without the very real risk – in many cases the likelihood – that the gold components would start to distort and even begin to come apart.

The enamelling of copper alloys is also encountered from the Third Intermediate Period onwards, but there has been no systematic study to date.

Iron

There are abundant supplies of iron ore in various parts of Egypt and in the Sinai peninsula (Lucas 1962: 235–6; el-Hinnawi 1965: 1497–509). Iron ores (including magnetite and haematite as well as accessory minerals such as red jasper) are found at Wadi el-Dabba in the Eastern Desert (Akaad and Dardir 1978). Bahariya Oasis in the Western Desert, almost on a latitude with el-Minya, is an important iron-ore source today, supplying haematite, limonite and goethite. El-Baz (1984) provides a good recent bibliography for the iron ores of this region as well as of others such as the iron ores in Aswan sandstone. However, these ore deposits were seemingly seldom if ever exploited in Dynastic times for anything other than pigments (see Chapter 4, this volume) and, we must assume, fluxing agents for copper smelting.

Garland and Bannister refer to old workings at Wadi Abu Gerida in the north Eastern Desert, but these are probably of Roman date (Garland and Bannister 1927: 85). Petrie identified two metal-working sites, possibly for iron smelting, in the Delta – at Naukratis and Tell Defena (Daphnae). He refers to 'the large quantity of iron slag found at Naukratis and occasion [sic] pieces of specular iron ore', dating to the sixth century BC, (Petrie 1886: 39), and he also mentions an 'astonishing' amount of slag – plus a crucible base with slag and charcoal intact – from Defena (Petrie 1888: 79). It is important to remember, however, that copper smelting can also produce a copious amount of iron slag.

Ancient iron can derive from fortuitous examples of meteoric iron (some of which weigh in excess of 30 tonnes), from native iron (telluric iron), or from smelted iron ores. The occasional use of meteoric iron is probably common to most early societies but meteoric iron did not provide a reliable and constant source of supply to early Egypt.

The identification of meteoric iron artefacts in Egypt is not straightforward. The usually quoted distinction between meteoric and smelted iron is a relatively high nickel content in the former. However, nickel-containing iron can derive from some smelted ores and long buried meteoric iron artefacts can have much, if not most, of the nickel leached from them. Hence Craddock has recently said that

> Some of the well-known small pieces of predynastic and early dynastic corroded iron from Egypt are totally devoid of nickel, but are almost certainly meteoric in origin despite Lucas's statement to the contrary. (Craddock 1995a: 104 and 256; *contra* Lucas 1962: 237–8).

Other examples, such as Predynastic sheet-iron beads (Lucas 1962: 237), are reported to contain 7.3 per cent nickel.

Telluric iron is very rare world-wide and, according to a recent survey by Craddock (1995a), only an occurrence on an island off Greenland was definitely exploited in the past. We must thus assume some confusion of terms in Scheel's suggestion that telluric iron was imported into Egypt from the Peloponnese and from the Near East and that tools of telluric iron appeared during the Saite period (Scheel 1989: 17).

The availability of iron on anything but a fortuitous or sporadic scale had to await the development of iron smelting. The relatively late adoption of this technology owes more to the complexities of the processes than to a lack of supplies, since iron ores are actually abundant world-wide. Iron production requires temperatures of around 1,100–1,150 °C, about the same as for copper smelting.

The initial result of smelting iron ores is a mixed mass of iron, slag and other materials. This has to undergo repeated heating and hammering before relatively high purity and usable *wrought iron* was left. Such iron could be easily hammered into shape (with repeated annealing to keep it workable) and joined by hammer-welding at temperatures around 1,100 °C. Wrought iron of this type could be made into serviceable tools and weapons but had little if any advantage in terms of hardness or ability to take a good edge over copper alloys. About its only noticeable benefit was its tendency to bend not break.

The scattered, supposedly early, ancient Egyptian examples of iron artefacts were possibly metallurgical curiosities as much as evidence of general cultural attainment although they have attracted considerable interest over the last century. Amongst the earliest examples are simple beads made of hammered and bent sheet of Predynastic date found at Girza and examined by Gowland and Desch (see Lucas 1962: 237). The most celebrated instance is the supposed iron sheet found in 1837 near an air passage in the Fourth-Dynasty Great Pyramid at Giza, deep within the masonry and revealed after blasting. The age of this piece has been the subject of much discussion – Lucas, for example, changed his mind about its origin, finally coming down on the side of a non-ancient origin (Lucas 1962: 237).

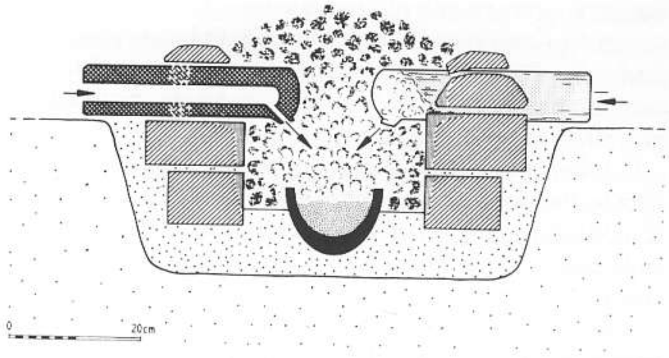


Figure 6.5 Reconstruction of the smelting process used by Ramesside metal-workers at the Delta site of Qantir; the arrows indicate the direction of air forced through the tuyères, while the black semi-circle represents the crucible.

A few years ago this piece was examined metallurgically and an early date again championed (el-Gayar *et al.* 1989c: 75–83). At the same time, Craddock and Lang expressed some doubts and recently published a full reassessment which concluded that the structure and composition of the iron 'strongly suggested that the plate of iron from the Great Pyramid is of no great antiquity' (Craddock and Lang 1989; 1993).

Few would agree with the opinion expressed by Garland and Bannister (1927: 104) that 'iron chisels were in use by the Fourth Dynasty', but it seems likely that a handful of iron objects might have existed from the Old Kingdom onwards. Of the various cited ancient examples, it is difficult to confirm chronology or provenance in most cases. Since small pieces of iron could be by-products of copper smelting using an iron oxide flux, the occasional presence of iron from the early Old Kingdom onwards is only to be expected. Generally speaking, there was some sporadic smelting of iron ores, and production of wrought iron, in the ancient Near East as far back as the third millennium BC, perhaps centred on Eastern Anatolia.

The impetus for iron production might well have derived from copper smelting. It is noted above that iron minerals were added to copper ores as fluxes to aid the smelting process. These could result in copper-iron alloys. However, iron with more than a minute trace of copper becomes unworkable and the true link, if any, between copper and iron production remains in doubt. Another possible link is between the introduction of red iron-based glazes, such as the red faience that appears in New Kingdom Egypt, and the development of iron ore smelting.

By the second half of the second millennium BC, iron was beginning to come into more common use, perhaps mainly deriving from the Hittite world. Documents of the period, such as the Amarna Letters, recount the fine iron objects including daggers received at the Egyptian court from foreign rulers (Lucas 1962: 240). Of the rare surviving New Kingdom Egyptian examples, the most famous is the dagger from the tomb of Tutankhamun (Lucas 1962: 239; Carter No. 256k), with its elaborate gold hilt supporting a finely worked iron blade. Another, less spectacular, example is the miniature headrest amulet also from Tutankhamun's tomb (Lucas 1962: 239).

Steel was being produced in parts of the ancient Near East by the closing centuries of the second millennium BC (Craddock 1995: 258–9). A process termed 'carburisation' adds carbon to the iron which thus provides a 'steel' which can be quench-hardened and tempered to considerable hardness. There are sporadic examples from about the middle of the second millennium BC onwards. Studied examples include a pick from Palestine, identified as carburised, quenched and tempered which has been securely dated to the twelfth century BC (Davis *et al.* 1985: 41–51). The technique of hammering together layers of carburised and uncarburised iron produces a strong tool and examples have now been identified from various parts of the Middle East. Perhaps the earliest Egyptian example is an iron knife in the Petrie collection (Carpenter and Robertson 1930: 428–30). This was initially dated to the late New Kingdom, but a date in the ninth century BC might be more likely (Muhly *et al.* 1977).

By the middle of the first millennium BC the production of iron had increased dramatically, but the exception appears to be Egypt. Indeed the supremacy of iron weapons over the copper-alloy ones has been seen as a major factor in the Persian conquest of Egypt. Moorey has recently noted that iron only became a cheaper metal than copper in Mesopotamia in the Neo-Babylonian Period, that is around 600 BC (Moorey 1994: 263) – the time of the Persian invasion of Egypt. It is perhaps not surprising that the largest group of iron objects from Egypt from this period is a set of almost two dozen iron woodworking tools found in the Delta in association with a Western Asiatic bronze helmet. This group dates to the seventh century BC (Petrie 1897: 18–19, 1909: 106; Williams and Maxwell-Hyslop 1976: 283–305). Four of these tools are steel. Craddock has recently largely dispelled any doubt as to the authenticity of the group (Craddock 1995: 259). It also seems likely that hafted hammers were introduced into Egypt in the Late Period. Hot-working iron with the earlier Egyptian hand-held hammers would have been an unpleasant experience.

With additions of between about 2 and 5 per cent carbon, the melting temperature of iron drops to around 1,200 °C and the result is *cast iron*. Cast iron has little relevance for the ancient Old World and can seemingly be ignored as far as Dynastic Egypt is concerned.

Lead

Native lead is extremely rare, but lead is relatively easy to produce from the main ores galena (lead sulphide) or cerrusite (lead carbonate). Lead can be smelted from galena using a simple charcoal or wood fire. As Moorey (1994: 292) has recently noted, these ores are of readily attractive metallic appearance and would have been easily spotted by early prospectors. Garland and Bannister (1927), as well as Lucas (1962), give the main ancient Egyptian source as Gebel Rosas (Arabic for 'lead mountain') south of Quseir on the Red Sea coast. Galena and cerussite were worked here in the early twentieth century and Garland and Bannister refer to ancient workings in the region (Garland and Bannister 1927: 31). There are, however, numerous other ore localities scattered through Egypt, almost down the entire length of Egypt's Eastern Desert. For example both cerrusite and galena are found at Um Gheig and Samiuki (Bishay *et al.* 1974: 47–53). Hassan and Hassan (1981) have recently published a map of some of the lead ore sources in the Eastern Desert accessible via the Wadi Hammamat, while Stos-Gale and Gale (1981) have provided a list of Eastern Desert galena deposits.

In some parts of the Old World, lead was being extracted from its ores during the sixth and even seventh millennia BC. The smelting of lead thus probably pre-dated the smelting of any other metal, copper included. Perhaps the oldest lead object so far published from Egypt is a hollow figure of a hawk – or perhaps hawk figure casing – found by Petrie in Grave 1257 at Naqada dating to the fourth millennium BC (Ashmolean 1895.137). This has sometimes been described as silver, but recent analysis vindicates Petrie's original view that it is lead, indeed of remarkable purity – 99.99 per cent lead with only minute traces of silver (about 0.025 per cent), antimony, arsenic, gold and copper (Gale and Stos-Gale 1981). The remarkably high purity of the hawk is matched by an unusual lead figure said to have been found at Abydos and obtained by the British Museum (BM EA99.10–11.1188) in 1899 (Krysko 1986). This figure appears to have had its detail, if not its entire form, produced by carving not casting. The surface patina is perhaps evidence of great age, but further study is required to establish its antiquity.

Lead objects seem to have become more common after the beginning of the New Kingdom (Garland and Bannister 1927: 30) for castings, for functional uses such as for filling weight, and as additions to copper alloys (see p. 154–5). This might relate to the increasing import of metallic lead into Egypt from the New Kingdom onwards.

Tin-lead alloys (pewter) are rare anywhere in the ancient world prior to the later part of the Roman Period (see p. 171). One possible New Kingdom example is discussed below under 'tin'.

More research on lead ores within Egypt is clearly needed before galena or lead sources can be clarified. One confusing factor in the past with regard to lead isotope provenance studies has been uncertainty as to whether silver was primarily derived from galena in antiquity (see pp. 170–71). It is not impossible that the galena used in mineral form for eye-paint and the like, was largely derived from Egyptian mines, while metallic lead was more typically imported, even from quite early times.

There is a huge literature on the isotopic characterisation of ancient Egyptian lead and lead-containing alloys (including copper alloys and silver) and the reader is directed to the relevant geological and Egyptological bibliographies and literature (el-Baz 1984; Stos-Gale 1995; Hassan and Hassan 1981). In theory, the ratios of the various isotopes of lead can 'fingerprint' a source and thus permit objects to be traced to their origin. Some researchers, however, are more pessimistic about the real potential for mine identification (Budd *et al.* 1995: 143–50). The research to date on Egyptian material is confusing, both local and imported lead and lead ores would have appear to have been used and the final word on the subject has by no means been written.

Mercury

Mercury is a silvery metal that is liquid at temperatures above −38.87 °C. It was first observed solid on the intensely cold Christmas day in St Petersburg in 1759. There is no evidence for the use of metallic mercury in Pharaonic Egypt, but the use of mercury compounds for other purposes is possible. Cinnabar (bright red mercuric sulphide) does occur in Egypt (Sabet *et al.* 1976b). In several parts of the ancient Old World there is evidence for its use as a pigment by about the fifth century BC (see p. 166), and it has even been reported that it was in use in Mesopotamia in the third millennium BC (Moorey 1994: 155).

Mercury combines with gold and silver to form semiliquid amalgams. These can be applied over metal surfaces as a plating; the mercury is vaporised off and the resulting gold or silver layer polished or burnished. There is little evidence for this process before Hellenistic times and the earliest examples from Egypt are a handful of ornaments of the Ptolemaic period, and in the Classical rather than Egyptian idiom (Williams and Ogden 1994).

Platinum metals

The platinum group of metals includes platinum itself, as well as palladium, ruthenium, iridium, osmium and rhodium. Small grains composed of various alloys of these metals (with mineralogical names such as osmiridium, iridosmine, rutheniridosmine etc., depending on composition) frequently occur in alluvial gold deposits. Due to their hardness, specific gravity and chemical inertness, they often remain with the gold throughout the separation and metal-working processes. The grains composed primarily of various proportions of osmium, iridium and ruthenium remain as hard white metal specks in the final goldwork. Such specks, varying from microscopic to several millimetres long, are commonly visible in many categories of ancient goldwork, including those from ancient Egypt (Ogden 1976, 1977).

Inclusions of this type have been noted in Egyptian gold by various authorities during the twentieth century (Ogden 1976), and Petrie was perhaps the first to describe them accurately, terming the inclusions in a Middle Kingdom gold scarab 'osmiridium'. Williams (1924) less precisely called such inclusions 'platinum metals' and Lucas (1962) was incorrect in assuming them to be 'largely platinum'. In more recent years, advances in analytical techniques have permitted the *in situ* analysis of many such inclusions in Egyptian and other gold (Ogden 1976, 1977; Meeks and Tite 1980). These analyses show that they are indeed predominantly osmium and iridium, sometimes with considerable ruthenium, and less commonly with some rhodium. Platinum occurs as little more than traces and palladium has not yet been detected.

The commonness of such specks in Egyptian goldwork indicates that the platinum group metal grains are common in the gold deposits exploited by the Egyptians and thus must almost certainly occur in the gold deposits of the Eastern Desert or Nubia. There has been no geological confirmation to date of any platinum metal occurrence in the Eastern Desert, although it is possible that it may exist in this region (see Ogden 1976), given the fact that:

(1) there are well-known (and recently exploited) platinum metal occurrences with gold in what is now Ethiopia;
(2) there is platinum in nickel ores from the island of Zabargad (St John's Island) in the Red Sea, about eighty kilometres southeast of Berenike; and
(3) there is an unconfirmed report of such metals in the Sudan.

Platinoid inclusions have been noted in Egyptian goldwork as early as the Old Kingdom, not so far before that. The inclusions are seen in many gold objects from Egypt from then on to the Roman Period and are typically primarily iridium-osmium-ruthenium alloys. However, the average proportion of ruthenium present seems to drop from the Middle Kingdom onwards, from over 25 per cent to under that amount, perhaps indicating a significant switch in gold mining region (Meeks and Tite 1980), mine type or perhaps even recovery processes.

In the nineteenth century, Berthelot (1900) identified the inlay in an Egyptian copper-alloy box as some sort of platinum metal alloy. It is not improbable that a composite platinum nugget, like those recorded more recently in Ethiopian streams, was inadvertently used instead of an electrum one (Ogden 1977). A new examination of this inlay would be useful.

It is generally assumed that platinum metal grains only occur in alluvial, not vein gold, deposits. It is true that the combination of gold and platinum metals is all but unknown in primary reef gold deposits, but combinations are found in some secondary deposits and it is not unusual for gold and platinum metal-bearing rocks to occur in proximity. Platiniferous rocks transverse auriferous quartz at

Yubdo in Ethiopia and similar associations are perhaps likely further north. The presence of chromite deposits in areas adjacent to gold mining areas (cubic chromite inclusions are also visible in some Egyptian steatite) and the auriferous quartz veins traversing serpentinite rock at the el-Sīd/Baramia gold mining area of the Eastern Desert could, from a geological point of view, point to platinoids being present with gold retrieved using ancient vein gold exploitation technology (Sabet *et al.* 1976a; Ogden 1977).

Silver

Lucas' suggestion that much Egyptian silver, particularly that of the earlier periods, was actually a natural alloy of silver and gold has been substantiated by recent studies by Gale and Stos-Gale (1981) and Mishara and Meyers (1974). This was presumably natural 'aurian silver' from Egyptian and Nubian 'gold' mines.

However, some silver with 1 per cent or less gold occurs from Predynastic times onwards. Since silver could not be separated from natural gold/silver alloys so early, the silver must derive from mineral ores. This is certainly implied by the small lead presence in such silver (Gale and Stos-Gale 1981).

There was, perhaps, some exploitation of silver ores such as argentite (silver sulphide) in antiquity but most of the silver probably derives from lead ores. When lead ores are smelted, the molten lead produced contains any traces of silver. When this lead is heated under strong oxidising conditions the lead is converted to litharge – lead monoxide – and the silver will be left as a shining globule of silver. This oxidising process is termed cupellation and was a process also used to remove base metals from silver and gold. As we saw above, lead was being smelted in some parts of the Old World by the seventh or sixth millennium BC, and analysis of Egyptian objects suggests that it was in use, on at least occasions, well before about 3000 BC.

It has often been assumed that the prime such source was the lead ore galena (lead sulphide) which does, indeed, contain some silver. However the silver levels in Egyptian galena are generally low (for ancient exploitation methods) and over recent years analysis, studies of early documentary evidence and experimentation, have indicated that the commonest sources of silver in antiquity might rather have been the oxidised lead ores, particularly cerussite (lead carbonate). Silver obtained from cerussite typically contains the noticeable amounts of gold and other trace elements that are typical of so much silver from antiquity. We can also note that silver right up to recent times usually contains a noticeable lead content. For the purposes of isotope provenance studies (see p. 168) it is vital to note that this lead need not always derive from the ores themselves, but might well represent the lead added during a refining process.

One of the earliest silver objects from Egypt is a box-lid from Naqada which dates to the middle of the fourth millennium BC (Ashmolean 1895.987). However, a recent analysis shows this to contain about 15 per cent gold and it is thus almost certainly aurian silver from a gold mine (Gale and Stos-Gale 1981). Nevertheless, the lead hawk casing mentioned above is perhaps evidence for a fairly sophisticated lead/silver production centre in this area during the fourth millennium BC. There is some debate as to whether the lead ores of Egypt's Eastern Desert have silver contents high enough for successful ancient exploitation (Garland and Bannister 1927: 31; Gale and Stos-Gale 1981). Certainly, so far, lead isotope analysis of ancient Egyptian silver objects has not supported an indigenous origin.

Recent analyses of various of the vessels and ingots in the Middle Kingdom 'el-Tod treasure' reveal relatively pure silver with gold concentrations generally under 0.2 per cent, (maximum about 0.65 per cent), lead well under 1 per cent and generally under 0.2 per cent (Menu 1994: 29–45). Many of the objects have only minute traces of copper, but up to 4 per cent copper in some objects suggests occasional intentional alloying for practical working reasons. The silver was obtained by the cupellation of an argentiferous mineral, and lead isotope studies show that the silver was almost certainly imported and a northern Greek or south Anatolian origin is possible. Most recently Maxwell-Hyslop has argued that it is quite likely that the el-Tod assemblage was collected by a ruler in north Syria and sent from there to Egypt (Maxwell-Hyslop 1995). The cylinder seals found with the treasure would support this (Porada 1982).

A Middle Kingdom silver mount from a scarab has a copper level of 26.4 per cent, and Lucas quotes another object with about 66 per cent copper to 34 per cent silver (1962: 249). However, in general copper levels in silver and aurian silver rarely exceed about 10 per cent and over 1 or 2 per cent is probably deliberate. A New Kingdom silver ring supposedly with about 15 per cent tin present is hardly surprising in view of the colour similarities of the two metals but more research is needed on this piece (see p. 171).

Silver was worked in much the same way as copper alloys. Sheet-metal objects were generally hammered and raised to shape, while three dimensional figurines could be cast by the lost wax process (see above under 'copper'). Fine examples of silver from the New Kingdom include a trumpet and pomegranate vase from the tomb of Tutankhamun. Once silver became less exceptional in Egypt, it could be used in great quantities – in the Ramesside Period we hear of enormous weights of silver statuary dedicated in the temples (Becker *et al.* 1994: 54 n. 31). However, few have survived – one such is a superb, hollow-cast silver statuette of a pharaoh presenting a figure of Maat (Louvre E27431, Ziegler 1988). Other surviving silver objects of this period include the magnificent silver vessels in the Ramesside 'Bubastis treasure' (for a summary and references see Ogden 1990/1). Indications of the later abundance of silver include the silver sarcophagi of the Tanite pharaohs (see Yoyotte 1987).

Silver statuettes of deities or royal figures are rare. Recently Becker *et al.* (1994) have listed and illustrated several of these in their comprehensive publication of a fine silver statuette of a naked woman of the Saite Period, now in the Metropolitan Museum of Art, New York. This piece was made of high purity silver (about 96.7 per cent silver, 2.6 per cent copper) as a casting with separately applied wig and necklet. The cast torso has small square silver plugs correcting casting flaws.

We cannot always assume that ancient silver was intended to have a bright, shiny surface. The deliberate production of a black surface on Classical silver objects has been the subject of some debate in recent years while in the ancient Near East some such tradition is implied by the Talmudic ruling against burning sulphur on the Sabbath to blacken silver. During the conservation of the fine silver Saite naked woman described above, the conservators found 'Black tabular hexagonal crystals in close contact with the silver . . . may be a silver sulphide, although this is rare in archaeological contexts.' (Becker *et al.* 1994). This black sulphide could perhaps be interpreted as an original deliberate surface. If so, the 'unusual feature' of the raised rather than incised cartouches on the arms would be explained – they would look magnificent in shiny silver against a black background. We can also note that the investigators found traces of a bright red substance on the wig that appeared to be composed of iron, calcium and silicon. This brings to mind the red iron oxide pigment over a very thin gesso layer noted by the writer on an Egyptian gold headdress (see p. 166).

Tin

Tin is a soft, light, silvery white metal that is obtained either as a native metal or derived from various ores – most commonly, if not invariably in antiquity, cassiterite (Earl 1994). Despite the use of tin as an alloying material in copper alloys from the Middle Kingdom onwards, most earlier authorities have expressed a belief that tin ores do not occur in Egypt (Garland and Bannister 1927: 4). However, there are deposits of cassiterite, some of high grade, in the Eastern Desert and some tin is commercially mined there today (Sabet et al. 1976c). There are also deposits of chalcocite in Sinai (Muhly 1978), and Wainwright reported placer tin deposits at Nahr Ibrahim (Wainwright 1934, 1943–4). Undoubtedly some tin was being imported into Egypt in antiquity, but probably not all of it.

Early tin objects from Egypt are extremely rare – perhaps suggesting that tin was generally employed in the copper and other industries in the form of mineral ores, not as metal. One recently studied exception is a small sheet tin bead from tomb 37 at Assasif, roughly contemporary with Thutmose III. Analysis showed this to be of high purity tin with just 0.6 per cent lead, 2.1 per cent copper and 0.4 per cent iron (Lilyquist and Brill 1993: 65). Interestingly the lead isotope ratio of this bead has led to the tentative suggestion that the tin might originate in the Taurus Mountains in southern Turkey, where, indeed tin ore (cassiterite) exists and where there are traces of ancient mining activity dating back to the early Bronze Age (Yener *et al.* 1989; Earl and Özbal 1996).

Other early uses of tin include a ring of late New Kingdom type from Gurob which was analysed by Dr Gladstone and shown to be pure tin (Petrie 1891: pl. 22.10; Garland and Bannister 1927: 29). There is also a well-known flask from a tomb at Abydos (Ashmolean E2442; Petrie 1904: 50; Douglas 1989). Analysis showed this to be made from an alloy of 95 per cent tin, 4.75 per cent lead, hence it is a low-lead pewter. Tin alloys with around 5 per cent lead – perhaps representing the optimum hardness – are well-known in Egypt and elsewhere from the Roman period onwards. Although the tomb context points to a late New Kingdom origin for the flask (and the basic flattened, two-handled shape can be paralleled in other materials at that period), the possibility that the vessel is somehow intrusive should be borne in mind. The composition and construction – with two horizontal seams – might well point to a later, perhaps even Islamic, origin.

With the exception of the above objects, tin objects are extremely rare in Egypt until Roman times when tin with low lead contents (pewter) became quite common for jewellery, vessels and some other purposes, including solders for copper alloy objects (Williams 1924).

Copper–tin alloys were discussed above with the other copper alloys. We can however note a ring of Nineteenth-Dynasty date analysed by Berthelot which was an alloy of almost 76 per cent tin, with around 16 per cent copper and 1 per cent lead (Berthelot 1895: 131–46). There is also a ring of possible New Kingdom date which is made of a tin–silver alloy (Williams 1924; Ogden 1983a: 30–1). The appearance of 'odd' tin alloys at the time when the Egyptians were, perhaps, first becoming acquainted with metallic tin is not surprising.

Zinc

With the exception of a few possible early, but non-Egyptian, examples, the use of metallic zinc has been limited to recent centuries (Craddock 1990). In the field of ancient Egyptian metallurgy, zinc is only known as a trace element in some copper and lead alloys. Both copper and lead ores in the Eastern Desert can contain zinc. As noted above, the available evidence suggests that zinc was not a deliberate addition to copper or other alloys until Ptolemaic times and, in any case, was added as a zinc ore or compound, not as the metal.

The alliance of science

A detailed study of the techniques of analysis now used on ancient metals would be out of place here, besides, much of what has been described in other chapters can apply equally to metals. In brief we can note that the scientific methods of study as applied to ancient metals include different types of microscopy and various spectrographic and other analysis techniques.

The simple binocular microscope, generally providing well under 100 × magnification allows us to examine technology and surface detail. It is a favourite tool of the conservator and curator. Ownership of, or easy access to, a binocular microscope should be an absolute minimum requirement for any museum department or excavation house.

A metallurgical microscope is used to examine prepared polished surfaces of the metal (typically etched to reveal internal structure). This type of microscope is generally used at higher magnifications (several hundred times in practice) and allows us to deduce much about composition, mode of manufacture, homogeneity and corrosion and ageing effects. Generally speaking, only a small, prepared sample taken from the object can be examined. A scanning electron microscope, which relies on electron beams not light, gives a much greater range of magnification (up to many thousand times) and a good depth of focus. However, constraints include the high capital and running costs and size, and also the need to place the observed item in a vacuum chamber which means that only relatively small items or samples removed from objects can be examined.

A major advantage of the scanning electron microscope is the frequent presence of in-built analytical features. Such analysis is usually based on x-ray fluorescence. Here, with the help of computers, the characteristics of the x-rays generated when an electron beam strikes the sample surface tell us what elements are present and, with varying degrees of accuracy, their relative proportions. This type of analysis is ideal for homogeneous materials or for small discrete areas such as plated layers, solders, joins and inclusions or various phases in metals. A disadvantage is that many metals, including copper alloys can be very inhomogeneous. Lead, for example, remains as discrete 'lakes' in copper alloys, and a series of 'point' analyses on a leaded copper alloy could easily show compositions ranging from no lead to almost 100 per cent lead! So, either a series of analyses must be made to give a likely average composition, or some other technique must be used which requires a more representative sample area or size.

Two techniques commonly used today on metals include atomic absorption (AA) and inductively coupled plasma spectroscopy (ICP). For the details of these and other techniques, the reader is directed to the relevant scientific and archaeometric literature. In essence, these are modern versions of traditional spectrographic processes whereby the composition is determined from the light or other radiation generated by burning or vapourising a small sample. For AA or ICP a small sample is required and this is typically the powder produced by drilling a hole with a 1 mm or 0.5 mm drill. This is hardly disfiguring to the vast majority of archaeological artefacts and the archaeologist or site authority who refuses a 1 mm hole on an object, when that object was itself revealed by digging a five-metre trench through an occupation site, can hardly claim to have logic, let alone archaeological best interest, on their side.

The scientific study of metal objects is a huge and potentially very informative field. The scope can range from microscopic observation in order to determine assembly techniques of gold jewellery to x-ray diffraction studies to identify corrosion products on copper alloys. No one person, whether scientist or archaeologist, can be *au fait* with all the disciplines applicable to ancient metals. However, excavators and curators should at least be aware of the type of information that can be gained by scientific study, should know what questions to ask of the scientists and, during excavation and post-excavation work, feel obliged to consider what can and should be done to facilitate the full study of the metal objects they find.

References

Akaad, M.K. and Dardir, A.A. 1978. The iron ore deposit of Wadi el-Dabbah, Eastern Desert, Egypt. *Precambrian Research*, 6/1: A6–A7.

Aldred, C. 1971. *Jewels of the Pharaohs*. London: Thames and Hudson.

Anwar, Y.M. 1964. Note on the occurence of copper minerals at Ras Benas, Eastern Desert. *Journal of the Geological Society of Egypt*, 8/2: 89–94.

Azer, N. 1966. Remarks on the origin of Precambrian mineral deposits in Egypt (UAR). *Tschermaks Mineralogische und Petrographische Mitteilungen*, Drittefolge 2: 41–64.

Bachmann, H.-G. 1980. Early copper smelting techniques in Sinai and in the Negev as deduced from slag investigation. In *Scientific Studies in Early Mining and Extractive Metallurgy* (ed. P.T. Craddock). British Museum Occasional Paper 20. London: BMP, pp. 103–4.

Bass, G. 1986. A Bronze Age shipwreck at Ulu Burun (Kas): 1984 campaign. *AJA*, 90: 269–96.

Baumgartel, E.J. 1960. *The Cultures of Prehistoric Egypt* II. Oxford: OUP.

el-Baz, F. 1984. *The Geology of Egypt: An Annotated Bibliography*. Leiden: Brill.

Becker, L., Pilosi, L. and Schorsch, D. 1994. An Egyptian silver statuette of the Saite Period – a technical study. *Metropolitan Museum Journal*, 29: 37–56.

Beit-Arieh, I. 1981. An Early Bronze Age II site near Sheikh 'Awad in Southern Sinai. *Tel Aviv*, 8, 2: 95–127.

1985. Serabit el-Khadim: new metallurgical and chronological aspects. *Levant*,17: 89–116.

Berthelot, M. 1895. Etudes sur les métaux. In *Fouilles à Dahchour* (J. de Morgan). Vienna: Adolphe Holzhausen, pp. 131–46.

1900. Sur les métaux égyptiens: études sur un étui métallique et ses inscrptions. *Monuments et Mémoires (Fondation Eugène Piot)* 7: 121–41.

Bishay, A., Naim, G., Amin, H. 1974. Zinc-lead deposits. *Geological Survey of Egypt* Paper 61: 47–53.

Brunton, G., Gardner, E.W. and Petrie, W.M.F. 1927. *Qau and Badari* I. London: BSAE.

de Bruyn, P. 1955. A graffito of the scribe Dhuthotpe, reckoner of gold, in the south-eastern desert. *JEA*, 41: 121–2.

Budd, P., Pollard, A.M., Scaife, B. and Thomas, R.G. 1995. The possible fractionation of lead isotopes in ancient metallurgical processes. *Archaeometry*, 37/1: 143–50.

Caley, E.R. 1964. *Analysis of Ancient Metals*. Oxford: Pergamon.

Carpenter, H.C.H. 1932. An Egyptian axe head of great antiquity. *Nature*, 130: 625–6.

Carpenter, H.C.H. and Robertson, J.M. 1930. The metallography of some ancient Egyptian implements. *Journal of the Iron and Steel Institute*, 121: 428–30.

Chappaz, J.-L. 1983. Working with gold in ancient Egypt. *Aurum*, 14: 34–40.

Coghlan, H.H. 1975. Copper artefacts from Tutankhamun's tomb. *Journal of the Historical Metallurgy Society*, 9/2: 64–7.

Constantinou, G. 1982. Geological features and ancient exploitation of the cupiferous sulphide orebodies of Cyprus. In *Early Metallurgy in Cyprus, 4000–500 BC*, (eds. J.D. Muhly, R. Maddin and V. Karageorghis). Larnaca: Pierides Foundation, pp. 13–23.

Cowell, R.M. 1987. Scientific appendix I: chemical analyses. In *Catalogue of Egyptian Antiquities in the British Museum: VII Tools and Weapons I: Axes* (W.V. Davies) London: BMP, pp. 96–118.

Craddock, P.T. 1980. The composition of copper produced at the ancient smelting camps in the Wadi Timna, Israel. In *Scientific Studies in Early Mining and Extractive Metallurgy* (ed. P.T. Craddock). British Museum Occasional Papers 20. London: BMP, pp. 165–76.

1985. Three thousand years of copper alloys: from the Bronze Age to the Industrial Revolution. In *Application of Science in Examination of Works of Art Proceedings of the Seminar September 7–9, 1983* (ed. P.A. England and L. van Zelst). Boston: MFA, pp. 59–67.

1990. Zinc in classical antiquity. In *2000 Years of Zinc and Brass* (ed. P.T. Craddock), British Musuem Occasional Paper 50. London: BMP, pp. 29–72.

1994. Secrets of Achilles' shield. *New Scientist*. 22 January: 32–5.

1995. *Early Metal Mining and Production*. Edinburgh: Edinburgh University Press.

1998. The black bronzes of Egypt. In *Proceedings of the First International Conference on Ancient Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)*. (ed. F. A. Esmael) Cairo: Ministry of Culture, Supreme Council of Antiquities, pp. 89–119.

Craddock, P.T. and Lang, J. 1989. Letter. *Journal of the Historical Metallurgy Society* 23/2: 123.

1993. Gizeh iron revisited. *Journal of the Historical Metallurgy Society*, 27/2: 57–9.

Craddock, P.T. and Giumlia-Mair, A. 1993. *Hsmn-Km*, Corinthian bronze, *shakudo*: black-patinated bronze in the ancient world. In *Metal Plating and Patination: Cultural, Technical And Historical Developments*. (eds. S. La Niece and P.T. Craddock). Oxford: Butterworth-Heinemann, pp. 101–27.

Craddock, P.T. and Meeks, N.D. 1987. Iron in ancient copper. *Archaeometry*, 29/2: 187–204.

Davey, C. 1979. Some ancient Near Eastern pot bellows. *Levant*, 11: 10–111.

Davies, N. de G. 1943. *The Tomb of Rekh-mi-re at Thebes*. New York: MMA.

Davis, D., Maddin, R., Muhly, J.D. and Stech, T. 1985. A steel pick from Mt. Adair in Palestine. *JNES*, 44/1: 41–51.

Dayton, J.E. 1978. *Minerals, Metals, Glazing and Man*, London: Harrap.

Delange, E. 1987. *Catalogue des statues Egyptiennes du Moyen Empire*. Paris: Musée du Louvre.

Desch, C.H. 1928. Report on the metallurgical examination of specimens for the Sumerian Committee of the British Association. *Report of the British Association*. London.

Dillon, E. 1907. A neglected point in the early history of enamel, *The Burlington Magazine*, 11: 373–5.

Doonan, R.C.P. 1994. Sweat, fire and brimstone: Pre-treatment of copper ore and the effects on smelting techniques. *Journal of the Historical Metallurgy Society*, 28 (2): 84–97.

Douglas, J.A. 1989. The Abydos flask enigma. *Journal of the Pewter Society* 7 (1): 1–2.

Earl, B. 1994. Tin from the Bronze Age smelting viewpoint. *Journal of the Historical Metallurgy Society* , 28 (2): 117–120.

Earl, B. and Özbal, H. 1996. Early Bronze Age tin processing at Kestel/Göltepe, Anatolia. *Archaeometry*, 38, (2): 289–303.

Eggebrecht, A. 1993. Mögen sie einen Erinnerung sein für die Nachwelt. In *Roemer- und Pelizaeus-Museum* (ed. A. Eggebrecht). Mainz: von Zabern, pp. 50–91.

(ed.) 1996. *Pelizaeus Museum Hildesheim: The Egyptian Collection*. Mainz: von Zabern.

Emery, W.B. 1939. A preliminary report on the First Dynasty copper treasure from North Saqqara. *ASAE*, 39: 427–35.

1970. Preliminary report on the excavation at North Saqqara 1968–9. *JEA*, 56: 5–11.

Fishman, B. and Fleming, S.J. 1980. A bronze figure of Tutankhamun: technical studies. *Archaeometry*, 22 (1): 81–6.

Fleming, S.J. 1982. Lead isotope analyses of Late Period Egyptian bronzes. *MASCA Journal*, 2 (2): 65–9.

Fleming, S.J. and Crowfoot-Payne, J. 1979. PIXE analyses of some Egyptian bronzes of the Late Period. *MASCA Journal*, 1 (2): 46–7.

Frantz, J.H. and Schorsch, D. 1990. Egyptian red gold, *Archaeomaterials*, 4: 133–52.

Gale, N.H. and Stos-Gale, Z.A. 1981. Ancient Egyptian silver. *JEA*, 67: 103–15.

Garland, H and Bannister, C.O. 1927. *Ancient Egyptian Metallurgy*. London: Griffin.

el-Gayar, el-S. and Jones, M.P. 1989a. A possible source of copper ore fragments at the Old Kingdom town of Buhen. *JEA*, 75: 31–40.

1989b. Old Kingdom copper smelting artifacts from Buhen in Upper Egypt. *Journal of the Historical Metallurgy Society*, 23/1: 16–24.

1989c. Metallurgical investigation of an iron plate found in 1837 in the Great Pyramid. *Journal of the Historical Metallurgy Society*, 23/2: 75–83.

el-Gayar, el-S. and B. Rothenberg, B. 1998. Predynastic and Old Kingdom copper metallurgy in South Sinai. In *Proceedings of* *the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)* (ed. F. A. Esmael). Cairo: SCA, pp. 147–58.

Giumlia-Mair A.1996. Das Krokodil und Amenemhat III aus el-Fayum. *Antike Kunst*, 27/4: 313–21 and 340.

Giveon, R. 1977. Egyptian finger rings and seals from south of Gaza. *Tel Aviv*, 4/1–2: 66–70.

el-Goresy, A., Schiegl, S. and Weiner, K.L. 1998. A chronological scheme for the technological evolution of copper in ancient Egypt. In *Proceedings of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)*. (ed. F. A. Esmael) Cairo: Ministry of Culture, SCA, pp. 215–34.

Greaves, R.H. and Little, O.H. 1929. The gold resources of Egypt. *Report of the Fifteenth International Geological Congress*. South Africa, pp. 123–7.

Hassan, A.A. and Hassan, F.A. 1981. Sources of galena in Predynastic Egypt at Nagada. *Archaeometry*, 23/1: 77–82.

Hayes, W.C. 1959. *The Scepter of Egypt II: The Hyksos Period and the New Kingdom* (1675–1080 BC). New York: MMA.

Haynes, D. 1992. *The Technique of Greek Bronze Statuary*. Mainz: von Zabern.

Hill, M. 1995. Statuette of Tuthmose III. *The Metropolitan Museum of Art Bulletin*, 53/2: 6.

el-Hinnawi, E.E. 1965. Contributions to the study of Egyptian (UAR) iron ores. *Economic Geology*, 60/7: 1497–509.

Hume, W.F. 1937. *Geology of Egypt II: The Fundamental Precambrian Rocks of Egypt and the Sudan, 3: The Minerals of Economic Value*. Cairo: Geological Survey of Egypt.

Jett, P., Sturman, S. and Drayman Weisser, T. 1985. A study of the Egyptian bronze falcon figurines in the Walters Art Gallery. *Studies in Conservation*, 30/3: 112–18.

Kaczmarczyk, A. and Hedges, R.E.M. 1983. *Ancient Egyptian Faience*. Warminster: Aris and Phillips.

Klemm, R. and Klemm, D.D. 1994. Chronologischer Abriss der antiken Goldgewinnung in der Ostwüste Ãgyptens. *MDAIK*, 50: 189–222.

Krysko, W.W. 1986. Comments on the oldest known lead figurine. *Journal of the Historical Metallurgy Society*, 20/2: 109–11.

Levene, D. 1998. Expedition to Atika. In *Proceedings of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995). (ed. F. A. Esmael)* Cairo: Ministry of Culture, SCA, pp. 365–78.

Lilyquist, C. and Brill, R.H. 1993. *Studies in Ancient Glass*. New York: MMA.

Lucas, A. 1962. *Ancient Egyptian Materials and Industries*. 4th edn., rev. J.R. Harris. London: Edward Arnold.

Maddin, R., Stech, T., Muhly, J.D. and Brovarski, E. 1984. Old Kingdom models from the tomb of Impy: metallurgical studies. *JEA* ,70: 33–41.

Markowitz, Y., Lacovara,P. and Hachfield, P. 1997. Jewellery fragments from the tomb of Nefertari in the Museum of Fine Arts, Boston. In *Chief of Seers, Egyptian Studies in Memory of Cyril Aldred*. (eds. E. Goring, C.N. Reeves and J. Ruffle). London: KPI, pp. 220–8.

Martin, G.T. 1991. *The Hidden Tombs of Memphis*. London: Thames and Hudson.

Maryon, H.G. 1971. *Metalwork and Enamelling*. 5th edn. New York: Dover.

Maxwell-Hyslop, K.R. 1995. A note on the Anatolian connections of the Tôd Treasure. *Anatolian Studies*, 45: 243–50.

Meeks, N.D. and Tite, M.S. 1980. The analysis of platinum-group element inclusions in gold antiquities. *JAS*,7: 267–75.

Mellado, E.P. 1995. Egyptian mining in Sinai during the Middle Kingdom. In *Abstracts of Papers presented at the Seventh International Congress of Egyptologists, Cambridge 3–9 September 1995*. London: EES, pp. 142–3.

Menu, M. 1994. Analyse du trésor de Töd. *BSFE*, 130: 29–45.

Merkel, J.F. 1995. Egyptian New Kingdom copper smelting – smelting experiments. In *Abstracts of the International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)*. Cairo: Ministry of Culture, Supreme Council of Antiquities, p. 22.

Mishara, J. and Meyers, P. 1974. Ancient Egyptian silver: a review. In *Recent Advances in Science and Technology of Materials: Proceedings of the Cairo Solid State Conference* III (ed. A. Bishay). New York: Plenum Press, pp. 29–45.

Montet, P. 1951. *La nécropole royale de Tanis II: les constructions et le tombeau de Psousennès à Tanis*. Paris: CNRS.

Moorey, P.R.S. 1994. *Ancient Mesopotamian Materials and Industries*. Oxford: OUP.

Moran, W.L. 1992. *The Amarna Letters*. Baltimore MD: Johns Hopkins University Press.

Morgan, M.H. 1914. *Vitruvius: The Ten Books on Architecture*. Cambridge MA: Harvard University Press.

Muhly, J.D. 1978. New evidence for sources of and trade in Bronze Age tin. In *The Search for Ancient Tin*. (eds. J.S. Olin, A.D. Franklin and T.A. Wertime) Washington DC: Smithsonian Institution Press, pp. 43–8.

Muhly, J.D., Wheeler, T.S and Maddin, R. 1977. An iron adze of the fifth–fourth centuries BC from al Mina. *Levant*, 9: 156–61.

Nassim, GL. 1949. The discovery of nickel in Egypt. *Economic Geology*, 44: 143–50.

Nibbi, A. 1987. *Ancient Egyptian Pot Bellows and the Oxhide Ingot Shape*. Oxford: D.E. Publications.

Nofal, A.A. and Waly, M.A. 1998. Foundry technology of ancient Egypt. In *Proceedings of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)* (ed. F. A. Esmael). Cairo: SCA, pp. 175–82.

Oddy, W.A., Padley, T.G. and Meeks, N. 1978. Some unusual techniques in gilding in antiquity. *Eighteenth International Symposium on Archaeometry and Archaeological Prospecting*, Bonn.

Oddy, W.A., Pearce, P. and Green, L. 1988. An unusual gilding technique on some Egyptian bronzes. In *Conservation of Ancient Egyptian Materials*, (Preprints of the conference organised by the United Kingdom Institute for Conservation, Archaeology Section, held at Bristol, 15–16 December 1988. (eds. S.C. Watkins and C.E. Browne). London: UKIC, pp. 35–9.

Ogden, J.M. 1976. The so-called 'platinum' inclusions in Egyptian goldwork. *JEA* , 62: 138–44.

1977. Platinum group metal inclusions in ancient gold artefacts. *Journal of. Historical Metallurgy*, 11/2: 53–72.

1983a, *Jewellery of the Ancient World*. London: Trefoil.

1983b. Surface changes in buried gold items. *Preprints of the Second International Symposium 'Historische Technologie der Edelmetalle'*. 25–28 April, Meersburg, pp. 24–6.

1989. Meroitic enamel work in Résumes of papers presented at the Seventh British Museum Enamel Colloquium, (1985), *Jewellery Studies*, 3: 83–4.

1990/1. Gold in a time of bronze and iron. *The Journal of the Ancient Chronology Forum*, 4: 6–14.

1992a. Gold in antiquity. *Interdisciplinary Science Review*, 17/3: 261–70.

1992b. *Interpreting the Past: Ancient Jewellery*. London: BMP.

1993. Aesthetic and technical considerations regarding the colour and texture of ancient goldwork. In *Metal Plating and Patination: Cultural, Technical and Historical Developments*, (eds. S. La Niece and P.T. Craddock). London: Butterworth-Heinemann, pp. 39–49.

1994. Black bronze and woven gold. *Gem and Jewellery News*, 3/2: 24–5.

Oldfather, C.H. 1935. *Diodorus Siculus: The Library of History*. Loeb Classical Library. Cambridge MA and London: Harvard University Press and Heinemann.

Ortiz, G. 1994. *In Pursuit of the Absolute: Art of the Ancient World*. London: Royal Academy.

Osman, A. 1995. Ancient gold mining in Egypt and its geologic aspects. In *Abstracts of the International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)*. Cairo: Ministry of Culture, Supreme Council of Antiquities, p. 8.

Petrie, W.M.F. 1886. *Naucratis I: 1884–5*. London: EEF.

1888. *Tanis* II. London: EEF.

1891. *Illahun, Kahun and Gurob 1889–90*. London: Nutt.

1897. *Six Temples at Thebes*. London: Quaritch.

1904. *Abydos* III. London: EEF.

1906. *Researches in Sinai*. London: John Murray.

1909. *The Arts and Crafts of Egypt*. Edinburgh: Foulis.

Porada, E. 1982. Remarks on the Tod treasure in Egypt. In *Societies and Languages of the Ancient Near East: Studies Presented in Honour of I.M. Diakonoff* (eds. M.A. Dandamayev, Postgate, J.N. and Diakonov, I.M.). Warminster: Aris and Phillips. pp. 285–303.

Pusch, E.B. 1990. Metallverarbeitende werkstätten der frühen Ramessidenzeit in Qantir-Piramesse/Nord. *Ägypten und Levante*, 1: 75–113.

Raven, M.J. 1992. A catalogue project of bronzes in Leiden. *Atti VI Congresso Internazionale di Egittologia, Vol 1*. Turin: International Association of Egyptologists, pp. 529–34.

Ray, J.D. 1972. Two inscribed objects in the Fitzwilliam Museum, Cambridge. *JEA*, 58: 247–53.

Riederer, J. 1978a. Die datierung Aegyptischer bronzehohlguesse mit hilfe der thermolumineszenz-analyse. *SAK*, 6: 163–8.

1978b. Die naturwissenschaftliche Untersuchung der Bronzen des Ägyptischen Museums Preussischer Kulturbesitz in Berlin. *Berliner Beiträge zur Archäometrie*, 3: 5–42.

1981. Metal analysis of Egyptian bronzes. *Revue d'Archaeometrie*, 3: 239–43.

1982. Die naturwissenschaftliche Untersuchung der Staatlichen Sammlung Ägyptischer Kunst in München. *Berliner Beiträge zur Archäometrie*, 7: 5–34.

1983. Metallanalysen ägyptischen Statuetten des Kestner-Museums. *Berliner Beiträge zur Archäometrie*, 8: 5–17.

1984. Die naturwissenschaftliche Untersuchung der Ägyptischen Bronzen des Pelizaeus-Museums in Hildesheim. *Berliner Beiträge zur Archäometrie*, 9: 5–16.

1988. Metallanalysen ägyptischen Bronzestatuetten aus Deutschen Museen. *Berliner Beiträge zur Archäometrie*, 10: 5–20.

Roeder, G. 1956. *Ägyptische Bronzefiguren*. 2 vols. Berlin: Staatliche Museen zu Berlin.

de la Roque, F.B, Contenau, G and Chapouthier, F. 1953. *Le trésôr de Tôd*. Cairo: IFAO.

Rothenberg, B. 1972. *Timna*. London: Thames and Hudson.

Russmann, E.R. 1981. An Egyptian royal statuette of the eighth century BC. In *Studies in Ancient Egypt, the Aegean, and the Sudan: Essays in Honour of Dows Dunham*. (eds. W.K. Simpson and W.M. Davis) Boston MA: MFA, pp. 149–56.

Sabet, A.H., Tsogoev, V.B. Bordonosov, V.B., Baburin, L.M., Zalata, A.A. and Fransis, M.H. 1976a. On gold mineralisation in the Eastern Desert of Egypt. *Annals of the Geological Survey of Egypt*, 6: 201–12.

Sabet, A.H., Bessonenko, V.V. and Mesiha. A.W. 1976b. On cinnabar findings in the Eastern Desert of Egypt. *Annals of the Geological Survey of Egypt*, 6: 213–21.

Sabet, A.H., Tsogoev, V.B., Shibanin, S.P., el-Kadi, M.B. and Awad, S. 1976c. The placer tin-deposits of Igla, Aby Dabbab and Nuweib. *Annals of the Geological Survey of Egypt*, 6: 169–80.

Scheel, B. 1989. *Egyptian Metalworking and Tools*. Aylesbury: Shire Egyptology.

Schorsch, D. 1988. Technical examinations of ancient Egyptian theriomorphic hollow cast bronzes. In *Conservation of Ancient Egyptian Materials*, (Preprints of the conference organised by the United Kingdom Institute for Conservation, Archaeology Section, held at Bristol, 15–16 December 1988 (eds. S.C. Watkins and C.E. Browne). London: UKIC, pp. 41–50.

1992. Copper ewers of Early Dynastic and Old Kingdom Egypt – an investigation of the art of smithing in antiquity, *MDAIK*, 48: 45–159.

Schoske, S. and Wildung, D. 1992. *Gott und Götter im alten Ägypten*. Mainz: von Zabern [analyses by J. Riederer].

Shaw, C.T. 1995. New Kingdom mining technology with reference to Wadi Arabah. In *Proceedings of the First International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)* (ed. F. A. Esmael). Cairo: SCA, pp. 1–14.

Shearman, F. 1988. An original decorated surface on an Egyptian bronze statuette. In *Conservation of Ancient Egyptian Materials* (Preprints of the conference organised by the United Kingdom Institute for Conservation, Archaeology Section, held at Bristol, 15–16 December 1988) (eds. S.C. Watkins and C.E. Browne). London: UKIC, pp. 29–34.

Smith. C.S. 1970. An examination of the arsenic-rich coating on a bronze horse from Horoztepe. In *Application of Science in the Examination of Works of Art*, (ed. W.J. Young). Boston: MFA, pp. 96–102.

Stos-Gale, Z. and Gale, N.H. 1981. Sources of galena, lead and silver in Predynastic Egypt. *Revue d'Archéometrie*, 3 (supplement): 285–96.

Stos-Gale, Z. 1995. The origin of copper metal excavated in el-Amarna. In *Abstracts of the International Conference on Ancient Egyptian Mining and Metallurgy and Conservation of Metallic Artifacts. (10–12 April 1995)*. Cairo: Ministry of Culture, Supreme Council of Antiquities, p. 61.

Teeter, E. 1981. Enamelling in ancient Egypt? *AJA*, 85: 319.

Tylecote, R. 1981. From pot bellow to tuyères. *Levant*, 13: 107–18.

Vandier, J. 1968. La vie des musées – nouvelles acquisitions, Musée des Louvre, départment des antiquités égyptiennes. *Revue du Louvre*, 2: 105–8.

Vassilika, E. 1997. Egyptian bronze sculpture before the Late Period. *Chief of Seers, Egyptian Studies in Memory of Cyril Aldred* (eds. E. Goring, C.N. Reeves and J. Ruffle). London: KPI, pp. 291–302.

Vercoutter, J. 1959. The gold of Kush. *Kush*,7: 120–53.

Vitruvius see Morgan 1914.

Wainright, G.A. 1934. The occurence of copper and tin near Byblos. *JEA*, 20: 29–32.

1943–44. Egyptian bronze making. *Antiquity*, 17: 96–8 and 18: 100–2.

1944. Rekhmirê's metal-workers. *Man*, 44: 94–8.

Weill, A.R. 1951. Un problème de métallurgie archéologique: examen aux rayons X d'un objet égyptien an électrum. *Revue de Metallurgie* , 48: 97–104.

Weinstein, J. 1974. A fifth dynasty reference to annealing. *JARCE*, 11: 23–5.

Weser, U. 1987. Biochemical basis of the use of copper in ancient Egyptian and Roman medicine. In *Recent Advances in the Conservation and Analysis of Artifacts* (ed. J. Black). London: Summer Schools Press, pp. 189–94.

Williams, A.R. and Maxwell-Hyslop, K.R. 1976. Ancient steel from Egypt. *JAS*, 3/4: 283–305.

Williams, C.R. 1919. A bronze figure of Horus in its original mold. *New York Historical Society Quarterly Bulletin*, April 1919: 3–7.

1924. *Catalogue of Egyptian Antiquities, Numbers 1–60. Gold and Silver Jewelry and Related Objects.* New York: New York Historical Society.

Williams, D. and Ogden, J.M. 1994. *Greek Gold: Jewellery of the Classical World.* London: BMP.

Winlock, H.E. 1936. An Egyptian flower bowl. *Metropolitan Museum Studies*, 5/2: 147–56.

Yener, K.A., Özbal, H., Kaptan, E., Necip, N.A. and Goodway, M. 1989. Kestel: an early Bronze Age source of tin ore in the Taurus Mountains, Turkey. *Science* 244, 4901: 200–3.

Young, E. 1959. Note on a hitherto unknown technique in Egyptian bronze working. *JEA*, 45: 104–6.

Yoyotte, J. (ed.), 1987. *Tanis, l'or des pharaons.* Paris: Association Française d'Action Artistique.

Ziegler, C. 1988. Jeune pharaon présentant l'image de la déese Maât. *Revue du Louvre*, 3: 181–5.

7. Egyptian faience

PAUL T. NICHOLSON WITH EDGAR PELTENBURG

Introduction

Much has changed since Lucas wrote the 'Glazed Ware' chapter in *Ancient Egyptian Materials and Technology*. Within a few years of 1962, when the fourth and last edition of Lucas' book appeared, important new studies demonstrated that the glazing of faience could take place using techniques other than 'application glazing' (where the glaze is applied as to pottery). This made the whole field of faience studies both more complicated and more exciting. Newly discovered were the 'self-glazing' techniques of 'efflorescence' and 'cementation', involving the production of the glaze from the body itself or by a reaction between the body and a glazing powder surrounding it (see pp. 189–90). To some extent, recognition of these diverse techniques cut across Lucas' faience variants, i.e. the system which he developed in order to classify all Egyptian faience. His system was therefore not widely adopted, although his 'Variant A' (faience with an extra layer) is still a useful type (see below), since it is specific to much Egyptian faience and is not found in contemporary Asiatic faience. Variant A was a deliberate innovation made to enhance glaze colours and refine modelling, and is readily detected in broken pieces.

On the other hand, there has been little advance with regard to another issue that exercised Lucas: the origins of glazing. Thus, it is still believed that steatite was the first material to be glazed and, despite Harris's advocacy of the introduction of glazing from Mesopotamia (Lucas 1962: 464–5), no compelling new evidence has been forthcoming to support such a diffusionist explanation.

Since the middle of the 1960s, only one major technical study of faience has been published: that by Kaczmarczyk and Hedges (1983), which includes a valuable appendix by Vandiver. The volume concentrated mostly on the chemical analysis of faience, and as a result has not been widely used by the Egyptological community. However, Kaczmarczyk and Hedges made some attempt to emphasise the relationship between faience and glass, an important theme which has also been explored by Peltenburg (1987) and more recently by Lilyquist and Brill (1993). Most recently the essays for the exhibition 'Gifts of the Nile' (Friedman 1998) have examined faience in social, artistic and technological terms.

Sadly, a number of things have not changed since Lucas' time, and most notable among these is the 'correct' use of terminology. As Lucas himself noted, 'faience' may not be the most suitable term for the material, but it is now so ingrained in Egyptological literature that it is unlikely to be superseded. A short review of the relevant terminology still remains a valid exercise.

Terminology

Faience is a glazed non-clay ceramic material. It is more correctly defined as 'Egyptian faience', in order to differentiate it from a type of pottery, now known as majolica, which is a tin-glazed ware made in Faenze in northern Italy (and elsewhere) from late medieval times onwards. Since such pottery is unlikely to occur in the same archaeological contexts as Egyptian faience, and since the Italian pottery has now been renamed majolica, it is usual to drop the 'Egyptian' element of the term when referring to the glazed non-clay ceramic. The material occurs widely in the ancient world, and is well-known from Mesopotamia (Moorey 1994), the Mediterranean and northern Europe as far away as Scotland (Stone and Thomas 1956). Most of this material is locally made (Newton 1980; Newton and Renfrew 1976), therefore the use of the term 'Egyptian faience' would, in these contexts, be potentially confusing.

As Lucas has discussed, much time has been spent in arguing the unsuitability of the term 'faience' for this non-clay product, but I do not intend to review such criticisms here, except to emphasise that one of them, frit, has been particularly persistent, and while it may emphasise a link with glass production (see Chapter 8, this volume) it has also led to a great deal of confusion between these materials and their technology.

Recent work (Tite 1986; Tite and Bimson 1987) has divided frits into two groups, firstly 'blue frits', whose dominant crystalline phase is a calcium-copper tetrasilicate known as 'Egyptian blue' ($CaO.CuO.4SiO_2$) in a very limited

Figure 7.1 A scene from the tomb of Ibi, chief steward of the divine adoratrice in the time of Psamtek I at Thebes (TT36; c. 664–610 BC); this may show a workman (right) mixing faience ingredients while another workman (left) finishes a more complete piece.

matrix of glass, and secondly 'turquoise blue frits', in which the dominant phase other than quartz is a calcium silicate known as wollastonite ($CaSiO_3$) which is crystallised from the copper-rich glass matrix. The frits can each be subdivided into coarse- and fine-textured, the coarse normally representing the first stage of production, which would then be ground more finely and moulded into artefacts or used as a pigment (Weatherhead and Buckley 1989).

Egyptian blue appears to be an Egyptian invention and, although of much greater antiquity, is closely allied to glass. Its texture may be so fine that it is virtually indistinguishable from glass, especially if the latter is weathered. It is known by the Old Kingdom and undergoes gradual refinement, becoming increasingly glass-like, into the early Roman period. It was known to the Greeks as *kyanos* (Cooney 1976: 37), while Vitruvius (Book VII, Chapter XI; see Morgan 1914: 218–19) refers to it as *caeruleum*, which was believed in his time to have been invented at Alexandria. Despite the possible confusion with glass, the Egyptian blue frits are easily distinguished from faience in a broken section, since they lack a core and are homogeneous throughout, with no separate glaze layer.

Faience, frits and glass are part of a continuum of materials which are based on silica plus varying amounts of alkali, lime and copper. They should, however be thought of as distinct materials in terms of their composition, since it would not be possible to turn faience into frit or frit into glass simply by further, or higher temperature, heating. The addition of further alkali would be necessary (see Tite unpublished).

Artistic and documentary evidence

It is not the purpose of this chapter to discuss textual and documentary evidence for faience at any length, not least since the identification of materials and technological processes with specific Egyptian words is a notoriously difficult area. Attention should instead be drawn to the dearth of information on faience.

Whereas there are many scenes in Egyptian art showing potters at work, which can be used in association with archaeological and scientific analysis, there is only one scene which might possibly show faience makers (Nolte 1977: 138–42), this is contrary to Drenkhahn's view (1995: 336) that the stages of all crafts are known from artistic evidence. The possible faience-making scene is in the Twenty-sixth-Dynasty Theban tomb of Ibi (Aba) chief steward of the divine adoratrice in the time of the Psamtek I (TT36; Davies 1902; Nicholson 1993: 17). One man is shown apparently grinding or rolling something while another is probably making an element of jewellery (Fig. 7.1). Unfortunately there is no accompanying text to identify it, so that the nature of the scene cannot be identified with certainty.

The Egyptians referred to faience as *ṯḥnt* (Nolte 1977: 138; Blanchi 1998: 24) and more rarely as *ḥsbḏ*, the same word that they used for lapis lazuli. Both words are related to those for the properties of 'shining', 'gleaming' or 'dazzling', emphasising the role of faience as an artificial gemstone. This does not necessarily mean that faience was regarded as inferior to lapis, or turquoise, although the phrase 'genuine lapis' is sometimes used (Aufrère 1991: 465).

The excavation of tomb shaft 879 at Lisht revealed the burial of Debeni (for other finds see McGovern *et al.* 1994), overseer of faience workers and there are also other funerary texts relating to such individuals. The Nineteenth-Dynasty funerary papyrus of Qn-hr (or 'Qennou'; Papyrus Vatican 64; Bellion 1987: 320, 397; Marucchi 1891) gives his title as *imy-r irw ḥsbḏ*: the director or overseer of faience makers. The title used here includes the word *ḥsbḏ*, which strictly means lapis lazuli, but which by the New Kingdom had also come to refer to faience (Aufrère 1991: 465 and footnote). The word can also be used to refer to glass, and surely illustrates the way in which the Egyptians thought of these materials, for their properties of brilliance, like those of gemstones, rather than for their actual composition.

Two Nineteenth-Dynasty faience stelae are in the collection of the Royal Museum of Scotland. One of these (Edinburgh 449, Acc. no. 1956.153 Friedman 1998: 250 cat. no.

166) belonged to Rekhamun, who held the title 'faience maker of Amun', again with the *ḫsbḏ* element (see Gaballa 1979: 45, 51, and note that his statement that the Edinburgh Stele is glass is incorrect, see Nolte 1968: 7–8). This is not a common title, although it is less rare than sometimes believed.

Chronological developments

Some indication of the development of faience technology is given below in discussing its composition and technology. This section attempts to summarise the main developments in faience technology over time, and to indicate the relevant factory evidence insofar as presently known.

The Predynastic period

The Predynastic period was one of experimentation. The glazing of stones was developed using application, and the glazing of crushed quartz as an artificial medium presumably developed from this. It has been argued by Peltenburg (1987: 20) that faience-working was essentially a cold technology, to be differentiated from glass in which the material was worked hot. Although it will be argued here that the link between glass and faience from the New Kingdom suggests that they were part of a generalised vitreous materials industry, it must be admitted that the earliest faience shares much in common with the cold working technology of stone. Stocks (1997) shows in his stone-working experiments that it is possible to produce faience paste and glaze consistent with ancient characteristics from the powdery by-products of drilling stone beads with copper tubes (see also Chapter 2, this volume, for discussion of some of Stocks' experimental work).

The making of a core, and its reduction to shape by abrasion, has features in common with the making of stone artefacts. However, this should not be regarded as surprising, since during the Predynastic neither metal nor glass technology had been developed. It must be assumed that there were advantages to be gained from being able to shape a fairly complex piece from plastic materials and then work it to final shape, rather than carving the whole from stone. Similarly, the glaze on natural stone, particularly steatite, is often less bright than that on faience, and the granular surface of the crushed quartz must have lent an added brilliance to the pieces.

Glazing techniques for this period are not well-researched. However, application glazing is particularly likely, and it is possible that efflorescence and even cementation were practiced (Vandiver 1982: 172), although there is no firm evidence for the latter before the Middle Kingdom. The objects made were mostly small and mainly comprised beads and amulets.

As might be expected at such an early stage of development, the composition of the material is by no means standardised, and examination of faience from graves in the cemeteries of Naqada and Tarkhan has shown that the composition of pieces varied even within the same grave (Kaczmarczyk and Hedges 1983: 63–8 and 230–44). Early experiments led to the combination of faience with precious metals, as demonstrated by a bead from el-Amra consisting of gold foil over a faience paste. Productive interaction between faience workers and other craftsmen, assuming they were already specialised, is an abiding feature of Egyptian faience traditions.

Old Kingdom and First Intermediate Period

With the Early Dynastic Period, the size of faience pieces increased somewhat, although beads and amulets were still the most common products. Vessels and small figurines, some of the latter showing considerable detail, were also produced.

For many years scholars regarded the Old Kingdom as a time when faience production was somewhat stilted, the exception being the mass production of the thousands of wall-tiles used in the Third-Dynasty Step Pyramid complex of Djoser at Saqqara. Lauer (1938, 1976) regarded the tiles as moulded; their width varies considerably, but this is not so surprising given that approximately 36,000 tiles were produced (Vandiver 1982: 174) and many moulds would therefore have been required. However, Vandiver has suggested a technique which is perhaps better described as 'controlled forming', namely rolling the paste between two parallel sticks in order to control the thickness and length but leaving the width to vary. The back of the tile is extensively ground to leave a pierced boss through which wires would have been threaded as an aid in mounting them in large panels. The rear of the tile often has very little glaze and suggests that they were glazed by efflorescence.

However, these tiles are no longer seen as the peak of Old Kingdom production, since the discovery of the finely made inlays unearthed by the Czech archaeological mission at Abusir. The inlays and tiles come from the pyramid temple of the Fifth-Dynasty ruler Neferefra (Verner 1984, 1986; Nicholson 1993: 212) and are of especially fine workmanship. Some of the faience bore decoration in gold leaf, which was itself incised. Some tiles exhibit the technique which was to become common in later times, namely the use of a coarse paste for the body of the piece, with a finer white layer underlying the glaze (as in the Lucas Variant A). This technique had already been developed on figurines from Hierakonpolis in the Early Dynastic period. A full technological examination of the Neferefra pieces has not yet been published, but it is likely that they too were glazed by efflorescence, and this method sems to have been used to glaze all the faience dating to the Early Dynastic through to the end of the First Intermediate Period (or at least all that has been examined by Vandiver's (1983) study and for which the technique could be ascertained).

The inlaying of one faience paste into another, which is seen in some of the Neferefra pieces, may have an antecedent in the inlays in the tomb of Nefermaat at Meidum. Here coloured paste was inlaid into stone. Much has been made of this technique as an ancestor of faience-working, but it is probably more important for introducing the concept of inlaying paste than for any development in the material technology. The paste in these inlays was neither fired nor effloresced, and its importance should not be overstated. It was not glazing that was the focus of experiment at this time, but rather the techniques of shaping. These techniques built on the methods of the Predynastic period, making extensive use of modelling and surface grinding, but also introducing the process of forming on a core, and probably also moulding.

Evidence from Abydos suggests that the production of faience went on relatively unhindered during the troubled times of the First Intermediate Period. This should probably not surprise us, since industries do not necessarily stop during times of political upheaval, and we know so little about industrial organisation in ancient Egypt that it is not possible to say what level of industry this represents, or who controlled it.

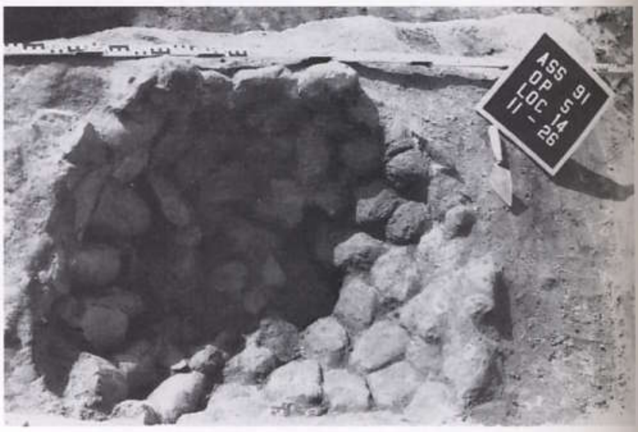


Figure 7.3 One of the Locus 14 kiln pits at Abydos, after excavation (looking south – see Fig. 7.2). The bowl-shaped construction is clearly visible, lined with bricks and fragments of pottery; the maximum dimension is 1.2 metres.

Factory evidence: Abydos

The earliest evidence for a faience workshop has recently come to light at Abydos. Excavations by the joint University of Pennsylvania Museum/Yale University/Institute of Fine Arts, New York University expedition, under the direction of Dr Matthew Adams, have recently unearthed part of a settlement on the edge of the area of modern settlement, not far from the Early Dynastic temple of the god Khentiamentiu. The site dates from at least as early as the middle of the Old Kingdom to the early Middle Kingdom, and the faience-working area is not associated with any house or workshop structure.

What appears to be a factory site comprises several very clear circular features (see Figs. 7.2 and 7.3), in the form of bowl-shaped pits, which are thought to be the remains of kilns. Some of these have a lining made from broken bricks, and all are fire-reddened; there is no sign of any superstructure. Lenses of ash suggest that some of these features were used several times. If there genuinely was no superstructure, then these are perhaps to be regarded as the shallow pits beneath what are, in effect, bonfires. This 'open firing' technique is well known from ethnographic studies of pottery manufacture, but would need certain refinements for the firing of faience. For example, the faience amulets and beads found at Abydos would need to

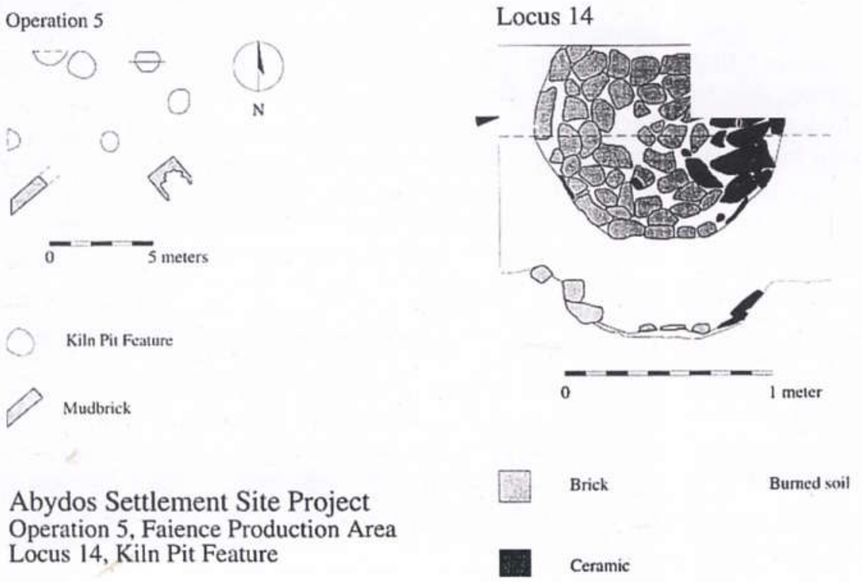


Figure 7.2 One of the kiln pits discovered in Locus 14 at Abydos by the excavations of the joint expedition of the University of Pennsylvania Museum, Yale University and the Institute of Fine Arts, New York University (see Fig. 7.3).

be placed inside something to protect them from the ash and fuel piled around them. Some kind of lidded vessel would be the most obvious container, and as far as I am aware no such vessel has been found to date, although it may simply have comprised a domestic jar with lid rather than a special type of vessel, and there are numerous fragments of such jars from the site.

One badly damaged mud-brick structure was also unearthed, which may be a kiln. However, this is not yet certain, and it is also possible that it is unconnected with faience manufacture. Until the latter can be more certainly assigned it seems best to assume that firings were of the 'open' type.

Numerous small clay balls (*c.* 0.75 cm in diameter), yet to be analysed, were also discovered. These may be the precursors of those known from Lisht, and perhaps even Amarna. Their function is not clear, although evidence from Lisht and Amarna suggests that they were used as a surface on which beads were fired. A clay disc from Abydos, with finger impressions, each approximately the size of the clay balls, may in some way be connected with these discs.

Nevertheless, it is clear from the 'kilns', as well as from the beads and amulets found showing evidence of manufacturing mistakes, that faience was produced at Abydos, and the results of future excavations may throw much light on manufacturing processes at this time. The question of how the industry was organised, and for whom it was producing must remain open. However, the presence of such an establishment on a site which was already of great religious significance might suggest that it was in some way related to cult activities and may have been connected with a temple.

Middle Kingdom and Second Intermediate Period

This period marks the greatest phase of diversity and experimentation since the Predynastic. The stable conditions following the First Intermediate Period seem to have acted as a stimulus to the accelerated development of the craft. From the site of Lisht comes the first known burial of an overseer of faience workers, which has been dated to the Thirteenth Dynasty (see below).

In addition to modelling, regular use began to be made of the techniques of forming on a core and of shaping over a form or *patrix* (a type of moulding). Shapes approximating to a sphere were sometimes modelled around a ball of straw, a notable example being the popular hedgehog figurines which seem to have had some magico–religious significance. Faience hippopotamus figures were also popular at this time, frequently decorated with scenes of aquatic plants applied in a manganese-based paint.

Vessels of the Middle Kingdom tend to have thick walls, although they were not necessarily clumsily executed, and indeed some, such as the bowls with Nilotic scenes, can be of very fine quality. The use of a fine quartz layer over a coarser body also became widespread, leading to some extemely fine, bright glaze effects. Jars were also made in faience; like bowls, they draw on forms well-represented in pottery. It is characteristic of faience, and later of glass, that the forms used are those first developed in pottery or stone.

Decorative techniques also developed, notably the mixing of two differently coloured body pastes to give a marbled effect, which had been a rare curiosity in the preceding period but now became somewhat more common. The incising and inlaying of faience also became more frequently employed techniques. Carefully executed linear designs in dark paint on a blue background also occurred more often, a critical development in light of its subsequent popularity for scenic compositions on faience vessels of the New Kingdom.

Glazes were frequently applied to objects made up of a fine white layer spread over a coarser body, and the resulting effect can be of the finest quality. The glazes themselves were produced by efflorescence, and by cementation, and it was is in this period that the latter technique is first securely attested. The earliest firm evidence for this process dates to the reign of the Twelfth-Dynasty ruler Senusret I. At Kerma in the Sudan there is evidence for the application of glazes as a slurry (Reisner 1923: 134–75).

Although faience was more widely used and underwent rapid development during this period, it should not be supposed that the use of glazed stone died out. Scarabs became important during the Middle Kingdom, but most were made of stone, perhaps because hieroglyphic inscriptions were clearer in stone than in faience. The development of somewhat harder faience bodies may have partly been an attempt to improve the durability of faience and to make it appear more like stone.

Factory evidence: Lisht

The excavations of the Metropolitan Museum of Art at the Middle Kingdom site of Lisht began in 1907 and continued until 1934, with work in the area around the North Pyramid of Amenemhat I concentrating in the period before 1922. In the 1920–21 season a so-called 'glaze factory' was unearthed in buildings AI.2 and and AI.3. From this area came numerous pieces of faience, mostly beads, and many hundreds of small marl clay balls along with the clay semicircles and possible kiln supports similar to those mentioned above.

Most convincing was the discovery of what may be a kiln. There are photographs of this structure, but it was not particularly well-recorded and there has been some question as to whether or not it could in fact be a grain silo from a later period, cutting into the Middle Kingdom layers. However, recent research by Drs Dieter and Felix Arnold suggests that it may indeed be a kiln. It is a semicircular structure with an external diameter of about 1.5 metres, built into the corner of a room, and apparently filled with an ashy deposit.

The factory was situated immediately south of the probable line of the south wall of the pyramid enclosure. Tomb shaft 879 was located immediately north of the main part of building AI.3, and just a little to the north of the kiln. This shaft is not only the provenance of the famous Lisht Dolphin Jug (Bourriau 1996: 110–11; McGovern *et al.* 1994) but also the findspot of the coffin of Debeni who held the title 'overseer of faience workers' (see p. 178). Along with a mention of such a worker on the faience stele in Edinburgh mentioned earlier, this is a rare reference to such a craftsman. It has been suggested that the tomb is related to the workshop, but chronological considerations are not sufficiently fine to make this a certainty, and the tomb and its contents are currently being studied by J.D. Bourriau and J. Allen. The presence of such an official may be significant in attempting to identify the status of the industry, and might imply that at Lisht production for the royal household was underway, although not necessarily at the site so far identified.

It is clear, then, that faience production was taking place at Lisht in the Middle Kingdom, although the precise technology is not yet known. Examination of the faience by the writer suggests that application glazing was taking place, along with efflorescence. These pieces comprise mostly beads, which possibly derive from flails and amulets. Cementation has not been identified with any certainty.

Factory evidence: Kerma

The site of Kerma in the Sudan is widely regarded as a centre of faience production, although it lacks any *in situ* factory evidence. A series of glazed quartz pebbles are thought to have served as supports for the firing of faience tiles which were apparently produced at the site. Kilns were not certainly identified, the most likely being 'too damaged to be drawn' (Reisner 1923: 135).

The probable 'kiln' structure appears to have been made from a truncated pottery vessel, or perhaps a clay cone fired *in situ*, a practice known from the so-called bread ovens at Amarna and elsewhere. Reisner suggests that the structure was heated from the outside, implying that the clay vessel served as a kind of saggar or separator, preventing the glazes from becoming damaged by ash.

There is evidence for the application of glazes as a slurry (Reisner 1923: 134–75) and Reisner believed that efflorescence glazing was also practiced. The writer has not personally examined any of the faience from the site, but in Reisner's opinion certain of the vessels had been thrown on the wheel, while others were core formed. If correct, Kerma would be the earliest recorded site at which the throwing of faience vessels is attested as a more than occasional practice. Inlaying of one faience paste into another is well-attested here. This faience is the subject of renewed investigations and there is evidence of compositional overlaps between local and imported material (Lacovara 1998).

New Kingdom

This period was the zenith of Egyptian faience-working, with widespread, varied production, masterpiece works, vivid use of polychromy and the dissemination of pieces abroad. It builds on the developments of the previous period, and the better preservation of factory evidence greatly enhances our knowledge.

The open-face mould is developed, and attested by many thousands of finds (see p. 183–4) allowing the production of large numbers of rings, amulets and beads. The making of rings was enhanced by the development of a more robust body which made use of glass in the matrix to fuse it more firmly. This 'glass' probably results from the efflorescence process rather than being a deliberate addition as was once thought (Kuhne 1969: 11–26). At the same time, glass was also used to extend the range of colours that could be produced in faience. Similarly, some of the colorants of glass also became widely used, notably cobalt, antimony and lead (Kaczmarkzyk and Hedges 1983) which occur from the reign of Thutmose III, the pharaoh generally credited with establishing glass production in Egypt. Thus, the establishment of glass-making, with its polychrome characteristics, greatly affected faience production. The harder faience body may have led to the greater use of the material for the production of scarabs, the most magnificent of which were the commemorative scarabs of Amenhotep III.

Faience paste was also used to lute faience elements, such as ring shanks and bezels, together and it is not uncommon to find that the elements of a ring are in different colours, or that the suspension loop of an amulet is of a different colour to the amulet itself. The making of these tiny suspension loops is not fully understood, their extremely small size, commonly less than 2 mm in diameter, often means that there is no trace of the body and all that remains is the glaze. In this respect they are glass objects, albeit with the compostion of faience glaze rather than true glass.

The luting together of faience elements was not confined to small items. The famous *was*-sceptre from Naqada (V&A 437–1895) was made in this way, by joining small sections together. Similarly, the faience lotus chalices, characteristic of the New Kingdom, had a join at the junction of the bowl and stem-foot (Vandiver and Kingery 1987b).

Forming over a *patrix* and around a core continued, as did incising and inlaying. The inlaying technique reached its height at this time, and can be divided into two broad groups. In one the inlay is inserted into a channel cut into relatively dry body-material, and the two shrink away from one another quite markedly, leaving a slight groove around the inlay. Vandiver (Vandiver 1983: A117) notes that at times the body has been allowed to become too dry and the inlay becomes detached. The inlay could also be added more quickly, before the background was so dry, so that shrinkage is much less. This can give the effect of a painted tile, accentuated by the bleeding of copper-based colours into the background colour which is often white. A kind of halo effect is thus produced around areas of the tile, notably foliage. Vandiver (1983: A120) was unable to determine the glazing method for this type of tile, although the shrunken inlay type seems to be produced by efflorescence, and that cannot be ruled out here. Both the polychrome tiles showing prisoners, and the inlays of fish and birds produced at this time are remarkable pieces of craftsmanship. Given our present knowledge of faience-making they would now be extremely difficult to replicate.

The use of faience in architecture should not be underestimated. This was not confined to the use of tiles and hieroglyphic inlays. There were also complicated floral inlays and three-dimensional pieces such as the well-known grape clusters from Amarna. These were mould-made, and could be either flat-backed for attachment to a wall or beam, or fully three-dimensional, made by joining two flat-backed pieces together. It has been suggested that these would have hung from the ceilings of buildings to resemble grapes in a vineyard.

Faience of the New Kingdom was exported around the Mediterranean (Peltenburg 1986) and is well-known from Cyprus and Crete as well as parts of the Greek mainland.

Factory evidence: Malkata

Between 1910 and 1921 the Metropolitan Museum of Art's expedition to Malkata, the palace of Amenhotep III at Thebes, unearthed evidence of faience and glass production. This comprised numerous fired clay moulds, faience objects and lumps of colouring matter. Although chronologically earlier, the Malkata finds are not as well-documented as those discovered by Petrie at Amarna. No faience kilns or furnaces were discovered at either Malkata or Amarna. Subsequent excavations at the site by the University of Pennsylvania and by Waseda University have also uncovered industrial debris, but not in such great quantities. For the moment, the importance of the site lies in the apparent occurrence of faience-making alongside glass production, and in the discovery of several moulds filled with unfired faience paste. These pieces are now in the Metropolitan Museum of Art (MMA 11.215.666–8) (Friedman 1998: 257; Nicholson 1998), and one of them has recently been examined by Wypyski (1998: 265) who believes that the contents may not be faience paste.

Factory evidence: Amarna

The Eighteenth-Dynasty city of Amarna, the Egyptian capital during most of the reign of Akhenaten, has been central to understanding New Kingdom faience, and more especially glass production, ever since Petrie's work in 1891–2. In his publication (Petrie 1894) a thoughtful discussion on faience production is given, although the division between excavated evidence and interpretation is not always clear, and certain details are lacking. For example he mentions finding 'three or four glass factories, and two large glazing works' (Petrie 1894: 25), although precise locations for these are omitted, as is their proximity to one another. It is also unclear whether there were also more minor workshops which are not covered in the account.

The area which is labelled 'moulds' on the map published by Petrie (1894: pl. XXXV) probably represents at least one of these glazing works and refers to the many thousands of fired clay moulds used for forming faience objects, notably amulets and inlays (Petrie 1894: 30). He thought that these would have been pressed against a lump of faience paste material, and the raised image so produced would have been sliced from the lump and put to dry (Petrie 1894: 28). He also believed that they would then have been coated in powdered glass and fired in order to glaze them (i.e. they would have had an applied glaze). Although he found moulds with paste in them, he assumed that this was the remains of fine quartz body material rather than the residue of the paste used in efflorescence, since this method was unknown to him.

As already noted, no kilns were located, although there has been some confusion over this aspect of the work (Vandiver 1983: A30) and, despite discussion of the technological evidence, the remains of actual workshop buildings are not recorded. It is probable that the remains were located in dumps outside the actual working area, or possibly in some part of the courtyard of the workshop. It should be borne in mind that much of the work probably took place out of doors, much as pottery production is undertaken in the simplest Egyptian workshops today (*cf.* Nicholson 1995a).

A recent geophysical survey carried out on the writer's behalf by Mr I. Mathieson succeeded in locating kilns or furnaces just to the south of the modern water tower, believed to cover part or all of Petrie's 'moulds' area. This site, O45.1, is currently under excavation and has yielded what is believed to be a workshop producing glass, faience and pigments (Nicholson 1995b, 1995c). Discriminating between the evidence for these three crafts is not easy, but because the large kilns seem to have been subjected to temperatures higher than those needed for the production of faience they are currently believed to have been used for glass, while a third, less highly vitrified, kiln was probably used for pottery and perhaps faience.

This difficulty in separating crafts, at least in the New Kingdom, may to some extent be an artificial one reflecting our present trend toward distinct, individual crafts. The Egyptians on the other hand, had not long had the use of glass, and they were not only using it as a material in its own right, but according to Kühne (1969: 14) and Vandiver (1983: A108), also adding it to faience body-material in order to strengthen it and extend the range of possible colours (see also Boyce 1989: 161; and discussion p. 182). They might therefore have regarded all these crafts as part of an ancient 'vitreous materials' industry, and while it is important to differentiate the technological processes of each manufacture we should not be surprised to find that different products made in the same workshop were produced using the same kilns/furnaces, possibly by the same group of craftsmen.

The Amarna work has yielded numerous pieces of evidence which are still difficult to interpret. Among these are calcareous plaster trays, usually with their upper surfaces impressed with textile. They may have served as drying trays for faience objects, particularly inlays, which often show textile traces on their underside. Petrie also found this type of tray, of which there are examples in the Petrie Museum (UC40569A, UC40570), although they are not mentioned in any of his publications. There are also small, flattened balls of clay to which adhere tiny faience beads, 2–3 mm in diameter. These are not the calcareous clay balls already known from Lisht, but are of Nile clay. In some cases the beads seem to have been pressed into them to some depth, in others they adhere only at their edges. The exact function of these balls is unknown. The same is true of numerous pieces of coarse yellowish plaster often with layers of crystalline blue pigment adhering to them. This pigment is not yet analysed but may be Egyptian blue.

There are numerous other enigmatic objects from the excavation which will require further study, and further excavation before their function becomes apparent. For the moment all that can be said is that, at least at Amarna, glass- and faience-making seem to be closely linked and that this link probably also extends to other pyrotechnical industries. At present however, there is no evidence of metal-working, which would be a similar technological activity, at O45.1.

Factory evidence: Qantir

In 1928 the Department of Egyptian Antiquities undertook excavations at the late New Kingdom site of Qantir in the Delta (Hamza 1930). These unearthed more than 10,000 fired clay moulds like those known from Petrie's excavations at Amarna, most of which were described as still bearing traces of the coloured faience paste they had contained (Hamza 1930: 42). Numerous faience tiles were also unearthed and cylindrical vessels and 'lumps of the favourite blue colour' (i.e. Egyptian blue pigment) were found.

When Hamza (1930: 42) states that 'the objects discovered make it certain that we are face to face with a faience and glazing factory of great size', he may well be correct, but he goes on to make it clear that these objects were not found in their primary context. He points out that 'the original workrooms had actually vanished, but the debris was full of hundreds of fragments which illustrate the finished objects and furnish us with almost every stage and detail of the mode of manufacture' (Hamza 1930: 45). The recent excavations of the Roemer-Pelizaeus Museum, Hildesheim have found similar remains in such a dump context (*cf.* Rehren and Pusch 1997). Interestingly they have been able to identify many of them with glass production, while some of Hamza's description probably refers to Egyptian blue. This would suggest that this Nineteenth- and Twentieth-Dynasty workshop probably shared close affinities with those at Amarna, and again illustrates the difficulty of separating the various processes. Once again no kilns were located, but a series of cylindrical clay tubes believed to be the nozzles of bellows were discovered. This is quite possible, although again one cannot say to which of several industrial processes they belonged. The text implies that they were found in primary contexts (Hamza 1930: 62) but unfortunately there are no plans or photographs from which to judge.

Hamza (1930: 51) rightly singles out the polychrome tiles as examples of master craftsmanship. These combine numerous colours of paste in a single tile, often depicting their subject in remarkable detail. Of particular quality are the tiles representing bound captives.

Another production centre may have existed at Gurob, but Petrie's descriptions of 'several moulds for rings and amulets and beads stuck together in the baking' are too equivocal to be certain (Petrie 1890: 37; see also Brunton and Engelbach 1927: 3).

From the Third Intermediate Period to the Roman period

By the Third Intermediate Period the technology of faience production had become widespread across the Near East and Mediterranean and it can be difficult to differentiate Egyptian imports from locally made copies.

Antimony and cobalt, introduced in New Kingdom times, almost disappear as constituents of faience in the Third Intermediate Period (Kaczmarczyk and Hedges 1983: 259). Interestingly, this is also a period when there is little evidence of glass production, and although it does not die out (as was once thought), it is certainly true to say that it carried on at a much reduced scale, and that most of the products were of lower quality. Cooney (1981) has suggested that the production of the material known as 'glassy faience' (Fig. 7.4) may account for the decline in glass production. However, this material is not well-defined, falling into a kind of negative category for materials which cannot be safely described as either faience or glass. The material was widely used, particularly for *shabtis*. The brown spots which are found on much faience of this time are believed to have been deliberately produced as decoration on a variety of blue-glazed objects (Bianchi 1996).

The nationalistic revival of the Twenty-fifth and Twenty-sixth Dynasties was evidenced in a renewed attention to traditional arts, including faience. A distinctive apple green colour was introduced, and there was a preference for high quality matt faience rather than the shiny glazes of earlier times. The quality of some of these matt pieces, such as *sistrum* handles is exceptional, with every element of the wigs and jewellery worn by the deities carefully executed.

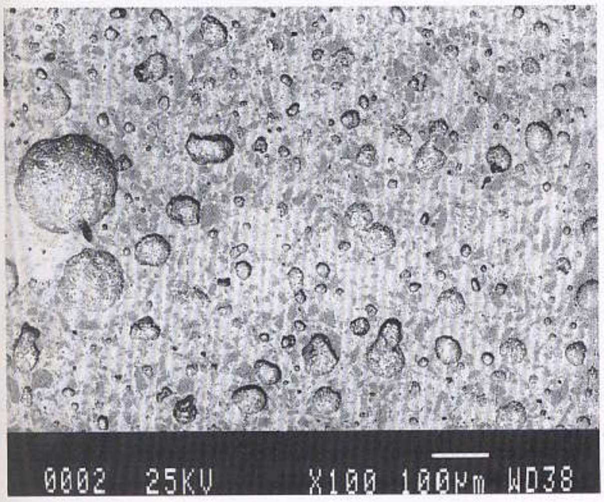


Figure 7.4 Scanning electron microscope photograph of a section through 'glassy faience', from a Twenty-fifth or Twenty-sixth-Dynasty shabti *(BM EA34095); unreacted quartz shows grey, precipitated devitrite as pale grey, and the dark rings are air bubbles.*

Where a high glaze was required, however, the Late Period faience-makers were capable of producing excellent work with an almost glass-like quality. Yellow glazes became possible again through the re-introduction of antimony as a colorant, a move perhaps not unrelated to the increase in glass in circulation at this time. The making of *shabtis* continued on a large scale, often with incised rather than painted inscriptions. They were commonly glazed by efflorescence or cementation, and could be of a very high standard.

The technology of the New Kingdom remained in place after the end of the period, but pottery-making techniques were added to the repertoire. Consequently one finds thrown vessels and the application of glaze as a slurry. Kaczmarczyk and Hedges (1983: 270) have suggested that the black glazes which became popular in the Late Period, and which were produced by the use of reducing kiln conditions, were derived from contact with the Greek mercenaries and traders who were an increasingly important part of Egyptian life, and who were familiar with the manipulation of kiln conditions in the production of their Attic pottery. Some evidence for this is to be found in the more widespread use of reduction in Lower Egypt, close to the Greek settlements, while Upper Egypt continued to produce black by using manganese. The reduction technique was already known in Egypt in Predynastic times, but had not been widely used on pottery subsequently.

Kaczmarczyk and Hedges (1983: 239) also propose a link with the metal industry, in that their analyses show low concentrations of tin in faience in those areas where the bronze also has a low tin concentration (see section on bronze in Chapter 6, this volume), while Stocks (1997) has proposed the same thing suggesting that metal abraded from copper drills used in stone-working was a source of some of the faience materials.

Relatively little attention has been paid to the examination of post-Pharaonic faience, although the publications of Nenna and Seif el-Din (1993, 1994) are exceptions in this respect. Relief decoration is a common feature of Ptolemaic and Roman faience bowls and vases, and the effect is often enhanced by two-tone glazes. A good example is a faience bowl recently acquired by the Metropolitan Museum of Art (MMA1988.18) which may have been made at Alexandria, from which the closest parallels come (Do. Arnold 1988). The two-tone effect here is very clear, the dark blue appears to be applied as an inlay over the turquoise body colour, and when examined has a slightly matt appearance.

From Ptolemaic times onwards, much Lower Egyptian faience seems to have used natron as an alkali source, although surprisingly Memphite faience from this period is high in potassium suggesting a plant ash source of alkali.

Complicated sculptural pieces were also produced including a head, believed to be of Augustus (MMA26.7.1428), which is in a particularly dense turquoise faience with a matt finish (Friedman 1998: 200; Wypysk 1998: 265). The workmanship on this piece suggests that it was hand-modelled, perhaps after the approximate shape had been moulded. The relief decoration on bowls and vases was moulded, probably in the manner of the relief on *terra sigillata* ('Samian Ware') pottery. In this method the paste or clay is impressed into a mould having the shape of the bowl or vase which is then revolved on the potters wheel to smooth the inside. In the case of faience bowls where the interior is also decorated this must have been separately moulded or incised.

After the Greco-Roman period, faience technology was taken up by Islamic craftsmen and used to produce a new generation of works, which fall outside the scope of this text (*cf.* Allan 1973).

Factory evidence: Naukratis

In 1884–5 Petrie excavated at the Greek settlement of Naukratis (modern Kom Giʿeif; Petrie and Gardner 1886), which dated to the Late Period. Although the foundation of the site is traditionally accredited to Ahmose II (570–526 BC) archaeological evidence suggests that it dates back to at least 630 BC.

Here Petrie discovered a so-called 'scarab factory' making Egyptian as well as Egyptian-style faience artefacts. Unfortunately however, the details of this are not well-recorded, and the publication concentrates on the finds themselves rather than their context. More recent excavations have unearthed pottery kilns at the site (Coulson and Leonard 1981).

Factory evidence: Memphis

Petrie excavated the Greco-Roman faience-producing site at Memphis (Petrie 1909: 14–15, pls. XLIX, L; 1911). This site has sometimes been overlooked because it was described as for the production of 'glazed pottery', but it seems likely from the excavator's account and from finds at the Petrie Museum that the site was actually for faience. However, the forming and firing techniques used to shape vessels at this time clearly owed much to pottery technology.

Misfired vessels were discovered, some with kiln supports still attached, showing how they were stacked in the kiln. Cylindrical vessels seem to have served as saggars for firing the objects, and Petrie (1909: 14) equates these with the cylindrical vessels he regarded as stands for glass fritting pans at Amarna, again emphasising the links between these pyrotechnical industries.

At Memphis, six unequivocal kilns were located; these were rectangular, with internal sides measuring between 42″ (106.7 cm) and 83″ (210.9 cm). The draught or stoke hole was more than half way up the profile, and the kiln walls are said to have been heavily slagged above the level of the stoke hole, but not below it. This pattern is consistent with the heating pattern of an updraught kiln. No traces of a perforated floor or chequer were discovered, leading Petrie (1911: 35) to suggest that stacks of saggars, some as much as 10 feet (3 m) high, were made, and the fuel thrown between them. The lowermost ones received a lower firing temperature than those uppermost. He records that the fuel was straw which was found carbonised in the slag, and that there was no trace of wood or charcoal.

Unfortunately we cannot be sure whether all of these kilns were contemporary, which makes any judgement of the scale of the industry uncertain. However, the number of wasters from the site, combined with the number of kilns (assuming some at least were contemporary) argues for some degree of sophistication.

He also found traces of the making of blue colorant which he assumed was for colouring the glaze, and which he believed was roasted in sealed vessels in the kiln, since he had found 'pills' of the material at the site. This may argue for a link with the pigment industry, or simply the making of colorant for this late faience. There is no suggestion here of any link with glass production, rather the similarities are with pottery production, and analytical work is needed to establish whether clay is mixed with the faience material, leading to a darker body colour.

Factory evidence: Buto

At the site of Buto (modern Tell el-Faraʿin), in the western Nile Delta, two rectangular furnaces were found, and at least one of these may have been use for faience production (Charlesworth 1972: 45). The most likely candidate measures 1.6 by 7 metres, but since both survived only as floors it is difficult to ascertain their function with certainty. Kiln supports ('spacers') were found at the site, some of which fitted scars left on waster vessels from the excavation. This suggests that vessels, rather than beads or amulets were made at the site.

Raw materials and primary processing

Vandiver and Kingery (1987a: 9) have described faience as 'the first high-tech ceramic' to emphasise its status as an artificial medium, effectively an artificial precious stone. It is a non-clay ceramic composed of crushed quartz or sand with small amounts of lime and either natron or plant ash. This body is coated with a soda-lime-silica-glaze which is most commonly a bright blue-green colour due to the use of copper.

Vandiver (1982: 167) has determined the typical faience body to comprise:

92–99% SiO_2
1–5% CaO
0.5–3% Na_2O
minor quantities of CuO, Al_2O_3, TiO_2, MgO and K_2O.

This high silica composition is similar to that described in AD 1301 by Abu'l-Qasim (Allan 1973), and was still in use in Iran in the 1960s (Wulff *et al.* 1968: 107), showing the persistence of the material.

Egypt is rich in readily accessible silica, in the form of desert sand. However, although it is likely that this source was sometimes used, it is probable that certain sand sources were considered to be superior to others. It should be borne in mind that sand is rarely pure silica (indeed one geological definition is by particle size: the Udden-Wentworth Scale, $\frac{1}{16}$ mm and 2 mm, see Table 2.3, p. 20); it is generally mixed with numerous impurities such as chalk, limestone or iron. Some of these, notably iron, are not beneficial to faience production, and can lead to a discolouration of the glaze. As a result much faience may have used a non-sand source of silica.

From Petrie's excavations at Amarna in 1891–2 (Petrie 1894) there is some evidence to suggest that a high-grade form of silica was produced from the crushing of quartz pebbles. Among the debris from faience/glass factories he discovered quartz pebbles, some cracked, with drips of glaze. These he believed had originally formed the floor of a furnace (Petrie 1894: 26) and he notes that the continued heating and cooling would lead to cracking which would more easily enable them to be crushed as a high quality source of silica. A number of such pebbles are now in the collection of the Petrie Museum, London (e.g. UC40568, UC 46178, Friedman 1998: 254). These pebbles would largely be free of impurities and so yield a clean body-material, which had the additional benefit of being a dazzling white. From the earliest times faience seems to have served as an artificial precious stone, the optical qualities of the fine quartz being used to reflect light through the glaze to give the brilliant effect of such a stone. Faience frequently has two distinct body layers; a coarse, often discoloured, core covered by a brilliant white layer over which the glaze was placed. This might itself argue for the more limited availability, or more laborious production of, the finer material.

Between 1 and 5 per cent of the composition of faience is calcium oxide (CaO) which, in practical terms, is lime. Natural sources of lime would be limestone or chalk. It is not certain whether the Egyptians derived their lime for faience from this source, or whether it was added unconsciously as an impurity when using sand. However, Kiefer and Allibert (1971: 113) state that between 2 and 6 per cent of the Egyptian sand they analysed comprised calcareous material perhaps implying that it was added unknowingly, as may have been the case in glass manufacture. If however, crushed quartz was being used then it must be assumed that the addition was deliberate.

Between 0.3 and 5 per cent of the faience body is made of the alkali, or soda (Na_2O). There are two main sources of this alkali. The best known is natron, a naturally occurring mixture of sodium carbonate and sodium bicarbonate with sodium chloride and sodium sulphate, the best known sources of this are the Wadi Natrun and the Elkab area (Kaczmarczyk and Hedges 1983: 243). Similarly effective is the ash of certain halophytic plants, particularly those of the *Salicornia* family. It is possible to determine which source of alkali was used chemically, by examining the quantity of magnesia. High magnesia is indicative of a plant ash source (see Chapter 8, this volume, on Glass).

The other materials found in faience occur only in small amounts and are added either accidentally as impurities or deliberately to impart colour to the glaze. Cobalt, however, may be an exception to this (below).

The purpose of the silica is to form the bulk of the body; essentially it is the material from which the object shape is formed and is also the source of the optical properties of the faience. According to the brilliance of the quartz, and whether a fine layer has been used, the material will scatter light in different ways. Unlike potter's clay, ground silica/sand is not easy to form and although the addition of water helps shaping, the finished object will crumble once dry. The addition of lime and soda helps to cement the quartz grains together in drying, thus lending the object a slightly greater mechanical strength than might otherwise be the case. Lucas (1962: 175) found that alkali or salt was particularly effective as a binder. However, the main strengthening role of these ingredients is in the firing.

Faience is closely related to soda-lime-silicate glasses, which share the same three major ingredients, though in different proportions. In a glass the silica is the 'network former' and the sodium and calcium the 'network modifiers'. These latter ingredients help to reduce the melting temperature of the silica and combine with it to make a non-crystalline material. In faience the proportions of the ingredients are different, and the higher proportion of silica, probably combined with a lower firing temperature and shorter firing duration, produce a crystalline material. However, the network modifiers are generally sufficient to develop some degree of interstitial glass, which fuses the mass together.

Recent work by Tite *et al.* (1998) has examined some of the cobalt-blue frit found in Petrie's excvations at Amarna and traditionally assumed to represent the first stage in glass manufacture (Petrie 1894: 25–6). Petrie speaks of the frit as a colorant and then goes on to place it in the context of glass manufacture. However, analysis of the frit has shown it to contain significantly less soda and lime than the glass, but a higher percentage of cobalt (Tite *et al.* 1998). This suggests that it cannot have been a first stage in the manufacture of glass but that it was intended only as a colorant. Its composition matches more closely with the blue-bodied 'vitreous faience' described by Lucas (1962: 163–4) but the grain size of the quartz in the frits is greater than that of faience. Tite *et al.* (1998) suggest that this frit was then ground up and added to the faience body, rendering the body blue prior to glazing by either cementation or application. Since frit, faience and glass occur in the same workshops, as shown by the recent excavations at Amarna site O45.1 (see Chapter 8, this volume, on glass), this must surely represent a close link between their production. It would not be surprising to find that the cylindrical vessels which Nicholson *et al.* (1997) have suggested to be moulds for glass ingots might be multi-functional and have also served in the fritting process. Frit has been found adhering to some of these, but it has not yet been examined and so may yet prove to be frit for glass-making.

The distinction between crystalline and non-crystalline vitreous materials is an important one when considering the similarity of the raw materials and any possible interrelations between crafts.

Secondary processing: shaping technology

Clay is composed of platelets, which slide easily over one another when lubricated and whose edges fuse when heated above 600 °C, but in contrast the silica particles of the faience body are angular and so do not slip readily over one another even when wetted, although this does facilitate their movement. Instead, the typical faience mixture is thixotropic; i.e. thick at first and then soft and flowing as it begins to be shaped. However, if shaping is too rapid the material cracks or splits, thus making its working properties much less attractive than those of potting clay. This apparent difficulty makes its long and continued use in Egypt, alongside clay ceramics, all the more interesting.

The difficulty of working this material into shape, and then handling it for insertion into the kiln have usually been stressed (cf. Vergès 1992), however, recent experiments by Mimi Leveque (Nicholson 1998: 51) and others have shown that if the paste is very finely ground it adheres well, while only the most coarse paste is friable. A number of possible binding agents have been suggested to help in this process, notably gum-Arabic, clay and lime. Neither Lucas (Lucas and Harris 1962: 175) nor Noble (1969: 73) found traces of clay in most pharaonic faience, while gum proved too sticky for the removal of objects from their moulds. Further experimental work is needed here however. Lucas in fact suggested that alkali played the greatest role as a binder, although the binding effect occurs primarily during firing, when the sodium carbonate combines with the silica. However, there are problems with their work. Firstly, Lucas assumes that the faience was fired and then glazed, rather than the firing and glazing being done in a single operation, which seems, in fact, to have been the norm. Secondly, although he found that a mixture incorporating 5–10 per cent of natron gave the best results, he actually found lower percentages in his analyses of faience artefacts, and was obliged to account for this discrepancy by suggesting that some natron would have disappeared through loss and chemical combination in firing.

There remains considerable scope for experimental work to determine how the plastic properties of faience were improved. This needs to be attempted for pieces to be glazed by each of the three glazing methods, and using a range of different particle sizes and binding media. Those who have attempted to make faience have remarked on the difficulty of forming it, yet most experimental work (other than that of Leveque) has concentrated on how the binders work during firing, rather than on how the material can best be treated to facilitate working. These initial working properties are at least as important as the effects of firing.

The means by which this material was shaped vary over time (see Table 7.1), although they can be thought of as three broad categories – modelling, moulding and abrasion, the last being used in conjunction with the first two.

Modelling might be free-form (i.e. the whole shape being formed by hand), although this is fairly uncommon. More common is the modelling of a core or rough-out of the desired object; this can then be shaped by abrasion once it has had the opportunity to dry.

Peltenburg (1987: 20) regards faience-making as an essentially cold technology, more akin to stone-working than to glass-making, which he relates to metallurgy. This is said because the glaze was added to, or effloresced from, a cold worked object, whilst glass is heated at every stage. Since Predynastic times the Egyptians had been carving and glazing soft stones such as steatite (which hardens to 'enstatite' in firing) as well as quartz. While there are certainly comparisons to be made between the abrasion of stone and the abrasion of a siliceous aggregate it seems to the writer that the situation is more complicated, and that there is a link between 'hot technology' as well as cold. In the New Kingdom, glass and faience production seem to be undertaken in the same workshops suggesting that the connection with pyrotechnology was just as strong for faience as for glass. As noted above, according to Kühne (1969: 14) and Vandiver (1983: A108) glass was even added to certain faience objects. However, as Andrew Shortland (pers. comm.) has pointed out, the presence of extensive interstitial glass may be unrelated to the addition of actual glass, and is more probably simply the result of the efflorescence technique of glazing. Nevertheless, the knowledge of colorants for glass production may have helped to extend the colour palette of faience workers (*cf.* Boyce 1989). Given the proximity of the two crafts at Amarna they may even have been regarded as one and the same industry.

Table 7.1. *Methods of Egyptian faience manufacture through time (summarised from Vandiver 1983 with new information added)*

Chronological Period	Body manufacture*	Principal glazing method*	Factory evidence
Predynastic	Modelling a core for grinding Surface grinding Free form modelling (rare)	Applicaton (?) Cementation (?) Efflorescence (?)	None known
Early Dynastic	Modelling Surface grinding	Efflorescence	None known
Old Kingdom	Painting with slurry Layering (rare)	Efflorescence	Abydos
First Intermediate Period	Core forming (rare) Marbleising (rare) Moudling (?)	Efflorescence	Abydos
Middle Kingdom	Modelling Moulding on a form (*patrix*)	Efflorescence Cementation	Lisht Kerma (Sudan)
Second Intermediate Period	Core forming Marbleising Layering Painting with coloured quartz slurry Incising Inlaying Resisting Painting with pigment wash	Application	None known
New Kingdom	Moudling on a form Pressing into openface moulds Layering Incising Inlaying with quartz slurry Painting with pigment wash Throwing	Efflorescence Application Addition of finely powdered glass to body (??) and/or glaze to extend colour range	Malkata Amarna Qantir Lisht
Post-New Kingdom	As New Kingdom but with greater use of throwing (?)	Application Efflorescence	Memphis Naukratis Buto

Note: *It should be noted that several methods of body manufacture or glazing might be used in combination on a single artefact.

Moulding is a more sophisticated technique, and allows the making of complicated shapes without the need for extensive secondary working by abrasion. In this technique a model of the object is made and impressed into wet clay to give a negative of the item to be made. The model used may be of wax or wood, or it may be a completely finished object made in another medium which it is desired to copy in faience. In this way, rings originally made in metal might be copied in faience. A finished faience object might also be used to produce the mould for others (Boyce 1989).

The clay mould would then be fired to make it durable. Once fired, the faience paste could be pressed into it, remaining for a short time, and then be tipped out for final drying or re-working by some manner of surface abrasion before firing. The mould could then be re-used for another artefact. In this way moulds could facilitate mass production of faience objects, such as amulets, rings and inlays.

There is one further technique, which may occur from the New Kingdom (*c.* 1550–1070 BC) onwards, namely wheel-throwing. This technique is certainly established by the Greco-Roman period, when large amounts of clay seem to have been added to the faience body. The result of this technology was the production of vessels more closely akin to those produced by potters, and presumably an increase in the rate of production.

Secondary processing: glazing methods

Vandiver (1982) has summarised the diverse accounts of faience glazing techniques, dividing them into three broad categories: efflorescence, cementation and application (see Fig. 7.5). It should be remembered however, that these can be used in combination, and are not always readily identifiable, as recently stressed by Vandiver (pers. comm.).

Efflorescence

Efflorescence is a so-called self-glazing method. The possibility of such a process was first noted by Binns *et al.* (1932: 271–2) and later developed by Noble (1969). In it the glazing materials, in the form of soluble salts, are mixed with the raw crushed quartz and alkalis of the body. As the water in the body evaporates so the salts migrate to the surface of the object to form a kind of scum. Vandiver (1983: A31) has noted that this forms within thirty minutes of shaping the object. The precipitated salts comprise sodium-carbonates, and to a smaller degree potassium-carbonates, sulphates and chlorides, from the natron or plant ash (Vandiver 1983: A31). In firing, this precipitated layer melts and fuses to leave a glaze whose thickness varies according to the amount of efflorescence developed in drying. It has been discovered that rapid drying leads to the greatest thickness of deposited salts, and thus to the thickest glaze. Peltenburg (1987: 10) has noted that it is most effective for fine-grained bodies.

The recognition of the various glazing techniques is not easy, and there are overlaps between the characteristic features. However, pieces glazed by efflorescence may show traces of stand marks, where the piece was set down to dry, as well as being prone to cracking and having a glaze which is thinnest toward the edge of the piece and in concave areas. Similarly, glaze will not be formed where evaporation was not possible, such as the underside of a piece where it was in contact with the drying surface. In firing the piece is usually stood on some kind of support, and this will usually leave some trace in the glaze. However, Vandiver (1983: A33) notes that if placed on a non-wetting support there may be no firing marks, and thus confusion with the cementation method of glazing may be possible.

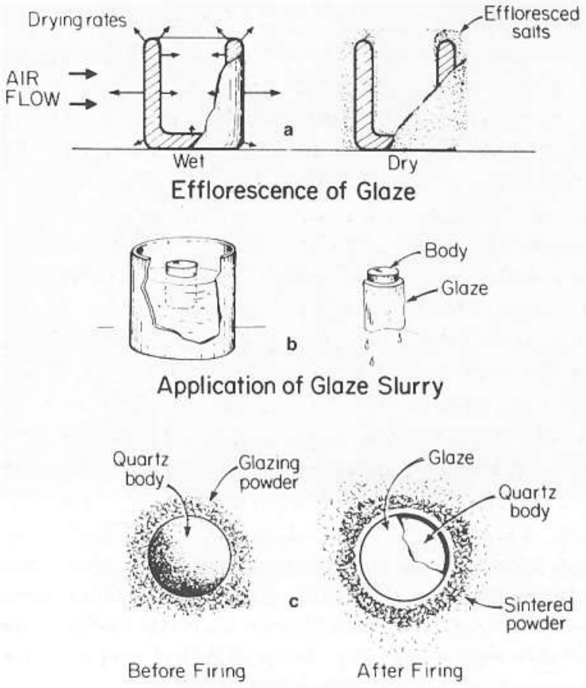


Figure 7.5 The three methods of faience glazing.

In a broken section across an object the interface between the glaze and the underlying body is generally narrow and well-defined. This is because where drying has been rapid the greatest concentration of salts has built up on the surface, and when fired at fairly low temperatures the glaze sinters without soaking into the body. However, where overfiring occurs the glaze becomes less viscous and so soaks into the surface of the object. The same effect is achieved if a greater amount of flux, in this case alkali, is added to the ingredients. Additional flux has the effect of lowering melting temperatures.

Examination under the scanning electron microscope (SEM) shows extensive interstitial glass, due to the presence of the alkali salts in the body (Fig. 7.6). Those which have not reached the surface fuse in the body, which has the effect of hardening it further.

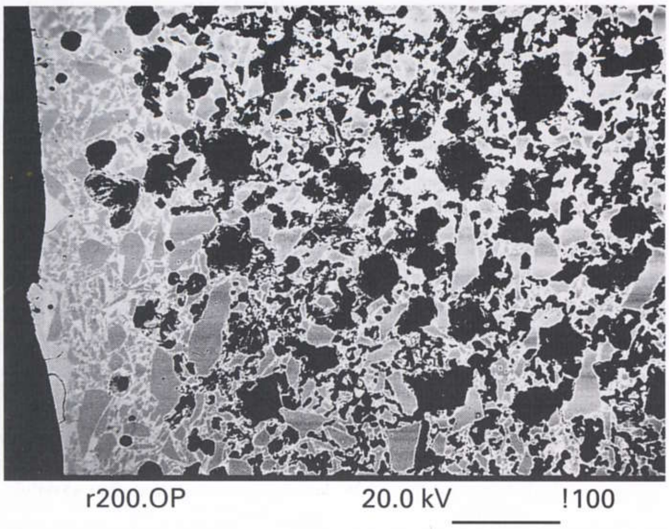


Figure 7.6 Scanning electron microscope photograph of a section through faience glazed by efflorescence, from an Eighteenth-Dynasty vessel excavated at Amarna (Petrie Museum UC30153). The glaze and interstitial glass show as pale grey, quartz as dark grey, and voids as black.

Cementation

A second self-glazing technique is that known as cementation, or the 'Qom technique', the later term deriving from the discovery of this method in use at the village of Qom in Iran in the 1960s (Wulff *et al.* 1968). The technique was also studied by Kiefer (1968) and Kiefer and Allibert (1971). In this method an artefact is buried in glazing powder with a high flux content, inside a vessel. When the vessel and its contents are heated, the powder becomes fused to the object by a chemical reaction between it and the surface of the object. The exact nature of this process is not fully understood, although Vandiver (1983: A33–34) states that the 'low melting alkalis presumably draw away from the mixture of calcium oxide and charcoal and wet the quartz. After firing, the friable, unreacted powder is removed from the object to reveal an even coating of glaze . . .'

A range of compositions for the glazing powder have been shown to yield satisfactory results and the following compositions have been discovered:

SiO_2	40%	
Na_2O	20%	
K_2O	3%	
CaO	20%	
MgO	2%	
CuO	1%	
Al_2O_3	6%	
Fe_2O_3	1.5%	
PO_4	2%	
Total:	98.5%	(Wulff *et al.* 1968: 100)

$CaCO_3$	50–75%	
Bauxite	0–20%	
Nitre	15–25%	(mostly potassium nitrate)
CuO frit	0–12%	
or		
$CaCO_3$	5–28%	
SiO_2	20–36%	
Na_2OCO_3	12–23%	(Kiefer 1968)

The cementation glazing process happens gradually, so that the firing time is longer than for the other processes, Wulff *et al.* (1968) record a twelve-hour firing time with a similar period of cooling. The temperature was experimentally determined to be 1000 °C.

The most important features resulting from cementation are (1) a glaze that is charactistically even all over, since the object was surrounded in the glazing powder leaving no drying marks, and (2) the fact that the concentration of copper rapidly decreases away from the surface (whereas in efflorescence and cementation the concentration is constant throughout the sample). Small objects, typically less than 1.5 cm square, which have been glazed by this method usually show no firing marks, although there may be indications on larger pieces (Vandiver 1983: A39). The glaze may sometimes be thicker on the underside of the object.

In broken section, the interface between glaze and body is thick and well-defined, but SEM examination shows little interstitial glass, since the glaze has had to penetrate the body from the outside, rather than growing from the inside as it does in efflorescence (Fig. 7.7).

Examination of Egyptian artefacts suggests that this technique was not discovered before the Middle Kingdom (*c.* 2040–1640 BC).

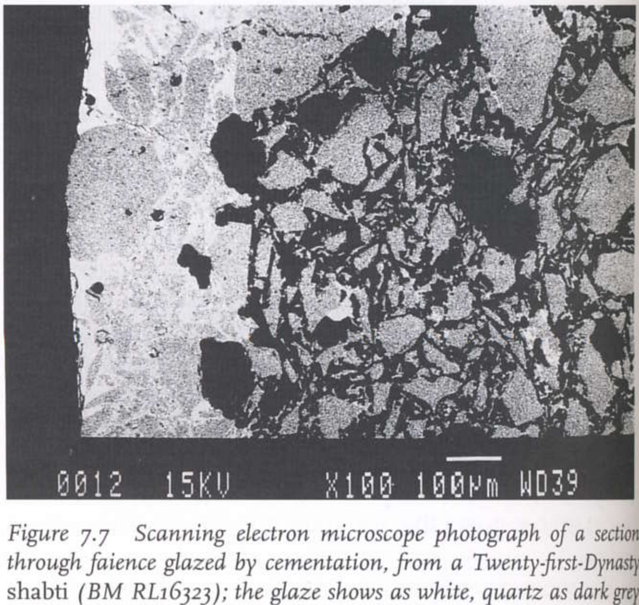


Figure 7.7 Scanning electron microscope photograph of a section through faience glazed by cementation, from a Twenty-first-Dynasty shabti *(BM RL16323); the glaze shows as white, quartz as dark grey and voids as black.*

Application

The final glazing method is that of application, the method formerly assumed to be the only one used for faience glazing (Petrie 1894; Lucas 1962). This was a reasonable view, given knowledge of the glazing processes employed for pottery, and was the method used in glazing stone objects, which predate faience. It is, however, an oversimplified view, which must be borne in mind when consulting early accounts of faience technology.

In this method the glazing materials, comprising silica lime and alkali are ground to a small particle size and mixed with water to form a slurry which is applied to the quartz core. They may be ground together in their raw state, or be partially fritted and then ground, as in the production of a pottery glaze. Fritting allows the materials to react together in the first stages of vitrification, a process which helps the final firing temperature to be lower. The object can be dipped into the slurry, or the slurry can be poured over the object. Brushing is also a possiblility, although Vandiver (1982: 168) found traces of it only on polychrome faience of the New Kingdom. In glazing pottery it is common to fire the body clay and then apply the glaze for a second firing but for faience a primary firing has been found to be unnecessary, and firing temperatures tend to be low so that the glaze does not become too liquid causing excessive flow.

Applied glazes characteristically vary in thickness, and may preserve the traces of kiln supports. The glaze covers all of the object, unless intentionally limited. A tendency to run and drip leads to pooling on the lower surfaces and thicker glaze on bases.

The interface of body and glaze in this method is not well-defined, and since there may be little interstitial glass the body itself may be quite soft (Fig. 7.8). Vandiver (1983: A28) notes that a sharp body–glaze boundary and soft friable body may result from firing below *c.* 900 °C and/or a flux content up to 5 per cent. At higher temperatures or greater flux content the body becomes harder as the glassy phase develops. A thick interaction zone and hard body result from prolonged firing at peak temperature, notably firing above 950 °C and/or flux above 10 per cent.

As with many technological processes, we must remember that faience craftsmen did not necessarily work to rigid formulae, and we should not be surprised to find a combination of techniques used on a single piece. For example, Vandiver and Kingery (1987b) report that a faience chalice of the New Kingdom was formed from a body capable of producing an effloresced glaze. However, when the relief decoration was carved into the surface of the piece it inevitably cut through some of the effloresced salts. This would have left a chalice with only partial glazing, and in order to correct this, the finished piece was dipped in a slurry of the body material. This was actually using the technology of application glazing to an effloresced piece. The new glaze layer was itself efflorescent, and allowed the complete glazing of the object.

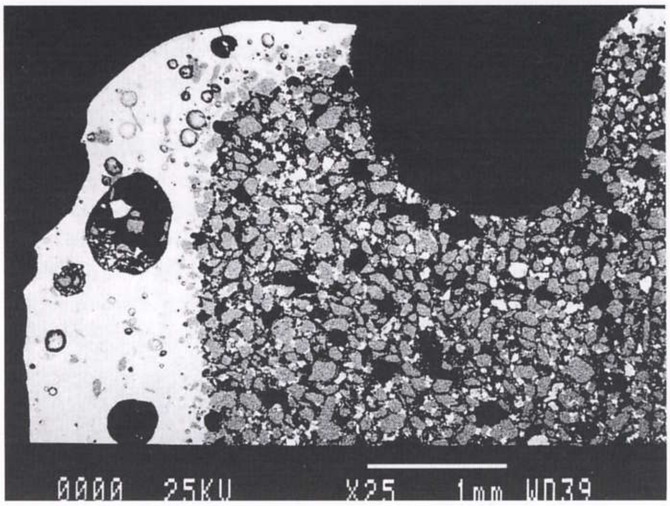


Figure 7.8 Scanning electron microscope photograph of a section through faience glazed by application, from a Late Period shabti *(BM RL16322); the glaze shows as white, the quartz as dark grey, and the voids as black.*

Tite *et al.* (1983: 26) have shown that the glaze composition can be quite variable, and this may be related to changes in the formation of the body, and variations in glazing method, applied regionally and/or chronologically. The forming of the body and glaze varies considerably over time, and according to the status of the workshop. Those workshops enjoying royal patronage presumably had better access to the best raw materials and, more importantly, greater freedom to experiment while smaller local concerns perhaps tended toward conservatism (see Kaczmarczyk and Hedges 1983).

Secondary processing: firing

Through recent experiments that attempt to replicate the ancient production of faience, more is now understood about ancient firing techniques (Vergès 1992; Stocks 1997). Such experimental studies have shown that faience is fired in the range 800–1,000 °C. These studies have been carried out using modern electric kilns and replica faience pastes and, although they are unlikely to be significantly different to the actual firing temperature used, experiment in replica kilns is needed. Such experimentation is required firstly because kiln atmosphere can play an important role in firing, and secondly because it is necessary to ascertain some of the difficulties likely to be experienced in firing this material by traditional means.

The difficulty for modern research is that until recently there were very few kilns known archaeologically. Ironically, the best-known kiln or furnace is the one mentioned by various sources (e.g. Vandiver 1983: A30) as having been found by Petrie at Amarna. This particular Amarna kiln in fact never existed and is a hypothetical reconstruction based on Petrie's finds. Although recent excavations at Abydos and Amarna have supplemented the picture gained from earlier excavations at Lisht, Memphis and Naukratis, the differentiation of glass furnaces from faience kilns/furnaces at Amarna still remains problematic.

Since few kilns have been found, and most of those in old excavations, it follows that the opportunity to examine fuel has been limited. However, charcoal fragments have been found in the recent work at Abydos, and from Amarna, although in this last case the structures with which the fuel is associated are more likely to be for glass production. The Amarna charcoal has been examined by Mary Anne Murray and shown to be of *Ficus sycomorus*. It is not known whether it was deliberately produced, or simply the by-product of incomplete combustion of wood used as fuel, but the fact that some of it takes the form of quite long pieces may suggest that it was the fortuitous product of incomplete combustion (Caroline Vermeeren pers. comm., based on description given by the writer). Further work is needed here.

Petrie (1894: 26) records the discovery at Amarna of what he considered to be a charcoal-burning furnace with large quantities of charcoal inside it. However, whether this was correctly identified, and whether it produced fuel for faience or glass production, or both (or indeed some other purpose) is not known. No analyses were carried out on its contents, and to date it has not proved possible to rediscover the location of this furnace.

Whether or not charcoal was deliberately produced, it is likely that a certain amount of wood and domestic rubbish was burned in the kilns, and animal bone fragments are certainly found among the ash from the kilns at Amarna. This is a likely situation in a country as relatively deficient in timber as Egypt, and one must assume that considerable effort was used in economising on fuel. Petrie (1911: 35) states that the fuel used in the Greco-Roman kilns at Memphis was straw. Although it is possible that straw was among the fuel used, it seems an unlikely choice as the main fuel source, since it burns quickly and huge quantities would be needed for a long firing. Dung might also be a possible source of fuel, perhaps used in combination with wood, but once again experimental work is necessary here.

The objects to be glazed would probably have been protected from the smoke and ash particles of the fire in some way. In efflorescence and application glazing, the pieces probably stood in deep trays or saggars, possibly with lids, to prevent ash from becoming stuck to the glaze. In the case of cementation glazing, they would have been buried in glazing powder, which would itself have been contained in some kind of vessel.

To prevent an all-over glazed object adhering to its saggar or to the kiln, or indeed to neighbouring objects, it would usually be necessary to rest it on some kind of support.

The form of these is not known, but it can be suggested that they were sometimes small cones or bars of clay, possibly rich in alumina which would help to prevent sticking. It is also possible that the numerous small marl clay balls discovered at Lisht may have served this purpose, the bottom of a tray being covered in them, much as modern potters might use alumina powder to prevent pots sticking to kiln shelves in firing. A number of marl clay annuli were also found at Lisht and probably served a similar purpose.

Analytical techniques

The technique by which a multi-part object has been manufactured may be determined by the use of conventional x-ray examination, or more satisfactorily by xero-radiography, as Vandiver and Kingery (1987b) have illustrated, since this clearly shows the joins between components.

The use of the scanning electron microscope (SEM) in determining the method of glazing from an examination of interstitial glass and glaze thickness has already been referred to above. Energy dispersive (ED) and wavelength dispersive (WD) X-ray analyses can be carried out on those instruments equipped for such analyses (see Henderson's contribution to Chapter 8). The SEM is the most satisfactory means for the determination of glazing technique, although examination under the petrological microscope can also be used. In this method a thin section (0.03 millimetres thick) is prepared from the faience and examined under a polarising microscope so that the mineral phases (mostly silica) and glass can be identified. Such sections may need to be consolidated by the addition of a suitable epoxy resin before they are reduced to the correct thickness.

For the most widely used modern study, however, Kaczmarczyk and Hedges (1983) employed x-ray fluorescence (XRF) which examines a small area of the surface of the object (usually 1.5 × 1.5 millimetres) non-destructively (Tite 1972: 267–72). Primary x-rays are used to bombard the sample which in turn releases energy in the form of fluorescent x-rays whose wavelengths are characteristic of particular elements. A diffraction crystal is used to separate the wavelengths which can then be identified and the concentration of the element measured. The technique is best suited to major elements, but can also detect trace elements.

Kaczmarczyk and Hedges (1983: 10) found that certain elements, notably sodium, magnesium and aluminium were best measured using atomic absorption spectrometry (AAS) (Tite 1972: 264–6), a method which requires the removal of a small sample from the object, twenty milligrammes in the case of their study. This sample is dissolved and the solution atomised in a flame. Focused on the flame is the light from a hollow cathode lamp made from the element to be analysed. The light thus has a wavelength corresponding to that of the element it is sought to examine. Atoms of the element absorb some of the light, and the intensity is measured using a photomultiplier, the quantity of light absorbed indicating the concentration of the element in the sample. The technique is best suited to minor and trace elements, which makes it an ideal complement to XRF.

Other techniques suited to the examination of glass can also be applied to faience and the reader is referred to Chapter 8, this volume, for further details of these.

Acknowledgements (Nicholson)

I would like to thank the Egypt Exploration Society and Mr Barry Kemp for their suppport of my work at site O45.1 at Amarna. I would also like to thank the Wainwright Fund for Near Eastern Archaeology, who funded the work at Amarna, and the Leverhulme Trust (grant F/407/J), who supported the analytical work by myself and Dr Caroline M. Jackson. Mr Ian Mathieson carried out geophysical survey at site O45.1 and I am indebted to him. Ms Susan Cole, Mr Ian Dennis, Dr Jackson, Professor Michael S. Tite and Dr Katharine M. Trott have all worked for the 'Amarna Glass Project' and their hard work is gratefully acknowledged. The work at Amarna would not have been possible without the kind cooperation of the Egyptian Supreme Council for Antiquities to whom I am indebted.

I am also indebted to Dr Dorothea Arnold for giving me the opportunity to examine faience in the Metropolitan Museum of Art, New York, and to Dr Florence Friedman and Dr Matthew Adams for discussions concerning faience and work at Abydos respectively. Dr Adams kindly allowed mention to be made of his unpublished work at Abydos and provided the photographs for Figures 7.2 and 7.3.

Finally, the advice on the production of this chapter given by Professor Edgar Peltenburg is gratefully acknowledged.

References

Allan, J.W. 1973. Abu' L-Qasim's treatise on ceramics. *Iran*, 11: 111–20.

Arnold, Do. 1988. Egyptian art. In *The Metropolitan Museum of Art: Recent Acquisitions: A Selection 1987–1988*. New York: MMA, pp. 6–7.

Aufrère, S. 1991. *L'univers mineral dans la pensée égyptienne*. Cairo: IFAO.

Bellion, M. 1987. *Catalogue des manuscrits hiéroglyphiques et hiératiques et des dessins, sur papyrus, cuir, ou tissu, publiés ou signalés*. Paris: Epsilon Reproductions.

Bianchi, R.S. 1996. Faience and glazes. In *The Macmillan Dictionary of Art Vol. 10*. (ed. J. Turner). London: Macmillan, pp. 46–9.

1998. Symbols and meanings. In *Gifts of the Nile: Ancient Egyptian Faience* (ed. F.D. Friedman). London: Thames and Hudson, pp. 22–31.

Binns, C.F., Klem, M. and Mott, H. 1932. An experiment in Egyptian blue glaze. *Journal of the American Ceramic Society*, 15: 271–2.

Bourriau, J.D. 1996. The Dolphin vase from Lisht. In *Studies in Honor of William Kelly Simpson* I. (ed. P. Der Manuelian). Boston: MFA, pp. 101–16.

Boyce, A. 1989. Notes on the manufacture and use of faience rings at Amarna. In *Amarna Reports* V. (ed. B.J. Kemp). London: EES, pp. 160–8.

Brunton, G. and Engelbach, R. 1927. *Gurob*. London: Egyptian Research Account/British School in Egypt.

Charlesworth, D. 1972. Tell El-Fara'in Egypt: an industrial site in the Nile Delta. *Archaeology*, 25: 44–7.

Cooney, J.D. 1976. *Catalogue of Egyptian Antiquities in the British Museum IV: Glass*. London: BMP.

1981. Notes on Egyptian glass. In *Studies in Ancient Egypt, the Aegean and the Sudan* (eds. W.K. Simpson and W.M. Davis). Boston: MFA, pp. 31–3.

Coulson, W.D.E. and Leonard, A. 1981. *Cities of the Delta I: Naukratis, Preliminary Report on the 1977–1978 and 1980 Seasons*. Malibu: ARCE.

Davies, N. de G. 1902. *The Rock Tombs of Deir el-Gebrawi*. London: EES.

Doran, J.E. and Hodson, F.R. 1975. *Mathematics and Computers in Archaeology*. Edinburgh: Edinburgh University Press.

Drenkahn, R. 1995. Artisans and artists in Pharaonic Egypt. In *Civilisations of the Ancient Near East I* (ed. J.M. Sasson). New York: Charles Scribner's Sons, pp. 331–43.

Friedman, F.D. 1998. (ed.) *Gifts of the Nile: Ancient Egyptian Faience*. London: Thames and Hudson.

Gaballa, G.A. 1979. False-door stelae of some Memphite personnel. *SAK*, 7: 41–52.

Hamza, M. 1930. Excavations of the Department of Antiquities at Qantîr (Faqûs district). *ASAE*, 30: 31–68.

Henein, N.H. and Gout, J.-F. 1974. *Le verre soufflé en Égypte*. Cairo: IFAO.

Kaczmarczyk, A. and Hedges, R.E.M. 1983. *Ancient Egyptian Faience*. Warminster: Aris and Phillips.

Kiefer, C. 1968. Les céramiques bleues pharaoniques et leur procédé révolutionnaire d'émaillage. *Industrie Céramique*, May: 395–402.

Kiefer, C. and Allibert, A. 1971. Pharaonic blue ceramics: the process of self-glazing. *Archaeology*, 24: 107–17.

Kühne, J. 1969 *Zur Kenntnis silikatischer Werkstoffe und der Technologie ihrer Herstellung im 2. Jahrtausend vor unserer Zeitrechnung*. Berlin: Abhandlung der Deutschen Akademie der Wissenschaften zu Berlin

Lacovara, P. 1998. Nubian faience. In *Gifts of the Nile: Ancient Egyptian Faience* (ed. F.D. Friedman). London. Thames and Hudson, pp. 46–7.

Lauer, J.-P. 1938. Fouilles du service des antiquités à Saqqarah. *ASAE*, 38: 551–65.

1976. *Saqqara: The Royal Cemetery of Memphis*. London: Thames and Hudson.

Lilyquist, C. and Brill, R.H. 1993. *Studies in Early Egyptian Glass*. New York: MMA.

Lucas, A. and Harris, J.R. 1962. *Ancient Egyptian Materials and Industries*. 4th edn., rev. J.R. Harris. London: Arnold.

Marucchi, H. 1891. *Monumenta papyrichea Agyptea Biblioteci Vaticani*. Rome: Ex Bibliotheca Vaticana.

McGovern, P.E., Bourriau, J.D., Harbottle, G. and Allen S.J. 1994.

The archaeological origin and significance of the Dolphin Vase as determined by neutron activation analysis. *BASOR*, 296: 31–43.

Moorey, R.S. 1994. *Ancient Mesopotamian Materials and Industries.* Oxford: OUP.

Morgan, M.H. 1914. *Vitruvius: The Ten Books on Architecture*, transl. M.H. Morgan. Cambridge MA: Harvard University Press.

Nenna, M.-D. and Seif el-Din, M. 1993. La vaiselle en faïence du Musée Gréco-Romain d'Alexandrie. *Bulletin de Correspondance Hellénique*, 117: 565–98.

1994. La petite plastique en faïence du Musée Gréco-Romain D'Alexandrie. *Bulletin de Correspondance Hellénique*, 118: 291–320.

Newton, R.G. 1980. Recent views on ancient glasses. *Glass Technology*, 21/4: 173–83.

Newton, R.G. and Renfrew, C. 1976. British faience beads reconsidered. *Antiquity*, 44: 199–206.

Nicholson, P.T. 1993. *Egyptian Faience and Glass.* Aylesbury: Shire Egyptology.

1995a. The potters of Deir Mawas, an ethnoarchaeological study. In *Amarna Reports* VI. (ed. B.J. Kemp). London: EES, pp. 279–308.

1995b. Recent excavations at an ancient Egyptian glassworks: Tell el-Amarna 1993. *Glass Technology*, 36 (4): 125–8.

1995c. Glass making/working at Amarna: some new work. *Journal of Glass Studies*, 37: 11–19.

1998. Materials and technology. In *Gifts of the Nile: Ancient Egyptian Faience* (ed. F.D. Friedman). London: Thames and Hudson, pp. 50–64.

Nicholson, P.T., Jackson, C.M. and Trott, K.M. 1997. The Ulu Burun glass ingots, cylindrical vessels and Egyptian glass. *JEA* 83: 143–53.

Noble, J.V. 1969. The technique of Egyptian faience, *AJA*, 73: 435–9.

Nolte, B. 1968. Die Glassgefäße im alten Ägypten. Munich: *Münchner Ägyptologische Stüden 14*

1977. Fayence. *LÄ* II: 138–42.

Oppenheim, A.L. 1973. Towards a history of glass in the ancient Near East. *JAOS*, 93: 259–66.

Oppenheim, A.L., Brill, R.H., Barag, D. and von Saldern, A. 1970. *Glass and Glassmaking in Ancient Mesopotamia.* New York: Corning Museum of Glass.

Peltenburg, E.J. 1986. Ramesside Egypt and Cyprus. In *Acts of the International Archaeological Symposium 'Cyprus Between the Orient and the Occident'* (ed. V. Karageorghis). Nicosia: Department of Antiquities, pp. 149–79.

1987. Early faience: recent studies, origins and relations with glass. In *Early Vitreous Materials* (eds. M. Bimson and I.C. Freestone), British Museum Occasional Paper 56. London: BMP, pp. 5–29.

Petrie, W.M.F. 1890. *Kahun, Gurob and Hawara 1889–90.* London: Nutt.

1894. *Tell el-Amarna.* London: Methuen.

1909. *Memphis I.* London: Quaritch.

1911. The pottery kilns at Memphis. In *Historical Studies II* (E.B. Knobel, W.W. Midgeley, J.G. Milne, M.A. Murray and W.M.F. Petrie). London: Quaritch, pp. 34–7.

Petrie, W.M.F. and Gardner, E.A. 1886. *Naukratis I.* London: Trübner and Co.

Rehren, T. and Pusch, E. 1997. New Kingdom glass melting crucibles from Qantir-Piramesses. *Journal of Egyptian Archaeology*, 83, 127–41.

Reisner, G.A. 1923. *Excavations at Kerma* IV–V. Harvard African Studies 6. Cambridge MA: Harvard University Press.

Stocks, D. 1997. Derivation of ancient Egyptian faience core and glaze materials. *Antiquity*, 71: 179–82.

Stone, J. and Thomas, C. 1956. The use and distribution of faience in the Ancient East and Prehistoric Europe. *PPS*, 22: 37–84.

Tite, M.S. 1972. *Methods of Physical Examination in Archaeology.* London: Seminar Press.

1986. Egyptian blue, faience and related materials: technological investigations. In *Science In Archaeology* (eds. R.E. Jones and H.W. Catling), Fitch Laboratory Occasional Paper 2. London: British School at Athens, pp. 39–41.

unpublished. Technology of early vitreous materials. *Paper given at Los Angeles Symposium On Archaeometry1992.*

Tite, M.S. and Bimson, M. 1987. Identification of early vitreous materials. In *Recent Advances in the Conservation and Analysis of Artifacts* (ed. J. Black). London: Summer Schools Press, pp. 81–5.

Tite, M.S., Freestone, I.C. and Bimson, M. 1983. Egyptian faience: an investigation of the methods of production. *Archaeometry*, 25/1: 17–27.

Tite, M.S., Shortland, A.J., Nicholson, P.T. and Jackson, C.M. 1998. The use of copper and cobalt colorants in vitreous materials in ancient Egypt. In *La couleur dans la peinture et l'emaillage de l'Egypte ancienne* (ed. M. Menu). Ravello: Centro Universitario Europeo per i Beni Culturali, pp. 111–120.

Vandiver, P. 1982. Technological change in Egyptian faience. In *Archaeological Ceramics.* (eds. J.S. Olin and A.D. Franklin). Washington DC: Smithsonian Institution Press, pp. 167–79.

1983. Appendix A: the manufacture of faience. In *Ancient Egyptian Faience.* (A. Kaczmarczyk and R.E.M. Hedges). Warminster: Aris and Phillips, pp. A1–A137.

Vandiver, P. and Kingery, W.D. 1987a. Egyptian faience: the first high-tech ceramic. In *Ceramics and Civilisation* 3. (ed. W.D. Kingery). Columbus OH: American Ceramic Society, pp. 19–34.

1987b. Manufacture of an eighteenth dynasty Egyptian faience chalice. In *Early Vitreous Material* (eds. M. Bimson and I.C. Freestone). London: BMP, pp. 79–90.

Vergès, F.L. 1992. *Bleus Égyptiens.* Leuven: Peeters.

Verner, M. 1984. Excavations at Abusir: season 1982 preliminary report. *ZAS*, 111: 70–8.

1986. Nouvelles découvertes des égyptologues tchécoslovaques. *Solidarité*, 4: 20–1.

Vitruvius see Morgan 1914.

Weatherhead, F. and Buckley, A. 1989. Artist's pigments from Amarna. In *Amarna Reports* V. (ed. B.J. Kemp). London: EES, pp. 202–40.

Wulff, H.E., Wulff, H.S. and Koch, L. 1968. Egyptian faience: a possible survival in Iran. *Archaeology*, 21: 98–107.

Wypyski, M. 1998. Appendix. In *Gifts of the Nile: Ancient Egyptian Faience* (ed. F.D. Friedman). London: Thames and Hudson, p. 265.

8. Glass

PAUL T. NICHOLSON [TECHNOLOGY] AND JULIAN HENDERSON [ANALYSIS]

[NICHOLSON – TECHNOLOGY]

Introduction and historical summary

Ancient Egyptian glass is among the finest from the ancient world. Despite its great technical competence its origins and technology are still imperfectly understood. Lucas (1962: 179) notes that while glass may have been made sporadically before the 18th Dynasty (*c.* 1550–1070 BC) it was probably a fortuitous product resulting from accidents in faience manufacture, while after that time its production was deliberate. Peltenburg (1987: 16) similarly credits the earliest glass to faience-workers, though he makes the valuable point that these early occurrences form no distinct regional or temporal pattern but are simply sporadic.

Both glass and faience were treated as artificial precious stones, and at least insofar as vessels were concerned neither developed its own distinctive repertoire, rather they copied forms originally made in stone or pottery. The link is further emphasised by the practice of imitating glass vessels in painted wood, in the same way as stone vessels were copied. Examples are known from tombs as rich as that of Yuya and Tuyu (KV46; Davis 1907: 32; Cairo CG3686–9). This also emphasises the high status attached to glass, it was a commodity fit for even the highest individuals, so that while it may have been an artificial precious stone it should not be thought of as a cheap substitute. Indeed Carnarvon considered it to have been sufficiently valuable to have been among the items robbed from the tomb of Tutankhamun (KV62; Reeves 1990: 200).

Beck (1934) and Lucas both summarised known early finds of glass, though by 1962 when Harris's revised edition of Lucas's *Ancient Egyptian Materials and Industries* appeared, many of these had been questioned, and Peltenburg (1987: 17) gives only fifteen occurrences from Egypt. All of these are beads, except for two unprovenanced Twelfth-Dynasty scarabs, (see Martin 1971: nos. 441 and 1198). Lilyquist and Brill (1993: 5–7) also discuss these early occurrences. Most of these 'early' pieces must be treated with extreme caution since many lack secure provenance and/or examination in recent times, and those that have been examined – such as the lion head pendant (BM EA59619) have proved to be of other materials (I. Freestone pers. comm.). Peltenburg (1987: 18) makes a distinction between these occasional pieces, which he calls Stage 1 of glass production and the deliberate products of Stage 2, beginning at around 1500 BC, although the scarabs may be an early outlier of Stage 2 production.

From 1500 BC onwards, glass emerges as a regular, if high-status, product in Egypt. Lucas, like Petrie (1894), took it for granted that glass was *made* in Egypt from its raw materials at least by the time of Amarna, but since his time opinion has shifted toward the view that the earliest glass was imported, or at least that craftsmen were brought in to establish the industry. This view stems from the realisation that the earliest glass is of remarkable technical competence, apparently the product of a fully fledged industry. Petrie himself believed glass to have been introduced into Egypt (Petrie 1926: 229) and then independently manufactured there once it had become established.

Furthermore, the words *ehlipakku* and *mekku*, apparently used by the Egyptians to refer to glass, are of foreign origin and come from Hurrian and Akkadian respectively (Oppenheim 1973, but see also Foster 1979: 21). Oppenheim (1973: 263) argues that the first glass-makers/workers may have been brought to Egypt following the campaigns of Thutmose III (1479–1425 BC) in Mitanni and that Pharaoh requested raw materials, perhaps as cullet or ingots, from which they simply *worked* the glass. The *Annals of Thutmose III* (Breasted, 1906: 204) mention under the tribute of Babylon during the eighth campaign of Thutmose III 'lapis lazuli of Babylon' which Smith (1928: 233) considers to be glass. Glass can also be referred to as 'stones of casting' or 'stone of the kind that flows', *inr n wḏḥ or ʿꜣt wḏḥt* (Tatton Brown and Andrews 1991: 26; Nolte 1977a: 614).

Newton (1980:176) states categorically that 'the Egyptians could only melt other people's glass even though they could fabricate the most exquisite items from it . . . glass-melting is a much simpler operation than glass-making . . . [and] the Egyptian court depended for their basic raw material, or for an essential ingredient thereof on imports from Asia'. The question of if and when a truly local production began is currently under investigation (Nicholson 1995 and pp. 200–1, this volume; Nicholson and Jackson, 1998).

Stern and Schlick-Nolte (1994: 25) point out that the largest glass vessel known from Egypt (CG 24804 – not 24808 as stated in their text) which bears a cartouche of Amenhotep II (1427–1401 BC) may be of foreign origin. Whatever the origin of this particular piece, it is clear that glass was of considerable importance, and Nolte (1968: 13) has suggested that glass was a royal monopoly throughout the New Kingdom. Some support for this view is to be found in the mentions of glass in the Amarna Letters (EA14, 25, 148, 235, 314, 323, 327 and 331; for translations see Moran 1992), where glass is clearly said to be imported into Egypt. However, letter EA14 also mentions glass among gifts sent by the Egyptian king to the king of Karaduniyaš (Moran 1992: 27–37).

Whether made, or simply worked, the glass produced was put to a wide range of uses, and subject to various shaping processes. Among the products were beads, amulets, items of sculpture and vessels. It was probably its association with stone which led to glass, as with faience, being used in the making of amulets. Certain types and colours of stone were considered most effective for particular purposes, and glass of the same colour seems to have been credited with the same effects.

Where vessels were produced they too might serve the same function as their stone or pottery counterparts, namely as containers for perfumes, ointments and cosmetics. These tended to be more solid than those favoured in Hellenistic times, and as a result the wide-mouthed forms decline at this later date in favour of a range of miniature 'classical' forms such as *amphoriskoi* and *aryballoi*. Both the container and its contents were costly, and the labour involved in producing both was great. It is not surprising therefore, that in the era before glass blowing (discovered in the first century BC, probably in the Levant) we possess relatively few vessels and that most are of remarkably high quality, the work of the most highly skilled craftsmen.

As well as use for containers of high value substances, and an imitation of precious stones, glass was also valued as a material in its own right. It may have been this which led to its use for sculpture in the round. Such glass sculpture appears to have been an Egyptian invention, and the earliest piece belongs to the reign of Amenhotep II (1427–1401 BC). Until recently the earliest known was a *shabti* figure (Cairo 5319; Cooney 1960: 12). However, since the time of Cooney's article on glass sculpture (1960) this *shabti* has been overshadowed by a head of Amenhotep II himself, in blue glass (Corning 70.1.4) (Goldstein 1979), while the damaged head of a sphinx may also represent this king (BM EA16374). Not only does this point to the acceptance of this novel material for royal portraiture, but further emphasises the status of the medium as a possible royal monopoly. The *shabti*, one of two known, was probably a royal gift. It is notable that both date before the reign of Amenhotep III when large-scale glass production is first suggested by finds from Malkata.

Shabtis require considerably more glass than small vessels, as well as requiring some skill in their finishing, and the same is true of the glass stand of Amenhotep III (1427–1401 BC) (private collection) which may have served as the base for a figurine (Mehlman 1982: 32). Such solid pieces were probably the technological precursors of the headrests described below (p. 202). Pieces such as the Amenhotep II sphinx were probably produced by lost-wax casting, the details probably being refined on removal from the mould. This is contrary to the statement by Stern and Schlick-Nolte (1994: 31) that the technique was unknown during the second millennium BC.

Smaller objects were also produced in glass, though again serving the same purposes as examples in other media. Notable among these is the use of glass as inlay (Bianchi 1983a, 1983b). In these instances the technology as well as the use may have been very much akin to faience production. The changing relationships between these two crafts, and others, through time is a subject requiring further investigation.

At the time of *Ancient Egyptian Materials And Industries'* revision (1962) it was believed that 'from *c.* 1050–400 BC glass is almost unknown in Egypt' (Cooney 1960: 29). However, by the late 1970s evidence for some measure of continuity was beginning to emerge and with evidence such as a glass-inlaid shrine door of Darius (BM WA37496) and a still earlier one of Ahmose II (Emery, 1967: 143). Cooney (1981: 33) revised his opinion in favour of limited continuity. It may be better to think of the period 1050–400 BC as one of 'reduced output' and with a lower standard of craftsmanship yielding vessels such as those from the tomb of Nesikhons, a wife of Pinudjem II, High Priest of Amun, who died during the fifth regnal year of Siamun, a Twenty-first-Dynasty Pharaoh (*c.* 974 BC; see Fossing 1940: 20, fig. 12; Kaczmarczyk and Hedges 1983: 260; Nolte 1968: Taf. XXI and XXVIII). Cooney himself (1960: 33) notes that 'glassy faience', which is known from the Twenty-second Dynasty onwards, may to some extent have taken over from true glass during this period.

From the Late Period (712–332 BC) onwards, Egypt was increasingly drawn into the broader Mediterranean world, and as a result was more open to the influence of the Greeks. Moorey (1994: 199) states that from the Twenty-fourth to Twenty-sixth Dynasties there is no evidence for production of cast or cut vessels in Egypt, and that these are usually assigned to Phoenician workshops, albeit largely on stylistic grounds. From around 550 BC (Tatton-Brown and Andrews 1991: 42) Mediterranean glass workshops flourished and Classical vessel forms were imported into Egypt as well as made there (Nolte 1977b).

The raw materials of glass production

Surviving texts giving the ancient Egyptian recipes for glass-making or working are as yet unknown, so that the constituents used must be reconstructed from analyses and from knowledge of early texts from elsewhere.

Modern technology allows the production of glass from pure silica, which has a melting temperature of over 1700 °C, far in excess of that achievable in ancient times. However, the addition of an alkali (such as soda or potash) which serves as a flux, to the silica significantly lowers the melting temperature. According to Freestone (1991: 39) the addition of 20 per cent of such flux would reduce the melting temperature to under 1,000 °C. However, the resulting glass is chemically unstable, and will decay rapidly unless lime is added to the mixture to stabilise it. It is this soda-lime-silicate glass which is the first known from the archaeological record.

Procurement of raw materials

Silica is readily available in Egypt, since it is the main constituent of the desert sand. However, Petrie (1894: 26) believed that at Tell el-Amarna certain white quartz pebbles found in his excavations had once lined the floor of glass furnaces and that their continual heating and cooling would render them friable enough to be pulverised as high quality silica for faience- and glass-making. Lucas (1962: 185) however, noted the presence of high levels of iron oxides and aluminium in the glass produced which suggests that the source was impure sand rather than pure silica. He also makes the valid point that the frit discovered by Petrie at Amarna contains impurities inconsistent with pure silica, so that unless the frit was not being used in glass production (which is possible) then sand must be the silica source (Lucas 1962: 186).

Further support for the view that sand was used is to be found in the presence of lime (CaO) in the glass. Assyrian glass-making texts (e.g. BM WA120960) of the fourteenth to twelfth centuries BC (Schuler 1963; Oppenheim 1970: 62) make no mention of the deliberate addition of lime (Newton 1980: 175), although earlier translators were misled on this point (Thompson 1925; Gadd and Thompson 1936). Similarly, Classical authors – including Pliny – also make no comment on the adding of lime, and yet it is present in both Assyrian and Roman glass. The most likely explanation is that it was added unconsciously as an impurity with the sand. This would probably have made particular sand deposits especially prized for glass-making. The Amarna sand, for example, has been shown to comprise up to 18.86 per cent lime (Turner 1956a: 281T; for comparisons of Egyptian sands see Lucas 1962: 481 and Parodi 1908: 25–7).

Lucas (1962: 187) considered that the source of the alkali in Egyptian glass was natron, since he observed that soda (Na_2O) frequently comprises 15–20 per cent of the glass (*cf.* Lilquist and Brill 1993). He had difficulty, however, in accounting for the presence of potash (K_2O) in levels exceeding those found in naturally occurring natron. Parodi (1908: 28–9) had already made the point that the high levels of potash argued against natron, as Turner (1956a: 284T) notes. Lucas however, followed Geilmann (1955) in arguing that the presence of potash was a result of contamination of the frit by fuel ash. Caley, on the basis of work by Turner (1956a), suggests that perhaps 'the ash of the fuel employed to melt the glass was often incorporated into successive batches as one of the raw materials' (Caley 1962: 81).

Recent work has shown that magnesia (MgO) levels in excess of 1 per cent occur in those glasses with potash above 1 per cent, and this combination is indicative of the alkali source being from the burning of plant materials (Henderson 1989). The most suitable plants for this purpose are halophytes, notably members of the genus *Salicornia* and *Salsola*. The species represented in Egypt are *Salsola herbacea*, *S. fruticosa* and *S. Lignosa*. Löw (1924–34) writing earlier this century states that the first of these species was then common in Egypt, Syria, Judaea and Arabia. However, Täckholm and Drar (1956) state that its distribution is now confined to coastal areas and the northern part of Lower Egypt. If the first glass-makers were brought from Mitanni it is likely that they may have found similar alkali plants to those with which they were already familiar from their homeland. So far however, no species of the *Salsola* genus have been reported from archaeological contexts in Egypt. Numerous other plants could also have been used however, and the most suitable in each region would presumably have been chosen.

This so-called 'high magnesia' glass (HMG) using plant alkali is differentiated from glass of the Roman period which is 'low magnesia' (LMG) and typically has concentrations of both magnesia and potash below 1 per cent which is consistent with the use of natron (see Brill 1988).

The basic glass produced by these raw materials would have a greenish or brownish tinge resulting for the iron impurities found in the sand. In order to produce a colourless glass, or one with deliberate coloration it would have been necessary to add either a decoloriser or colorant material.

In fact it is much easier to colour than to decolorise glass. Despite this, colourless 'name beads' of Queen Hatshepsut (*c.* 1473–1458 BC) and her official Senenmut are known (BM EA26289–90; see Reeves 1986). These beads are compositionally similar to glasses from Amarna dating to about a century later (Bimson and Freestone 1988: 11). Some of the inlay in the seat-back of the throne from the tomb of Tutankhamun (KV62; *c.* 1333–1323 BC) is also of colourless glass, as are parts of a pair of earrings and other items from the tomb. The decoloriser may have been manganese (Mn), a mineral found as a weathering product of some iron-bearing rocks. Three oxides of the mineral (wad, pyrolusite and psilomelane) are recorded by Petrie from ancient sites (Petrie 1924: 262) but not known to have been used (Lucas and Harris 1962: 262). Nevertheless, oxides of manganese are widely distributed in Egypt (e.g. in the Red Sea hills and in outcrops of Nubian sandstone), and it seems certain that local sources would have been used to supply the glass industry. This same mineral could also be used to give glass an amethyst-purple colour, as is shown by analyses by Lucas (1962: 187) and others. Black could also be produced by the use of copper and manganese compounds (Neumann and Kotyga 1925: 858, 863).

The best-known of the colorants for Egyptian glass is cobalt (Co). There has been much discussion over the source of this material, with some workers suggesting sources as far away as central Europe (Dayton 1981; but see Kaczmarczyk and Hedges 1983: 301–2 for rejection of this). Some workers, notably Stern and Schlick-Nolte (1994), maintain that the source was Iran or Asia Minor; this may have been so for the very earliest blue glass, but Kaczmarczyk (1986) has identified the likely source of the mineral as the alum deposits of the Kharga and Dakhla Oases in the Western Desert. Here it occurs in association with manganese (Mn), iron (Fe), nickel (Ni) and zinc (Zn) as well as magnesium (Mg) and aluminium (Al). Kaczmarczyk subsequently identified these deposits as the source of the *wʿbt* referred to by the Egyptians (Kaczmarczyk 1991; Harris 1961: 185–9). Also noteworthy is Kaczmarczyk's comment (1986: 373) that the 'particular historic period (New Kingdom) during which cobalt became a recognised pigment in Egypt suggests that the use of the substance might have been learned in Asia, but it would not have taken the enterprising Egyptians long to discover their own source of the mineral in their own backyard.' This would support the suggestion that the craft of glass-making was first brought to Egypt from Asia and quickly adopted and developed by native craftsmen.

Kaczmarczyk's analyses also led him to suggest that the Egyptian cobalt source was in use only from the sixteenth until the eleventh century BC. After that date, no cobalt seems to have been used in Egypt until the seventh century BC, when its occurrence in glass and faience is associated with different minerals, suggesting a different source. It is this later source that is probably to be located in Iran (Kaczmarczyk 1986: 373–4).

Exploitation of the alum deposits of Dakhla and Kharga is known to have taken place in ancient times and there is extensive evidence of mining (Beadnell 1901, 1909; Lucas 1962: 257–9). Lucas was aware of the presence of cobalt in the deposits mined but did not believe that the Egyptians were capable of extracting it (Lucas 1962: 260; see also Segnit 1987). Expeditions to obtain alum would presumably have been under state control, and the value of the deposits can only be regarded as higher if the precious blue colorant was extracted from them afterwards. This may be a factor in keeping the production of glass as a royal monopoly. It should be noted that the cobalt aluminate in its raw state is pinkish, rather than blue, in colour and requires processing to render it usable. This process has been described by Noll (1981: 50) and by Kaczmarczyk (1986: 372–3). It is suggested that the alum was mixed with water and natron, plant-ash or ammonia added to make it slightly alkaline. It would then be precipitated, and the precipitate heated at between 800 °C and 1,000 °C to produce the blue pigment.

Copper could be used to produce a turquoise-blue glass. Copper ores are found in Egypt, particularly in Sinai and were widely exploited in ancient times both for metallurgy and use as pigments (see Chapters 4 and 6, this volume). Glass- and faience-making may be practised alongside pigment production at Amarna (Nicholson 1996), and it is not surprising to find copper being added to glass as a colouring medium. It is the preferred colorant in the glass excavated at Lisht which probably dates to the Nineteenth or Twentieth Dynasty (Keller 1983: 25). This may represent either a different grade of workshop, or difficulties in the supply of cobalt due to slackening central authority.

As well as colouring translucent or transparent glass, the glass could be made opaque, and/or coloured white, by the use of tin. The use of tin for this purpose was identified in early compositonal studies such as those of Neumann and Kotyga (1925: 776–80, 857–64) and Parodi (1908). Lucas himself identified a lump of tin oxide from the tomb of Tutankhamun (KV62; Lucas 1933: 176–7). Antimony (Sb) was also used to render glass opaque in certain colours, as well as being used to make yellow glass when added with iron in concentrations above impurity levels. Both manganese and antimony can produce yellows, amber, brown and black, when used in association with additional iron, and Sayre (1963) has shown that they were used in this way prior to the discovery of their use as decolorants (see also Bimson and Werner 1969a). Lucas (1962: 195–9) is insistent that antimony was readily available only as an impurity in copper in Egypt, although notes that it has been detected as a colorant in yellow glass (Lucas 1962: 190). It may be one of a number of glass-making ingredients which were not individually recognised, but whose source was prized for the properties its compound materials imparted to glass. Brill *et al.* (1974) record that the yellow colouring of Egyptian glass used a local lead source, distinct from that of Mesopotamia. Kaczmarczyk and Hedges (1983) also argue that antimony oxide might have been used in the making of clear glass from the Twenty-sixth Dynasty (see Moorey 1994: 199).

Red glass is particularly difficult to produce, but appears to have been a speciality of the workshops of Qantir dating to around the time of Ramesses II (*c.* 1290–1224 BC; see Rehren 1997; Rehren and Pusch 1997). The colorant used was evidently copper, and the workshop was probably associated with the enormous bronze foundry discovered at the site (Pusch 1990). Red glass has probably been under-recorded by Egyptologists due to its tendency to discolour to green.

Rehren (1997: 364–5) believes that the red glass was produced in crucibles heated by blowpipes to temperatures around 1,150 °C and notes a series of 'hot spots' on the vessels (which are the type elsewhere referred to as cylindrical vessels or ingot moulds). These hot spots have not been observed by Nicholson on vessels from Amarna (but see Rehren 1997: 365), suggesting that this method of heating was only applied to vessels used to produce red glass. The colorant was added to the molten glass in these crucibles.

Secondary processing: the making of raw glass

Once the necessary raw materials for glass production had been procured, they had to be combined to form a glass. It has already been noted that the melting temperature of silica alone (*c.* 1700 °C) was too high to have been reached by the ancient Egyptians, and that the addition of flux was necessary, along with lime as a stabliliser. The combining of these ingredients however, would not have been a simple matter for the ancient Egyptians, and indeed glass-making remained precarious well beyond the middle of the nineteenth century AD (Turner 1956a: 298T). It is likely that it was undertaken in stages as originally suggested by Petrie (1894: 25–6).

The raw materials would first have been ground as finely as possible and mixed together. In the case of the plant ash any incompletely burned material would have been removed. Once thoroughly mixed, the ingredients would have been heated together in the process known as 'fritting'. This process is mentioned by several early scholars including Pliny, the monk Theophilus (tenth century AD) and Neri (AD 1612). Neri stresses the importance of the ingredients reacting together without becoming liquid. In other words what is described is a solid-state reaction. Work by Howarth *et al.* (1934) has shown that, for a soda-lime-silica glass of modern composition, the sand grains are acted upon by the sodium carbonate from temperatures below 600 °C, but that the ingredients remain in powder form below 700 °C. From about 750 °C the ingredients become sintered together, or 'fritted', so that the fritting process can be said to take place between 750 and 850 °C.

During the process, the ingredients are continually stirred though the duration of this operation is unclear. Theophilus states that this is for 'the space of a day and a night' while Neri allows for the 'space of five hours' (both quoted in Turner 1956a: 293T). The duration of the process will depend upon the exact composition of the ingredients, their proportions and the temperature and redox conditions of the fritting furnace (Turner 1956a: 293T). The purpose of this exercise was to combine the materials in such a way that much of the gas produced in the reaction would be lost to the atmosphere. If the process had been continued and the frit allowed to melt the gases would form as bubbles (known as seed) in the glass. The viscosity of the glass (*cf.* Vandiver *et al.* 1991: 609) would not allow the bubbles to escape leading to a poor quality product. Furthermore, any unreacted solid material (known as stones) would remain in the finished glass.

After fritting, the finished product would be allowed to cool and would then be ground up. At this stage any large unreacted particles could be removed. This is much the same process as that used by the ancient Egyptians to produce 'Egyptian blue' pigment, sometimes known as 'blue frit', which was used both as a pigment and in the manufacture of objects (Tite 1986; Tite and Bimson 1987; Weatherhead and Buckley 1989). Recent work at Amarna (Nicholson 1995) suggests that pigment manufacture was carried out alongside glass production, probably because of this sharing of technology (below).

Petrie believed that the ingredients were fritted in pans of 10″ (25 cm) diameter and 3″ (7.5 cm) deep (Fig. 8.1). He based this statement on a fragment of a pan of frit from Amarna (Petrie Museum, UC36457) which clearly preserves the profile of the vessel in which it was produced. The frit also shows numerous white flecks of unreacted silica and a large number of vesicles where gases had formed in the spongy mass. No actual fritting vessels are known to the writer from Amarna or elsewhere though small sherds of possible examples are known.

He believed that at Amarna the glass would then be melted in vessels 'deeper than the fritting pans; being about two or three inches in depth and diameter' (Petrie 1894: 26). This clearly contradicts his first statement, and is further confused in some of his later descriptions (Petrie 1909: 124, 1925 ; see Nicholson 1995: 12). However, evidence for these melting vessels or crucibles is difficult to find. A piece of glass which Petrie (1894: pl. XIII/no. 40) believed to preserve the outline of the vessel has not been certainly identified, but it may be UC25042 in the Petrie Museum. If so, then the profile is not original and cannot be used to reconstruct the vessel. Nevertheless, it is clear that some kind of melting vessel must have been used, and

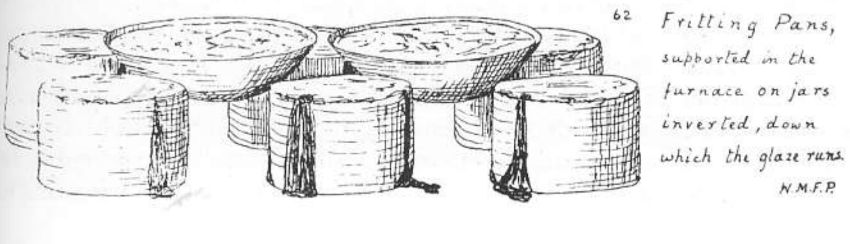


Figure 8.1: Petrie's reconstruction of the glass-making process. Pans of frit are supported on the inverted cylindrical vessels now believed by Nicholson to be actual crucibles/ingot moulds.

it is quite likely to have been of a fairly small size, although it is an open question as to how many might have been arranged in a furnace. The temperature at which the glass melted is still a matter of some uncertainty, but is believed to have been between 1,000 and 1,200 °C. At these temperatures the glass would not have been fluid, but a sticky viscous mass with a viscosity of 10E7.9 or even 10E10 which Vandiver *et al.* describe as the consistency of 'taffy' or even 'cheddar cheese' (1991: 609).

At such viscosities, any gas bubbles which formed as a result of the continued reaction between the raw materials would tend to become trapped in the finished glass and it is even possible that the glass might have been ground up and re-melted, possibly several times, in order to improve the quality.

A third class of ceramic vessel described by Petrie has been the source of much speculation. These vessels are described as 'cylindrical jars, about seven inches across and five inches high' (Petrie 1894: 26). They frequently had runs of glass, which he believed ran from base to rim, suggesting that they stood upside down, and he duly reconstructed them as stands on which the fritting pans or melting vessels rested (1894: pl. XIII no. 64; see also Fig. 8.1 here). Although Turner (1954) was slightly misled by the contradicitons in Petrie's accounts (see Nicholson 1995: 12), it was clear to him that some of these vessels actually contained raw glass and that they could not therefore have served exclusively as stands. Many further examples with glass on their interiors have now been discovered (e.g. Nicholson 1993: 51 fig. 42). Turner (1954: 440T) also noted that the interiors of these vessels were treated with a white slip. Such a slip is unknown from any other type of vessel from Amarna, or indeed other sites. Analyses of the slip by Turner (1954: 441T) showed it to be high in CaO. This would firstly help to prevent discoloration of clear glass by iron contained in the clay from which the vessel was made, and secondly – probably more importantly – facilitate the release of the glass from the vessel after cooling, since it seems clear that most of the pots were deliberately broken to extract the glass.

Turner considered the vessels to be 'melting crucibles' (1954, figs. 2a–c), and in the absence of certain evidence for smaller crucibles this may well be so. However, new evidence suggests that they might have had still greater importance.

Excavation of the Ulu Burun shipwreck off the Turkish coast has yielded numerous circular glass ingots contemporary with the New Kingdom (Bass 1986, 1987; Bass *et al.* 1989), in fact timber from the wreck has recently been dated by dendrochronology to 1316 BC (reported by Eisenberg 1996: 49). These ingots clearly show concentric ridges and grooves on their undersides (Bass 1987: 716 – plate) which are matched in negative by similar structures on the interior of the cylindrical vessels from Amarna. Thanks to the generosity of Professors Bass and Pulak of the Ulu Burun project a cast of one such ingot was made available to the writer and has been found to fit snugly into several of the cylindrical vessels from Amarna. Others have recently been examined and found to confirm this view (Nicholson *et al.* 1997).

In the opinion of the writer, there is no doubt that the cylindrical vessels were ingot moulds, although they probably also served as crucibles and the glass was allowed to cool in them. The colorant may have been added during the process or it may have been mixed with the ingredients from the start. Rehren (1997) has noted that similar moulds known from Qantir have been found to match an ingot of (now discoloured) red glass in the Cairo Museum (JE64296) found by Hamza at Qantir in 1928, further confirmation of their function (see Hamza 1930; Rehren and Pusch 1997).

Since Petrie's time, and more especially since the 1950s, there has been a shift away from the view that glass was actually made in Egypt, and towards the belief that the Egyptians depended on imported raw material, which they then simply re-melted (Newton 1980: 176). Although not yet fully published, analyses of the Ulu Burun ingots are said to show them to be of a composition closely similar to Egyptian and Mycenaean cobalt-blue glass of the time (Bass 1987: 718; Jackson *et al.* 1998), and given the source of cobalt mentioned above this strongly argues for New Kingdom glass export from Egypt. Consequently, those who argue for the import of all glass to Egypt must satisfactorily explain the presence of ingot moulds from at least as early as the reign of Akhenaten. One way of doing this would be to suggest that colorant was added to imported glass in these moulds (see Rehren and Pusch 1997) but, in the opinion of this writer, such a theory seems unlikely.

It was long believed that a series of elongated ingots with a hemispherical cross-section (MMA 26.7.1162 and 18.2.12, Freer Gallery 09.856, V&A C10–1946, BM EA67068–67070) were ancient glass ingots, but Cooney (1981) has convincingly shown them to be fragments from the decoration of a mosque. He also notes two Twentieth-Dynasty ingots with rectangular cross section, excavated from Tell el-Yahudiya (Cooney 1981: 32). In view of this evidence, our only certain ingots are the one from Qantir, those from Tell el-Yahudiya (not seen by the present writer) and probably those from Ulu Burun. A large lump of blue glass from Lisht (MMA 22.1.1201) should probably also be regarded as an ingot of some kind, although this is less certain. It should be noted that the term ingot is not well-defined, and that there are probably other lumps of glass which were cast in workshops simply for local use, thus having nothing to do with an organised glass trade.

Once ingots had been produced, they might be transferred to other factories for processing or even be exported as the Ulu Burun ingots might indicate, but whatever the case they would need to be broken up and worked.

Understanding of the glass-making process has been hindered by the lack of any actual glass furnaces dating to

Pharaonic times. While Petrie's excavations at Amarna yielded much material which had been, or was thought to have been, associated with furnaces no actual structures were found, either for glass- or faience-firing, and Petrie is quite specific on this point: 'Of the furnaces used for glass making we have no example' (Petrie 1894: 26). However, because of his plausible description of the firing process this lack of actual furnaces has often been overlooked and so has led to confusion (e.g. Vandiver 1983: A30).

A recent attempt to locate one of the glass- and glazing-works mentioned by Petrie (1894), who gives no precise location for these workshops, has led to the excavation of kilns and furnaces at site O45.1 at Amarna (Nicholson 1995; see Fig. 8.2). There are four such structures in all; one is certainly a pottery kiln, another may be for pottery or faience/pigment-making while the two largest are believed by the writer to be for glass-making. These two furnaces are of larger size than might have been expected, but their massive construction, with walls three bricks thick, is clearly designed to help conserve heat. Furthermore, a 'sacrificial render' of mud-plaster lines these structures and has become heavily vitrified during the firings. This is not a phenomenon known from any pottery kiln at Amarna.

There is some evidence from the best-preserved of the large furnaces to suggest that they were originally covered by a low dome. This would be expected on a furnace working at the limits of updraught kiln technology. Examination of the heavily vitrifed furnace lining suggests that there were a series of ports around the furnace at approximately ground level and that these opened onto small shelves protruding from the walls. There is no evidence for a perforated floor spanning the entire furnace. Although no actual stokehole was found, the only area of damage to the furnace walls is on the north side where a later wall overlies them. The footings of this later wall are deliberately built up on the northern side, probably in order to fill the void left by the stoke hole. If this supposition is correct, then the furnaces could have made use of the prevailing wind blowing from the north.

Quantities of charcoal have been discovered embedded in the vitrified material and a sample of this has been found to be *Ficus sycomorus*, the sycomore fig (Mary Anne Murray pers. comm.). Some pieces of this charcoal are in long lengths, suggesting that it became charcoal during the firing, rather than having been deliberately produced in a separate process (Dr Caroline Vermeeren pers. comm.). A structure discovered by Petrie (1894: 36 and pl. 42) and believed by him to have been used for charcoal production may therefore have been used for some other purpose, or alternatively the charcoal produced in it may have been used for some other manufacturing process (see also Chapter 7, this volume).

The size of these furnaces has led to suggestions that they could not have been for glass-making, since it would be impossible to achieve the desired temperatures, particularly without some forced-draught system (see Nicholson 1996). In order to test this view, a full-size replica of the best-preserved furnace was reconstructed and used to fire glass (see Nicholson and Jackson 1998; Fig. 8.3). Temperatures in excess of 1,100 °C were readily achieved and maintained, and it proved possible to produce both blue frit and cobalt-blue glass from basic raw materials (plant ashes, Amarna sand and cobalt). The cobalt-blue glass was achieved in a single stage, without the need for producing frit in a separate firing. No forced draught was used, the prevailing wind being quite sufficient.

While such experimental archaeology can never prove that these furnaces were actually used for glass-making, the work has demonstrated that the furnaces were not too large to achieve the necessary temperatures and that they

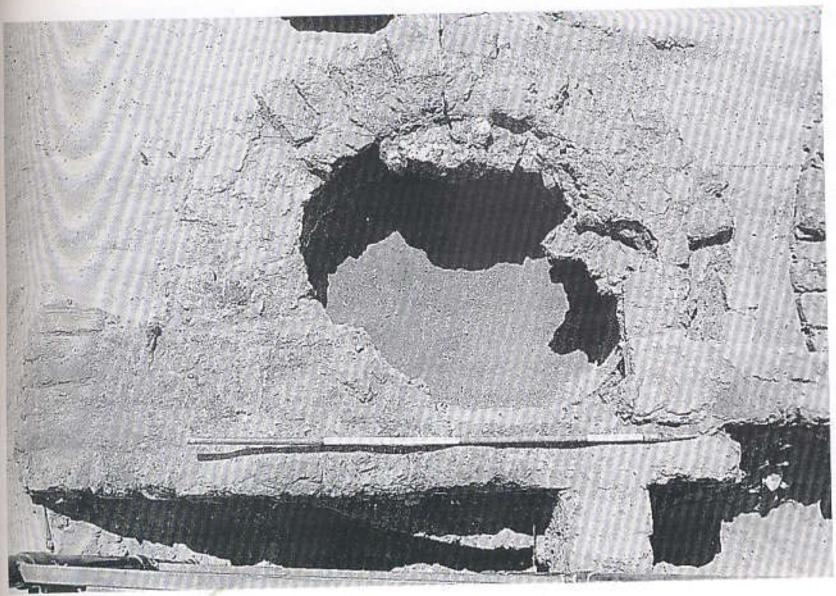


Figure 8.2 'Kiln 3' at site O45.1, Amarna. A small 'embayment' can be seen at the right (west) from which an area of heavily vitrified material runs to the top (south). Notice the complicated brickwork pattern. The scale is 2.0 metres long.

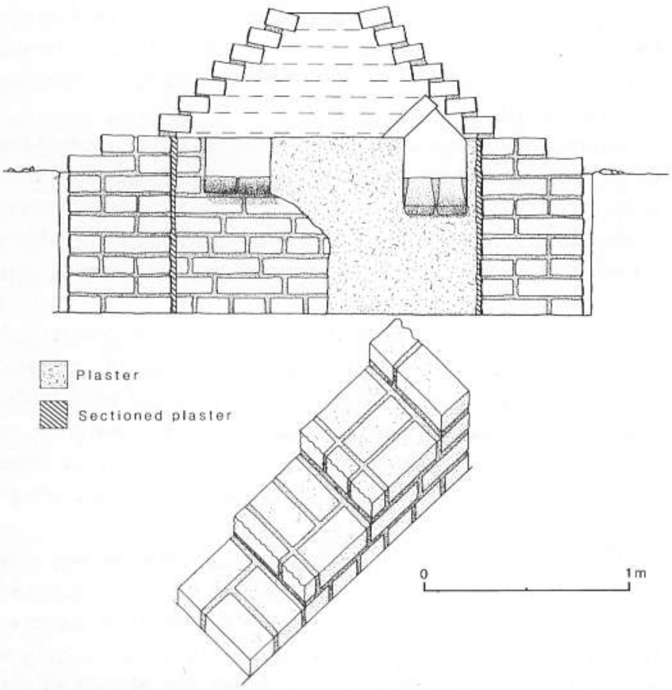


Figure 8.3 *(Top) Schematic cross section through the reconstructed furnace. The stokehole, with sloping 'chute' can be seen to the right, whilst one of the protruding shelves is seen to the left. Note the thickness of the walls and the complicated brick pattern. (Bottom) Schematic diagram to show the complicated pattern of brickwork found in 'Kiln 3' at site O45.1 and used in the replica furnace. Wavy lines indicate where bricks have been cut away for clarity.*

would have been capable of making glass. It has also been shown that the fritting stage may not have been necessary. When combined with the glass finds from building O45.1 at Amarna, the balance of probability currently suggests that they are the earliest glass furnaces so far known from Egypt, or indeed elsewhere (Jackson *et al.* 1998).

Tertiary processing: the manufacture of glass artefacts

Stern and Schlick-Nolte (1994) have recently identified a number of different types of glass-working used in the production of artefacts. The simplest of these is that most closely related to what is now called 'lamp-work', the use of a concentrated flame to heat glass during shaping. These authors argue that most ancient glass-workers used an open hearth assisted by bellows but were unable to achieve the concentrated heat used by modern lamp-workers. Instead they softened pieces of glass and shaped them over the fire, a technique suitable for the manufacture of beads and amulets. A similar technique might be employed to press viscous glass into an open-face mould so that the material could be formed in much the same way as faience. In such instances a parting agent would be needed, and Stern and Schlick-Nolte (1994: 23) suggest bone ash as one such medium.

This technique of softening pieces of glass for working, or even blowing in later times, over the fire or in a furnace is referred to as 'chunk gathering' since a heated rod is used to pick up glass chunks for heating. Pincers might also be used in the shaping process.

Given that glass frequently seems to have played the part of an artificial precious stone, it is perhaps not surprising to find that it is sometimes worked in the same way. A small kohl jar of the early Eighteenth Dynasty (BM EA24391) appears to have been solid cast and then to have had its interior drilled out in the same manner as for a stone vase. The degree to which the exterior shape of vessels and other objects was cast rather than carved is still a matter of some debate. Egyptian glass would have had a viscosity sufficiently high to prevent it being poured in the way one might cast bronze. This would make pouring into a mould almost impossible. Instead the glass would have had to be added to the continually heated mould as a powder and gradually melted until the hollow shape was full. This may have been the technique used to cast the delicate clam-shell vessels which were probably made at Malkata or Amarna (e.g. BM EA65774), and Harden (1968: 51–2) believes it to be the method used to produce a small seated figure of Tutankhamun in blue glass (Cairo JE60719).

Perhaps the most spectacular examples of cold working (following casting) are two headrests from the tomb of Tutankhamun. A turquoise example (Cairo Tutankhamun Collection 531, Carter's No. 403a) is made in two parts and joined at the stem, the junction being hidden by an inscribed gold band (Harden 1956: 319; Newton and Davison, 1989: 69). The other piece (Cairo SR641) is dark blue and has the edge banded in gold foil. It is again likely that the basic outlines were cast, and the faceting then carved. This raises the question of how such large pieces were cast, and one must assume that powdered glass was again used. They would amply repay a more detailed scientific examination.

Stern and Schlick-Nolte (1994) believe that virtually all glass-working was done at the open hearth, and that annealing could have been carried out by burying the vessel in embers, rather in the manner suggested by Henein and Gout (1974) in their study of contemporary Cairo glass-workers. While this view of open-hearth working has much to commend it it should be borne in mind that it stems partly from the lack of recognised furnaces such as those now beginning to emerge at Amarna. It is not improbable that at least such large pieces as the headrests might have been cast in moulds placed in a furnace and allowed to cool there.

Moulding was probably the technique employed in the manufacture of certain open forms, such as the conglomerate glass bowls known from Malkata and elsewhere. These comprise small fragments of coloured glass fused together (e.g. Brooklyn 48.162; see Riefstahl 1968: pl. III). This is a precursor of the well known later (European) millefiore technique. A one- or two-piece mould would be used, and the product would require considerable finishing by abrasion

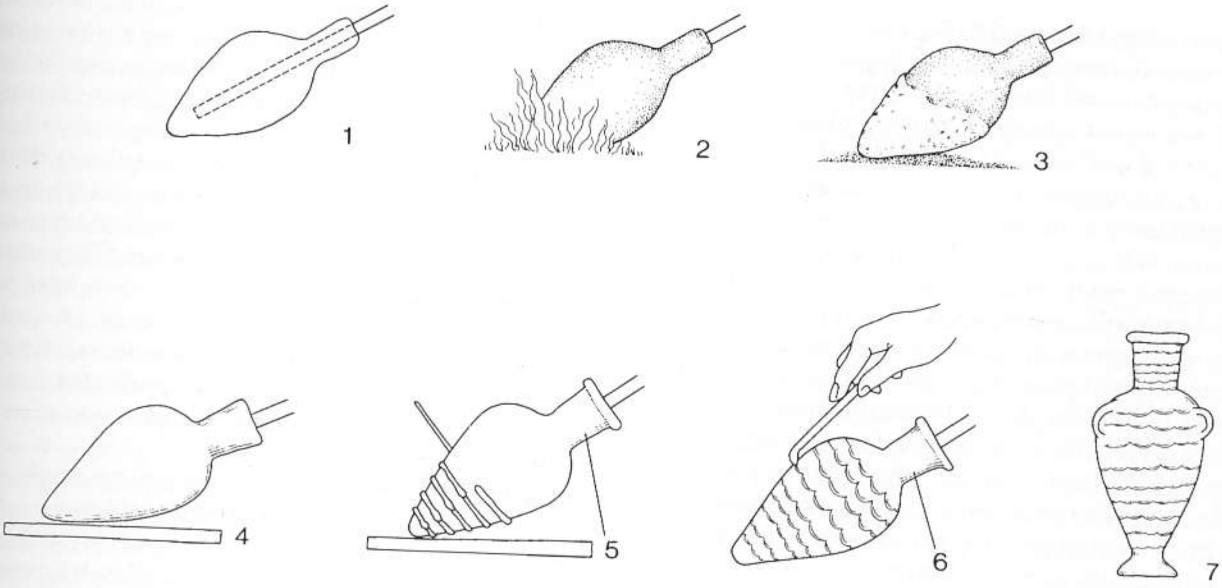


Figure 8.4 Making a glass vessel by the core forming process. 1. A core of clay and dung is formed around a handling piece. It has the form of the inside of a finished vessel. 2. The core is heated so that powdered glass will adhere to it. 3. The heated core is rolled in powdered glass and built up around the core. 4. The heated glass is rolled on a marver stone. 5. Bands of coloured glass are applied in rings around the vessel and marvered in. A similar band is added to the rim of the vessel. 6. The bands of coloured glass are pulled down with a tool to make a 'feathered' pattern. 7. The completed vessel, with foot shaped and handles added. The vessel will be annealed at this stage and the core and handling piece removed.

and/or fire-polishing, after its removal from the mould.

The best-known technique of Egyptian glass manufacture however, is core forming (see Fig. 8.4). This was the technique used to manufacture vessels, and has been the subject of considerable research. It was originally referred to as the 'sand core' technique (Petrie 1894: 27), but this term has been abandoned in the light of recent studies. Bimson and Werner (1969a and b) examined the cores from two objects in the British Museum, one of them a glass coffin (BM EA66654, Bimson and Shore 1966) and the other a Cypriot bottle. In both cases, the core was found to comprise 'a flaky mass of a dark brown material through which were scattered white siliceous skeletal remains of seeds and small fragments of leaves thus indicating . . . a large amount of organic matter . . .' (Bimson and Werner 1969a: 265). These had been covered with a highly ferruginous clay which in turn was coated with a finely ground mixture of limestone/calcite and the same iron-rich clay. Wosinski and Brill (1968) also reject the idea of sand cores and their work broadly supports that of Bimson and Werner, although they note the possiblity that the organic material derived from dung, and found no evidence of a calcareous layer on the exterior of the core.

Previous, experimental, studies of core material, such as those of Schuler (1962), had assumed that the core was rigid. Consequently, when the glass cooled on contraction it tended to do so at a greater rate than the core, leading to cracking. The more friable, organic-rich core was capable of contracting, not least into the voids left by the burning out of plant material. At the centre of the core must have been some kind of rod or handle by which it could be manipulated, this would be removed when the core was crumbled out of the vessel on completion.

The question of how the glass was applied to the core remains contentious. Petrie (1894: 27) opted for the most obvious explanation; the dipping of the core into the molten glass. However, the temperatures likely to have been achieved by Egyptian glass-workers at this time might make this difficult, since the glass would be very viscous and difficult to deposit evenly around the core. Schuler (1962) conducted dipping experiments, building up several thin layers of glass, but was led to the conclusion that core formed vessels were made by lost-wax casting around the core, a view which has, however, found little archaeological support. Stern and Schlick-Nolte (1994: 30) note that Kühne's (1969) experiments, in which dipping of a core was successful, were carried out at temperatures of 1,100 °C, probably higher than the temperature at which Egyptian glass was worked.

Labino (1966) successfully made a vessel by trailing the viscous glass onto a core while rotating it. He then smoothed the walls using a wooden paddle. Although the method has gained wide acceptance, and examples of Labino's work are well-known, Stern and Schlick-Nolte (1994: 31) argue convincingly that Egyptian glass does not show the spiral trails of glass which would be expected from this technique, particularly where the trails were in contact with the core.

The technique favoured in the most recent study (Stern and Schlick-Nolte 1994: 31) is the application of powdered glass to a pre-heated core, by rolling it in the glass. The core would then be heated again to melt the glass, and more and more applied until several layers had been built up. This is a variant of a suggestion made by Schuler (1962: 36) who attempted to dip a core into a suspension of powdered glass and water. While it is clear that there is scope for further experimental work, it is equally apparent that several methods might have been used.

From Amarna and elsewhere come numerous rods or canes of coloured glass. The main function of these seems to be for the application of decoration to the vessel body. The rods were softened and wound around the vessel, but not as a spiral (a feature of first-millennium Mediterranean vessels, see Nolte 1977b). They would be impressed into the body by marvering on a flat surface (probably stone), and were often trailed to make chevrons, swags or feather patterns (for a typology see Nolte 1968: 40–1).

The foot of the vessel would be formed from the body glass, and, like the rim, it might also be decorated by the application of rod or cane. Handles could also be added to vessels. Nolte (1968: 31) states that the earlier glass vessels had handles which were strengthened with metal inlays inside the glass (e.g. CG24829–30; see Daressy 1902). Fossing (1940: 16), following Daressy (1902), argues that the reinforcement was bronze tubing. Detailed technological study of these pieces would be desirable.

The completed vessel would need to be cooled slowly; the process known as annealing. Modern practice is to have an annealing oven next to the main furnace, where completed pieces are put to cool, however there is no evidence for this in ancient times. Stern and Schlick-Nolte (1994) believe that working took place over the open fire, and that it would be within the ashes from this that the finished items were buried for annealing. A small ash-filled hearth is known from excavations by the writer at Amarna, but there is as yet nothing to connect it with this process. If furnaces were used in working, the pieces could have been allowed to cool in them. Until the function of the Amarna furnaces is further elucidated, this remains speculation.

After cooling, the friable core would be broken up and removed via the vessel neck. In narrow-necked vessels it frequently proved impossible to completely remove the core from under the shoulders of the vessel, and it is often traces of core which make ancient Egyptian glass appear more opaque than might be expected.

Industrial organisation

It is clear from Petrie's (1894) account, and from the recent work at Amarna site O45.1 (Nicholson 1995), that glass production did not take place in isolation. At Amarna it seems that glass-making and glass-working were both taking place in the same areas as faience production, and quite possibly also the making of blue pigment (Weatherhead and Buckley 1989). There is, in addition, clear evidence for the production of pottery at site O45.1, so that the appearance given is of a specialised vitreous materials 'quarter'. There is, as yet, no sign of metal-working in the area.

There are stratigraphic reasons for placing site O45.1 into an early phase of the development of Amarna, something which must strengthen the likelihood that the vitreous products may have been manufactured under direct royal control. Since glass, faience and blue-painted pottery, as well as blue pigment, can all make use of cobalt, and since the occurrence of this material is limited, it may well be that where we find clusters of industries using this limited resource they may be doing so as part of an enterprise subject to direct state control.

As well as the use of cobalt, there is the more general use of high temperatures in the production of faience and glass, and it may well be that the production of at least these two, and possibly also pigment, might in some way have been regarded as a 'vitreous materials industry' rather than as distinct crafts.

However, the distinction between glass-making and glass-working is here an important one. O45.1 has some evidence for both of these, though the emphasis, as presently understood, is on making. Other sites at Amarna, however, preserve evidence for glass-working and these may have been under much less direct control. Boyce (1989: 161) and Vandiver (1983: A108) note the possibility of adding glass to faience finger-rings as a means of strengthening them as well as extending the range of possible colours. This reinforces the relationship between glass- and faience-working.

According to Boyce (1989: 61–2), 'Both large and small [faience] workshops could have co-existed in a manner analogous to that of pottery manufacture at the site. The considerable numbers of faience inlays needed for official buildings at Amarna could have created the need for large organised centres of manufacture, while the majority of the population's requirements were met by smaller localised workshops'. The distribution of some of these workshop areas has recently been published (Boyce 1995). It was probably at these smaller establishments that glass was worked for adding to faience and perhaps – in some – worked into vessels. The making of the raw glass may have remained centralised at sites such as O45.1, which then supplied glass in the form of glass rod or cane to these lesser workshops.

It is unfortunate that we do not know more about Malkata, since the workshops there were probably the direct ancestors of the Amarna workshops, and while it is known that both glass production of some kind and faience-making went on at Malkata, their relationship is not known. Malkata seems to have been the original source of the conglomerate glass bowls known from numerous fragments at the site, and which are the precursors of true mosaic glass.

The site of Gurob in the Fayum is also likely to have been a production centre, operating from the reign of Amenhotep III (1479–1425 BC) to that of Rameses II (*c.* 1290–1224 BC; Tatton-Brown and Andrews 1991: 31). Petrie recovered a collection of glass vessels from the site (Petrie 1891: 16–18: 1892: 132–3) but these were from domestic contexts, therefore the presence of the workshop itself can only be inferred. It is possible however, that Gurob supplied glass products to Lower Egypt, notably the royal court at Memphis.

As yet the evidence from Qantir (Rehren and Pusch 1997) does not include actual glass workshop remains, only the debris from them. Nevertheless, the detailed work carried out on these finds has reconstructed the specialised process of making red glass (Rehren 1997). Given the nature of the site as the Rammesside capital it is not unlikely that these specialised workshops were also under royal control. As at Amarna, there is ample evidence to suggest that glass production was going on alongside the making of faience objects (see Hamza 1930), again suggesting the possibility of a more generalised vitreous materials industry.

Newberry (1920: 156) records a 'factory site' on the east bank of the Nile, south of el-Mansha (near Akhmim in Middle Egypt). Its status as a factory has been questioned by Keller (1983: 20), who assumes that Newberry had simply been told of the site as a source of artefacts looted elsewhere. However, Newberry in fact seems to have visited the site and found glass manufacturing debris there (1920: 156). Unfortunately it is not possible to speculate further on the nature of this site nor on its connections – if any – with other crafts. Tatton-Brown and Andrews (1991: 33) suggest that this site may have taken over from Malkata as the main supply centre for Thebes.

The work of Keller (1983) at Lisht has already been cited as illustrating clear differences between that site and Amarna, in that the predominant colouring agent for the blue glass seems to be copper. There are numerous reasons why this might be, including preference and chronological differences but it is also possible that it represents a different kind of organisation, perhaps less directly related to royal control. The large block of glass from the site might suggest glass-making, or at least substantial glass-working, but without further excavation it is impossible to tell.

Our evidence suggests that faience, glass and glassy faience may not at all times have been regarded as distinct materials, but rather as part of a generalised vitreous materials industry. In this case the apparent decline in production after the New Kingdom may be apparent to us but not to the Egyptians themselves.

Related materials

In view of the confusion which frequently occurs over faience, Egyptian blue 'frits' and glass, it may be helpful to briefly review these related materials. Recent work (Tite 1986; Tite and Bimson 1987) has resulted in the division of frits into two groups, firstly blue frits, the dominant crystalline phase of which is a calcium-copper tetrasilicate known as 'Egyptian blue' ($CaO.CuO.4SiO_2$) in a very limited matrix of glass, and secondly turquoise-blue frits in which the dominant phase other than quartz is a calcium silicate known as wollastonite ($CaSiO_3$) which is crystallised from the copper rich glass matrix (Fig. 8.5). The frits can each be subdivided into coarse- and fine-textured, the coarse normally representing the first stage of production, after which it would be ground finer and moulded into artefacts or used as a pigment (Weatherhead and Buckley 1989).

Egyptian blue appears to be an Egyptian invention and, although of much greater antiquity, is closely allied to glass. Its texture may be so fine that it is virtually indistinguishable from glass, especially if the latter is weathered. It is known by the Fourth Dynasty (Ullrich 1979) and undergoes gradual refinement, becoming increasingly glass-like, into the early Roman period. It was known to the Greeks as *kyanos* (Cooney 1976: 37), while Vitruvius (VII, 11; see Morgan 1914) refers to it as *caeruleum*, which was believed in his time to have been invented at Alexandria. Egyptian blue, in both coarse and fine form, is a frit. This is the product of a solid state reaction similar to that used in the first stages of Egyptian glass manufacture. Despite the possible confusion with glass, the frits are easily distinguished from faience when a broken section can be viewed, which illustrates the lack of a core; they are homogeneous throughout and have no separate glaze layer.

Egyptian blue may be used both in the manufacture of objects and as a pigment (Chase 1971; Bayer and Wiedmann 1976; see also Chapter 4, this volume).

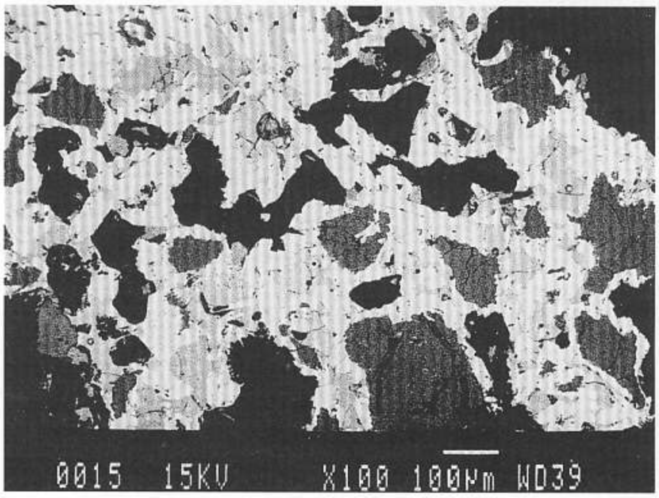


Figure 8.5 Scanning electron microscope photograph of 'Egyptian blue' from a Roman mosaic of the second century AD (BM EB14122). Unreacted quartz appears dark grey, crystals of Egyptian blue as white and the glass matrix as light grey.

[HENDERSON – ANALYSIS]

Chemical analysis of ancient Egyptian glass and its archaeological interpretation

Introduction

Since Lucas (1948) published his account of ancient Egyptian glass, much scientific research has been devoted to its chemical composition. Building on seminal analytical work by Farnsworth and Ritchie (1938) and Turner (1954, 1956a and b), several review papers have been published, discussing the kinds of information that can derive from Egyptian glass analyses. An early paper by Sayre and Smith (1961) provided clear evidence for at least five distinct compositional groupings, of which Egyptian glasses fell into the 'second millennium BC' group (soda-lime-silica, with high magnesia). Despite some criticism of the paper, the groupings have stood the test of time, especially for glasses from reliable archaeological contexts; other compositional types can now be added.

Two early papers by Brill (1963, 1968) provide more clear evidence for distinct compositional groupings of ancient Egyptian glasses, which relate directly to the use of discrete combinations of raw materials in the glass batch. Kaczmarzyck (1986) appeared to show that there was a link between the chemical analyses of cobalt and associated impurities in Egyptian cobalt-blue glasses and faience (Kazmarzyck and Hedges 1983) and the impurities found in Egyptian alum, a source of cobalt. Other review papers which incorporate a discussion of Egyptian glass technology have been published (Henderson 1985, 1989; Freestone 1991). However, of most significance to this work is a recent comprehensive survey of Egyptian glass by Lilyquist and Brill (1993), which includes chemical analyses of glasses dating back to the reigns of Hatshepsut, Thutmose III and Amenhotep II (Lilyquist and Brill 1993: 36, table 2).

The techniques used for the chemical analysis of Egyptian glass

Arc-source emission spectrometry (AES) and its applications

Early techniques used for the analysis of Egyptian glass involved either destruction of the artefact or, at least, the removal of samples. Almost all of these were conventional forms of wet chemical analysis which tended to be time-consuming; wet chemistry involves the dissolution of the material being analysed. They included 'classical' methods such as gravimetric, colorimetric, flame photometric, electrolytic and redox titration determinations.

One of these techniques, the one most frequently used for the chemical analysis of ancient Egyptian glass and other vitreous materials (Hedges and Moorey 1975), from the 1930s until about 1960, was arc-source emission spectrometry (AES). Since spectrometry forms the basis of most analytical techniques to be discussed it should briefly be defined here.

Spectrometry is a form of measurement in which exciting radiation (for example X-rays and gamma-rays) is directed at the glass, and the interaction generates wavelengths of energy which are characteristic of the elements in the glass. If the exciting radiation is of a sufficient energy, such as X-rays, gamma-rays, electrons or protons, ionisations characteristic of the elements in the glass will occur, which, in turn, will yield particles characteristic of the material. In the case of X-ray spectrometry the result of bombarding a soda-lime silica glass is to produce secondary X-rays of sodium, calcium and silicon (among others). X-ray spectrometry therefore involves a primary excitation of the sample and spectrometry of the secondary radiation; the spectrograph records the components in the form of spectra. It is worth noting that the process can be non-destructive.

Arc-source emission spectrometry was being used for archaeological investigations until *c.* 1960, when more accurate, automated and less destructive techniques were introduced for analysing ancient glass. The technique involved a powdered sample. A graphite electrode was positioned so that an arc occurred beween electrode and sample causing the sample to be volatilised and to emit light. The elements present emitted wavelengths which were recorded on a photographic plate. The relative intensities of each line recorded on the photographic plate were measured and could be related to the relative concentrations in the glass; the results were semi-quantitative, not quantitative, but did often provide a basis for chemically classifying the Egyptian glass (Farnsworth and Ritchie 1938).

This analytical technique was time-consuming and destructive. As a result, a relatively small number of analyses were carried out on the materials concerned. For example, many of the analyses cited in *Analyses of Ancient Glasses* (Caley 1962) were carried out using AES.

Using arc-source emission spectrometry, Farnsworth and Ritchie (1938: 159) chemically analysed a series of cobalt-blue Eighteenth-Dynasty glasses, and attributed the colour to the presence of cobalt and copper modified by manganese in the glass; they explicitly stated that they regarded the presence of cobalt as being a deliberate addition (1938: 160). Earlier workers (Neumann, 1929; Neumann and Kotyga 1925) who used wet chemical techniques to analyse Egyptian glasses suggested that copper was responsible for the blue colour and that they were unable to detect cobalt in the glass; the first cobalt being used in fifteenth-century AD Venetian glasses (Neumann and Kotyga 1925: 862). AES was sufficiently precise to be able to show that very low levels of cobalt, later determined as *c.* 0.05 per cent (see Table 8.1b, analyses 6, 8, 15, 20, 23 and 26, p. 215, this volume) were present and produced a deep cobalt-blue colour in Eighteenth-Dynasty glasses. On the basis of their qualitative AES analyses, Farnsworth and Ritchie (1938) went so far as to suggest that Egyptian sources of alum which contain traces of cobalt might have been used as the source of the cobalt-bearing mineral.

Garner (1956a and b) also suggested that a cobalt-bearing ore was used for the coloration of Egyptian glass (Garner 1956a: 148). Farnsworth and Ritchie's work was later expanded upon by Kaczmarczyck and Hedges (1983) and by Kazmarzyck (1986) using X-ray fluorescence analysis (see p. 210). However, Lucas (1934: 218) suggested a Persian source for a cobalt colorant.

Atomic absorption spectroscopy (AAS) and its applications

A more advanced wet chemical analytical technique is AAS (Hughes *et al.* 1976). This technique gradually replaced AES, and in the 1970s AAS was being used to examine archaeological materials on a routine basis.The technique involves very similar principles to those of arc-emission spectroscopy. However the analysis involves the use of a flame to atomise the sample. The sample is dissolved in solution which is then injected into a flame. The basis of the technique is that a hollow cathode light source for a specific element generates light wavelengths characteristic of that element. When passed through the dissolved sample dispersed in the flame, the light is absorbed by the same element if present in the sample. The degree of absorption is a measure of the concentration of the particular element in the sample. AAS is a quantitative technique, and involves the use of standard solutions.

The introduction of computer automation has provided a much faster processing time for AAS. As with all analytical techniques, however, it is not always straightforward. For example, the results can suffer from interference between two or more elements if they occur in the sample together, and solutions have to be made up in order to assess the extent to which the quantitative results are affected (Hughes *et al.* 1976). Analysis of glass by Lambert and McLaughlin (1976) focused principally on Eighteenth-Dynasty glasses, and has shown that they conform basically to a soda-lime-silica composition with low magnesia and potassium oxides.

Robert H. Brill of the Corning Museum of Glass in the USA, one of the most important workers in the field of ancient glass analysis, uses AAS to conduct most of his chemical examinations of ancient glass based on the production of excellent glass standards (Brill 1972). Brill's AAS analyses of a number of Egyptian glass samples, ranging in date between the late sixteenth and fourteenth century BC, provide one of the most comprehensive data sets for the material (Lilyquist and Brill 1993). In *Studies of Early Egyptian Glass*, energy-dispersive X-ray fluorescent analyses (see p. 210) of pre-Malkata glasses by Wypyski have been added to Brill's analyses (Lilyquist and Brill 1993: 47). In Brill's analyses of ancient glasses the level of silica is measured by difference, and the results totalled to 100 per cent (Lilyquist and Brill 1993: 40, n.86). Four groups of glasses were analysed, three of them were from Egyptian sites (pre-Malkata, Malkata and Amarna), and the fourth was from the Mesopotamian site of Nuzi. All three groups of Egyptian glasses were found to be of a similar soda-lime composition, with high magnesia levels. By comparison the potassium oxide levels varied widely: in Egyptian cobalt-blue glasses, in particular, they were found to be lower than in non-cobalt-blue glasses from Egypt and Nuzi (see p. 213 – electron-probe analyses). It is only by analysing this number of securely dated glass samples from a range of periods that such technological information results. It should be noted that there are distinct compositional *similarities* between Egyptian glass and that found at Nuzi. The only difference between the two is the lower soda levels of some of the Nuzi glasses (Lilyquist and Brill 1993: 41), although even this does not separate them compositionally. This example of an analytical project clearly illustrates that, although some pottery fabrics have been chemically fingerprinted using AAS, such results are not obtainable for Egyptian glasses.

X-ray diffraction spectrometry (XRD) and its applications

Another technique which was already available to workers in the 1950s was XRD; it was used specifically to make unambiguous identifications of crystalline material in glasses. Whereas the chemical analysis of Egyptian glass using AAS destroyed the sample and removed its structure, XRD provided a way of identifying the crystals present in glasses. The crystals may be present as undissolved or partially dissolved raw materials such as silica, or as the crystals used to opacify the glasses. The XRD technique involves firing monochromatic radiation at the crystalline material. The diffraction of the radiation with the crystal lattice produces an X-ray pattern characteristic of the structure of the crystal(s). Crystals are composed of lattices built up in a regular pattern; their size and spacing is characteristic of the crystal species. Thus, while it is possible to identify the presence of calcium and antimony oxides by using AAS, elements which make up the commonest opacifying material found in Egyptian glass, calcium antimonate, it is only with X-ray diffraction that it is possible to identify the crystalline species and to distinguish between the two forms $Ca_2Sb_2O_7$ and $Ca_2Sb_2O_6$. Often such crystals are too small to identify with any other method.

Some of the earliest work on the crystalline nature of an Egyptian material was carried out on Egyptian blue using X-ray diffraction analysis (Jope and Huse 1940). Later work by Rooksby and Turner (Rooksby 1962, Turner and Rooksby 1959, 1961, 1963) used XRD to identify definitively a range of opacifying materials for the first time in ancient Egyptian and other ancient glasses. Opacity in Egyptian glass, as in other glasses, is due to the presence of a dispersion of crystals in a translucent glass matrix. All of these opacifiers have been identified by using X-ray diffraction (with supporting imaging using a scanning-electron microscope; see Figs. 8.6 and 8.7). The opaque white, turquoise and yellow Egyptian glasses all contain opacifiers based on antimony (Turner and Rooksby 1959, 1961, 1963; Rooksby 1962; Henderson 1985).

Figure 8.6 Photomicrograph of calcium antimonate crystals in opaque white fourteenth-century BC Egyptian glass (magnification ×2,500).

Figure 8.7 Photomicrograph of lead antimonate crystals in opaque yellow fourteenth-century BC Egyptian glass (magnification ×1,000).

The opacifying crystals cause the light to be reflected by the glass and prevent light transmission, thus causing opacity. Calcium antimonate ($Ca_2Sb_2O_7$ or $Ca_2Sb_2O_6$) does not occur naturally as a mineral, therefore antimony needs to be added to the glass where it can react with the calcium to produce calcium antimonate crystals (Turner and Rooksby 1961: 3). In order to produce an opaque turquoise colour in the glass the same procedure is followed as for opaque white glasses, but the antimony is added to a translucent turquoise glass instead of a weakly-tinted glass. The opaque yellow glasses used by the ancient Egyptians are coloured and opacified by the presence of lead antimonate crystals (Rooksby 1962: 23). A lead antimonate occurs naturally as Bindheimite ($Pb_2(Sb,Bi)_2O_6(O,OH)$), so a trace impurity of bismuth in ancient lead antimonate opacified glasses (which would need to be detected using a technique such as electron microprobe or particle-induced X-ray emission) *might* show that this mineral had been used as an opacifier. In the process of heat-treating lead-containing batches, a reaction between lead and antimony would also produce opaque yellow lead pyroantimonate ($Pb_2Sb_2O_7$). No tin-based glass opacifiers were used in ancient glasses until the second century BC (Henderson and Warren 1983, Henderson 1985). Neumann (1929: 835) claimed quite specifically that tin was only found in specimens of three opaque yellow glass specimens used as decoration from Gurob 'Die Trübungsmittel finden sich also nur in den Verzierungsfäden, nicht aber in der Grundmasse' (Neumann 1929: 835). However only compounds of antimony have subsequently been found in opaque Egyptian glasses of the second millennium BC (Brill 1968: 59, table 7; Henderson 1985: 285–6). Figures 8.8–8.10 are energy-dispersive analyses of opaque white, opaque yellow and opaque blue Amarna glasses. It can be seen that for the white and yellow glasses there are significant peaks for antimony (Sb), with no tin oxide detected; in the opaque blue glass a trace of tin (Sn) oxide is visible, but again the dominant peak is antimony. The most likely interpretation, as for the specimens analysed by Neumann (1929: 835) is that the tin was introduced as an impurity in the colorant; all are blue glasses so the impurity would probably have been introduced with the copper present (Sayre and Smith 1967: 297). The only possible yellow opacifier that could have been used for the opaque yellow decoration of the Gurob specimens analysed by Neumann would have been lead antimonate, $Pb_2Sn_2O_7$, (Rooksby 1962), but no lead was detected in the glass compositions published by Neumann (1929: 835) so the results remain anomalous.

The two ionic states of copper produce two correspondingly different colours in Egyptian glasses: a turquoise-blue colour when the cupric (Cu^{2+}) ion is present (Brill 1970: 120) and a dull brown-red colour when the cuprous (Cu^{+}) ion is present (Hughes 1972; Freestone 1987; Guido *et al.* 1984). Again, X-ray diffraction is necessary to unambiguously identify the oxidation state of the copper in opaque reddish-brown glass often used for the decoration of Egyptian glass vessels. The crystals causing the opacity are a form of copper, either copper droplets and/or the reduced form of the oxide, cuprous oxide. All Egyptian opaque red glasses which pre-date the ninth century BC contain lead levels of less than 3 per cent oxide; after this date the lead oxide levels generally rise and a brighter (sealing-wax) red glass colour is produced (Freestone 1987) with the development of different, dendritic, cuprous oxide crystals in the glass. When low levels of lead oxide are present there can be a problem dissolving the copper in the glass. Replication of opaque red glasses has shown that this can be overcome by introducing between 1.37 per cent and 2.29 per cent iron oxide in the glass (Guido *et al.* 1984) – which has been detected in ancient Egyptian glass. This also provides the appropriate (reducing) environment for the precipitation of crystals of cuprous oxide or metallic copper.

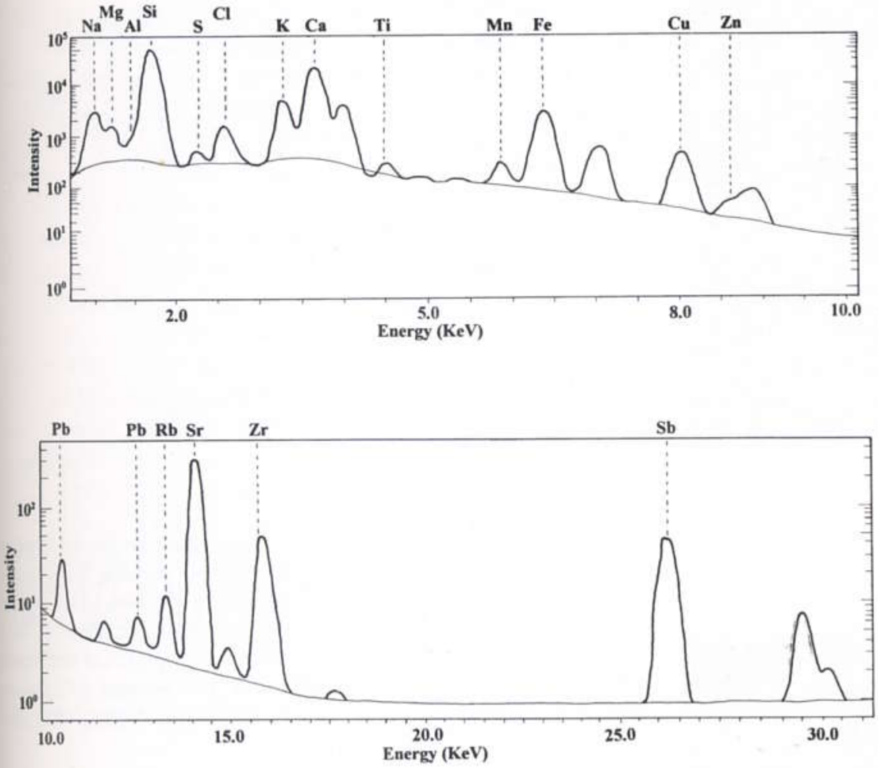


Figure 8.8 X-ray spectrum for an opaque white glass from Amarna showing X-ray peaks above background. Apart from the major components, soda, lime and silica, the glass contains a significant level of antimony because calcium antimonate crystals cause opacification.

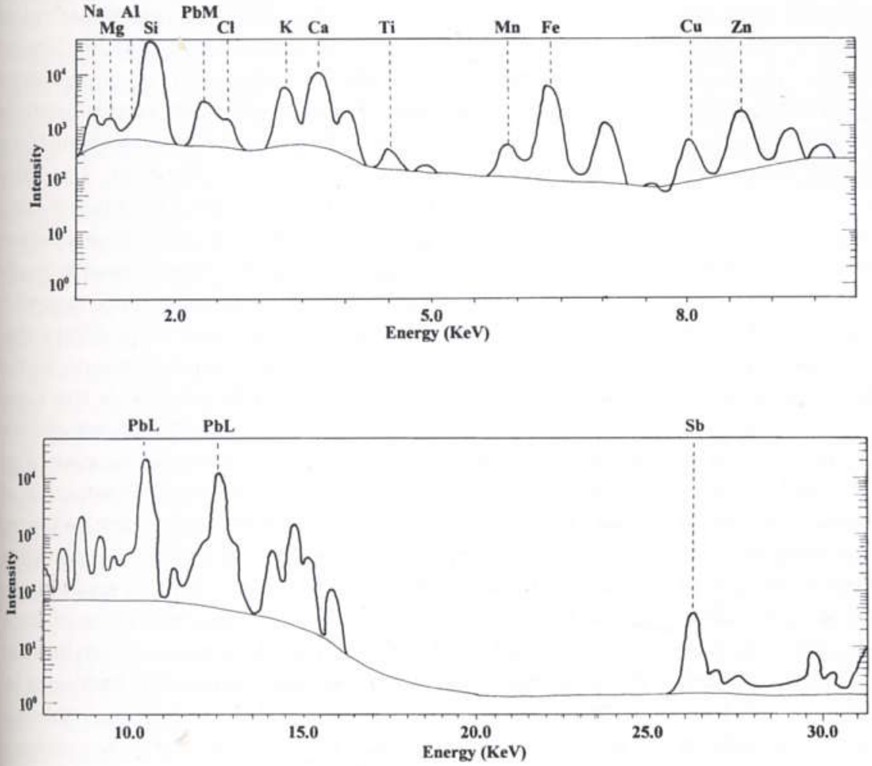


Figure 8.9 X-ray spectrum for an opaque yellow glass from Amarna showing X-ray peaks above background. The major components are sodium, calcium, silicon and lead oxides, with significant antimony peaks; the opacifier and colourant present is lead antimonate.

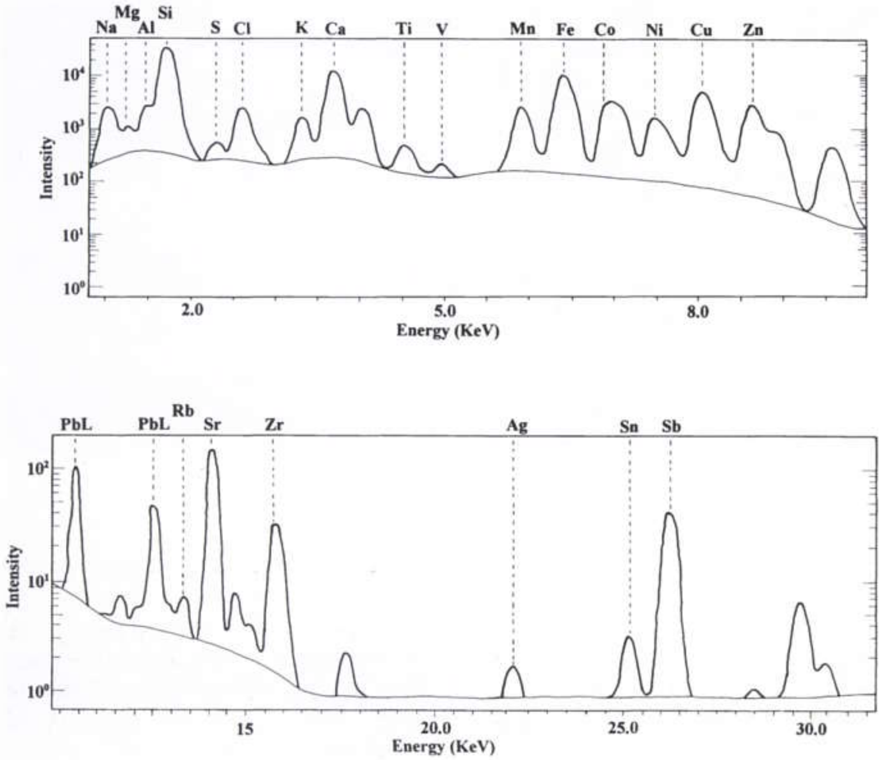


Figure 8.10 X-ray spectrum for an opaque blue glass from Amarna showing X-ray peaks above background. In addition to the major components (sodium (Na_2O), 'lime' (CaO) and silica (SiO_2)), the significant antimony (Sb) peak reflects the presence of calcium antimonate as the opacifier. Cobalt has also been detected.

Neutron activation analysis (NAA) and its applications

A technique which began to be used in the 1960s, especially for ancient glass analyses, was NAA. In order to carry out NAA, it is necessary to have access to an atomic pile to be found in an atomic reactor. Samples in capsules, which are often in powder form, are irradiated in the atomic pile for a defined period of time. This causes the samples to become radioactive and to decay according to their half-lives emitting gamma rays. The elements with short half-lives obviously decay fastest. The decay is monitored in a special counter, the number of counts being directly proportional to the concentration of the element in the material being analysed. As the sample decays, the results will be displayed as a spectrum of wavelength against peak intensity. Much of the analytical work reported by Sayre on Egyptian glasses, which subsequently formed the basis for seminal papers (e.g. Sayre and Smith 1961 and Sayre 1964), used NAA and led to the recognition for the first time of groups of ancient glass types based on their compositions (even though only fifteen analyses of second millennium BC glasses were published). Thus, the technique – which was somewhat quicker in terms of the man-hours involved – enabled Sayre and Smith (1961) and Sayre (1964) to answer quite specific points about ancient Egyptian glasses, such as the fact that Eighteenth-Dynasty glasses were of a characteristic soda-lime type some of which at the time were regarded as similar to Middle Eastern glasses of the second millennium BC.

X-ray fluorescence spectrometry (XRF) and its applications

Non-destructive and micro-destructive techniques have also been used for analysing Egyptian glasses. One of these is X-ray fluorescence spectrometry (XRF). Similar physical principles underlie XRF and electron probe microanalysis (EPMA); the distinguishing characteristic is the primary source of excitation (X-rays or electrons); the X-ray spectrometry used is virtually identical. The principles of XRF will be described first (for EPMA see p. 213). X-ray fluorescence analysis can be a totally non-destructive technique. It is a surface technique of spectroscopic analysis which relies on the interaction of primary X-rays with the sample generating a range of secondary X-rays that have energies characteristic of each of the elements in the sample. It produces a spectrum of energies in the same way as AES. The primary energy source can either be a radioactive material which will generate gamma-rays or an X-ray tube. When fired at the sample the interaction of energy with the sample will generate secondary X-rays. In an energy-dispersive system the secondary X-rays hit a detector (typically lithium drifted with silicon) and the secondary X-ray energies are displayed as a spectrum of X-ray energies against intensity in a multi-channel analyser as peaks above background. An X-ray spectrum produced by the analysis of an Eighteenth-Dynasty Egyptian translucent blue glass is shown in Figure 8.11. The figure shows a series of peaks above a background level (produced using proton-induced X-ray emission). The vertical axis gives the relative intensity of the peaks above the background level,

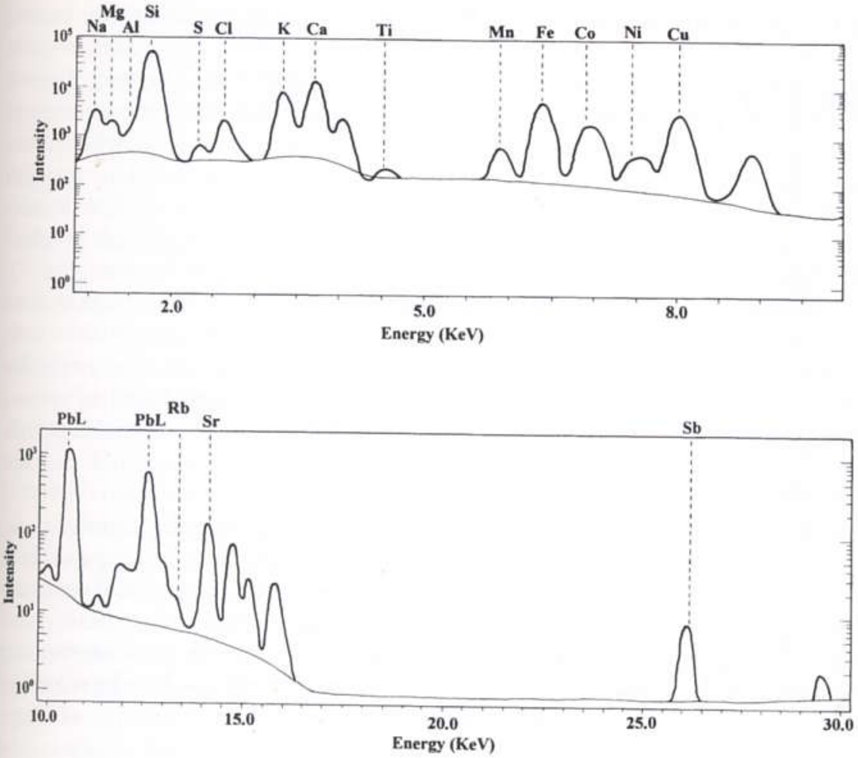


Figure 8.11 X-ray spectrum for a translucent blue glass from Amarna showing X-ray peaks above background. The peaks for the three principal components, sodium (Na), 'lime' (Ca) and silica (Si) are visible between 1 and 4 KeV. The remaining are colorants and impurities.

and the horizontal axis the emission energy of the peaks along the X-ray spectrum, measured in Kilo-electron volts (KeV). Each of the peaks is characteristic of the chemical elements present in the glass analysed; each element may have more than one peak depending on its atomic number (silica has an atomic number of 14 and lead 82). In Figure 8.11 it can be seen that lead (Pb) has two lead L peaks between 10 and 13 KeV labelled as PbL. On the other hand there is only one visible silicon (Si) peak at 1.639 keV; this is for a Silicon K X-ray. Further detailed information about this technique can be found elsewhere (Jenkins 1988).

There are two principal types of X-ray spectrometry: energy-dispersive and wavelength-dispersive. Energy-dispersive spectrometry (EDS) operates by collecting data from the detector, separating them according to their energy and displaying them in spectral form. During energy-dispersive XRF, an X-ray interacting with the detector produces an electrical pulse proportional in size to the energy of the X-ray. These pulses are measured and sorted electronically. During wavelength-dispersive XRF, X-rays are diffracted from the crystal in the spectrometer, the angle of diffraction being determined by the energy/wavelength of the X-ray. The wavelengths are measured sequentially, since the sorting is done physically rather than electronically. Wavelength-dispersive spectrometry (WDS), on the other hand, relies on a different means of operation; the spectrometer consists of crystals which cause the secondary X-rays to be diffracted at particular characteristic angles into the detector. This angle is determined by the atomic number of the element. With WDS the dispersion of the secondary X-rays is greater than with ED X-ray spectrometry. This makes it possible both to separate the X-rays peaks to a greater extent and to overcome some of the interference effects encountered with EDS. WD XRF is therefore generally a more sensitive technique, which is also able to detect elements at lower levels. Wavelength-dispersive spectrometry is normally slower, simply because the spectrometer angle needs to be changed, and from time to time also the crystal in the spectrometer, depending on what elements are sought.

Wavelength-dispersive X-ray spectrometry is often used to analyse material that has been powdered and made into a silicon borate glass bead; ED XRF is normally quicker but can also involve this sample preparation. The bead is cast so that its lower surface is flat and of the appropriate diameter for the beam of primary X-rays used for its analysis. Energy-dispersive spectrometry, on the other hand, can more readily be used as a totally non-destructive technique and is therefore more appropriate to a museum environment. However, if the sample has an irregular surface and/or is weathered/depleted in any way, it is impossible to produce a quantitative result using ED XRF. The obvious use for ED analysis in a museum is to provide an initial qualitative analysis of the glass, although the technique will only provide an analysis of the surface. The depth to which the exciting energy penetrates the sample when an x-ray tube is used as the source of x-rays is dependant on the voltage used and also the matrix composition of the material: for a 'light' matrix the depth from which the heaviest secondary X-ray may escape to be detected may be as deep as *c.* 40 microns, for the analysis of materials with 'heavy' matrices (e.g. high lead glasses) the maximum depth may be 15 microns.

By using ED XRF analysis, Kaczmarczyk and Hedges (1983: 46) have discovered the association of cobalt with manganese, zinc, nickel and alumina in New Kingdom cobalt-blue faience and other cobalt-blue objects including glass, with abnormally high alumina concentrations. Extending the work by Farnsworth and Ritchie (1938), Kaczmarczyck (1986), again basing his discussion on the results of ED XRF analyses, suggested that a source of alum with a significant cobalt impurity was used for Egyptian New Kingdom glass coloration. If this suggestion is taken at face value, then the relative levels of impurities in the final glasses are inconsistent with the suggestion (Lilyquist and Brill 1993: ns. 78 and 94). Nevertheless the correlation between the presence of abnormal alumina levels and cobalt in Egyptian glasses needs to be explained: the most likely interpretation would seem to be that the cobalt-bearing alum was purified in some way, just as later, in the medieval period in Europe, when *zaffre* (or Damascus pigment) was roasted to remove any sulphur or arsenic before use. This evidence only provides a suggested means of changing the constituent levels in the cobalt-bearing alum.

Scanning-electron microscopy (SEM) and its applications

Another non-destructive technique is scanning-electron microscopy, in which the same size of object or sample can be used as for EPMA (*c.* 1 mm or less) (see below). It is possible to attach both energy-dispersive and wavelength-dispersive spectrometers to the microscope, but the quality of the analyses will not usually be as high as for a dedicated electron microprobe analysis. Indeed the systems should not be confused – they are different and should be referred to as an electron microprobe and an analytical SEM respectively. The SEM is primarily used for imaging structures and compositional variations of materials.

The secondary electron detector measures the electrons which escape from the surface atoms of the sample by surface geometry, whereas the backscattered detector builds up pictures of compositional heterogeneity by recording the electrons backscattered from the sample, a measure of the variation in relative average atomic number in the area being analysed. The secondary electron images therefore provide highly magnified images of the surface textures of materials; if weathered glass is of interest it can be examined in an unpolished state. In the mid 1970s this was the first opportunity to examine Egyptian glass under high magnification.

Perhaps of greatest relevance to the study of Egyptian glass technology was the use of backscattered electron images to provide the first clear images of crystals used in opacification. Chemical analysis of a 'name bead' of Queen Hatshepsut dated to between 1473 and 1458 BC was carried out using an energy-dispersive X-ray spectrometer in a scanning-electron microscope (BM EA26289–90; Bimson and Freestone 1988; see also section on procurement of raw materials, p. 197, this volume). The opacifiers present in the dark blue glass from a canopic jar dated to 1353–1333 BC and an opaque green Ptolemaic plaque from a foundation deposit, dated to 246–221 BC, were also photographed using the same microscope (Bimson and Freestone 1988). The technique showed the beads to be of the high magnesia soda-lime composition, and also demontrated that both glasses were opacified by calcium antimonate crystals (Bimson and Freestone 1988: figs. 3, 5). In addition, of course, the SEM can be used to show great compositional contrasts between crystals and the matrix material in which they are embedded, between layered glasses and between depleted/corroded surfaces and the unweathered parent material. By examining cross-sections through materials it is possible to relate structural corrosion to changes in chemical composition which can, in turn, be recorded photographically.

If the material being analysed is glass, glaze or obsidian and does not conduct electrons then it needs to be coated in order to prevent distortion and deflection of the electron beam; this is also true for electron microprobe analysis (see below). The sample size that can be examined under the SEM is determined by the size of the sample chamber. Since samples are examined under vacuum within an evacuated sample chamber, space is limited which, in turn, limits the sample sizes; some stand-alone systems incorporate large sample chambers. A range of SEM systems are manufactured and relatively large objects can be accommodated, up to *c.* 5 × 3 cm in dimensions.

Particle-induced X-ray emission (PIXE)

More recently (since the late 1970s) PIXE has been used for the analysis of archaeological materials. The features that characterise PIXE are its cost and the large size of the instrument. The analytical technique requires a tandem van der Graaf accelerator in order to generate particles which are accelerated at high speeds towards the sample, where they collide with and penetrate the sample also at great speeds. The technique can be used for X-ray spectrometry; in this case the excitation is caused by a primary proton beam.

Analytically, the most significant difference from electron microprobe analysis (EPMA) is that the background produced by PIXE is a factor of 10 lower (see Fig. 8.8). The background in EPMA arises from 'white' radiation produced by decelerating electrons. The reason that PIXE background is lower is that protons bombarding the sample enter it at great speed and are more massive than electrons. The net result is that the background on which the elemental peaks accumulate is significantly lower, allowing far lower concentrations of the components to be detected.

If the PIXE system is fitted with a scanner (a scanning proton microprobe), then maps of the distributions of a range of elements in a glass sample can be produced, providing interesting correlations in the occurrence of elements in different glass colours. The technique can be used for the analysis of Egyptian glasses down to parts per million, which is generally a factor of 10 more sensitive than EPMA, but the systems are much more difficult to calibrate than EPMA.

Inductively-coupled plasma-emission spectroscopy (ICPES)
Some fifteen years ago ICPES was added to the range of analytical techniques used by archaeological scientists, but has not yet been used for the analysis of Egyptian glass (see Heyworth *et al.* 1989, Hughes *et al.* 1991; Hatcher *et al.* 1995).

Electron microprobe analysis (EPMA) and its applications
A non-destructive technique which produces high quality results is electron microprobe analysis, also known as electron-probe micro-analysis (EPMA). This followed on from the milliprobe (Hall 1965: 110–11; Hall, Sweitzer and Toller 1973) and its early use for glass analysis (Brill and Moll 1963), becoming commonly used, especially for research in mineral sciences, in the 1970s. Micro-samples as small as 0.5 mm can be mounted and analysed non-destructively, and if necessary repeatedly. The technique involves the use of a micro-beam of electrons which is focused on the sample surface using magnetic lenses. The electrons themselves are generated using an electron gun (see Fig. 8.12). The interaction of the electrons with the sample generates secondary X-rays which are characteristic of the chemical elements in the material. This technique provides an analysis of a shallower layer of glass than with XRF (3–5 microns compared to *c.* 30–50 microns, depending on the conditions employed) and by sampling and preparing the sample carefully, in general, the quality of the results when compared to ED X-ray analysis are far higher, and the technique is considerably less destructive than WD XRF. The samples are normally embedded in epoxy resin and polished flat so that the geometry of the analysis is repeated exactly each time samples are analysed and so as to remove surface roughness. In the process of doing this any weathered material can be removed.

In the case of glass it is essential to defocus the beam in order to minimise or eradicate damage by the electron beam and the volatilisation of the sample surface, causing elements like sodium to be boiled off (Vassamillet and Caldwell 1969; Henderson 1988: 79). In practice during the analysis of glass the beam needs to be deliberately defocused to approximately eighty microns. It is possible to locate the electron beam precisely on the area of the sample to be analysed by moving the sample under a light microscope attached to the system until the beam is located on the desired spot. If compositional heterogeneity is suspected an energy-dispersive detector attached to the system can be used to carry out quick qualitative point analyses before the quantitative WD analyses are performed. It would be possible to quantify the ED results from the system (and defocussing the beam is not necessary) but the levels of precision and detection achieved with the wavelength dispersive probe are of a far higher quality so there is little point (Henderson 1988: 80, table 1; Veritá *et al.* 1994: table 1). This same point can be made for a comparison between the results from an ED spectrometer attached to a scanning-electron microscope and those from a wavelength-dispersive system in an electron microprobe: the levels of detection of the WD system are considerably better. For example, it is often not possible to detect cobalt in a cobalt-blue glass when using the ED system in an SEM , whereas the level of detection for cobalt in a soda-lime glass using WD analysis can be 0.04 per cent cobalt oxide.

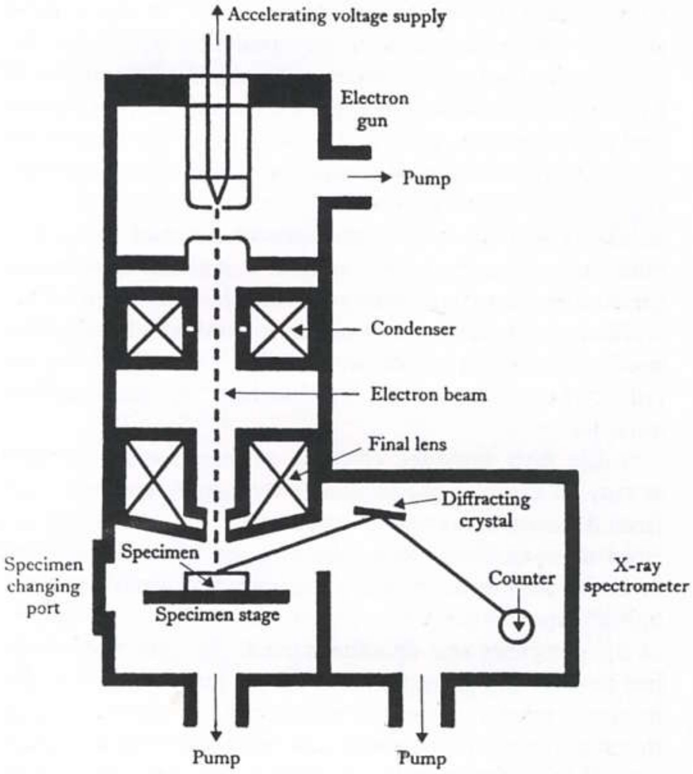


Figure 8.12 Schematic diagram (section) of an electron microprobe. Note the magnetic lenses in the electron gun on the left. The electron beam is focused on the glass samples mounted in a block of epoxy resin. The spectrometer is on the right-hand side of the diagram. It consists of a diffracting crystal and a counter. The system operates under vacuum, hence the presence of three (vacuum) pumps.

Electron microprobe analysis of Eighteenth Dynasty glasses from Amarna

Electron microprobe analysis is a quantitative technique, and given the small beam size it is normal to analyse three to five spots of a homogeneous material, like glass, and average the results. As with any analytical technique, the cross-analysis of a multi-element standard not used in calibrating the system and of proven reliability at the start and end of the analysis will provide two things: the determination of relative analytical accuracy and a means of monitoring any drift in the system. One of the advantages of using EPMA is that the system only provides a total analysis of what it has detected. This means that if the analyst has omitted an important element from the analysis the total will be low. By using analytical techniques which normalise results to 100 per cent there is a danger of distorting the results if one or more element has been omitted from the anlaysis.

Table 8.1b provides electron microprobe analyses of twenty-six samples of Eighteenth-Dynasty Egyptian glasses from Amarna. The range of information that can be derived from these analyses falls into a range of interconnected areas: a definition of the glass compositional type; the identification of the primary components; the identification of the colorants and opacifiers used; the detection of impurities in the glass which help to fingerprint the raw materials used, occasionally allowing the analyst to suggest their sources and an assessment of the compositional variation among the samples. A description of the samples is given in Table 8.1a. It can be seen that glasses of a range of colours have been analysed: translucent turquoise, translucent purple, opaque yellow, opaque white, opaque blue and opaque turquoise. All of these glass samples were taken from vessel fragments which derived from Petrie's excavations and which are now in the Ashmolean Museum, Oxford. All the analyses were carried out using electron-probe microanalysis (for full technical specifications of the wavelength-dispersive electron microprobe used, see Henderson 1988: 78–80).

The basic chemical composition of all the glasses is soda (Na_2O) – 'lime' (CaO) – silica (SiO_2). The only other major component present in some specimens is lead oxide, making lead oxide–soda–lime–silica glasses. Lead oxide is present at levels of up to 9.4 per cent in these glasses (Table 8.1b, analysis 5). X-ray spectra are given in Figures 8.8–8.10 for translucent blue, opaque blue, opaque white and opaque yellow glasses from Amarna; these were obtained using PIXE however.

Table 8.1a. *Description of the Amarna glass samples taken from core-formed vessel fragments*

Sample numbers 1–3
Ashmolean Museum 1924. 118e (55A) Thickened rim fragment with a straight sided neck. Translucent truquoise (1) with combed opaque yellow (2) and opaque white (3) decoration.

Sample number 4–7
Ashmolean Museum 1924. 118b (55A) Thickened rim fragment with a straight sided neck. Translucent turquoise (4) with combed opaque yellow (5), opaque blue (6) and translucent turquoise (7) decoration.

Sample numbers 8–9
Ashmolean Museum 1924. 118a (55A) Opaque pale green vessel wall fragment with combed opaque blue (8) and opaque yelow decoration. Further decorated with an opaque white (9) and blue cable.

Sample numbers 10–11
Ashmolean Museum 1924.416 (55A) An opaque 'apple green' vessel wall fragment (10) with combed opaque white (11) and opaque yellow decoration.

Sample numbers 12–14
Ashmolean Museum 1924. 92 (55A) A translucent purple vessel should fragment (12) with combed opaque yellow (13) and opaque white (14) decoration.

Sample numbers 15–18
Ashmolean Museum 1921.1158 (55A) A deep translucent cobalt blue vessel neck (15) with combed opaque turquoise (16), opaque yellow (17) and opaque white decoration (18).

Sample numbers 19–21
Ashmolean Museum 1936.623 (55A) An opaque yellow vessel wall fragemnt (19) with an inlaid blue band (20) and inlaid stratified eyes of a 'saucer' of blue glass (20) with a superimposed saucer of opaque whtie and a central circular setting of opaque turquoise (21).

Sample numbers 22–24
Ashmolean Museum 1924.117d (55A) An opaque white vessel wall fragment (22) with inlaid stratified eyes with a 'saucer' of opaque blue glass (23) with a dark reddish-brown (24) centres.

Sample numbers 25–26
Ashmolean Museum 1924. 117f (55A) A thick opaque white vessel fragment with inlaid opaque white (25) and opaque blue (26) (bichrome) cables enclosing the possible remnants of an opaque yellow disc inside an opaque turquoise setting.

The alkalies used

It is generally agreed that the principle source of alkali in Egyptian glasses of the second millennium BC was a plant ash of the genus *Salicornia* or *Salsola*, both of which grow in the desert or maritime environments found in Egypt and the Middle East. The compositional characteristics of these halophytic plants (high soda with a relatively high impurity level of magnesia and a low impurity level of potassium oxide) are carried through into the glass made from them, and can be seen in Table 8.1b. Analytical and experimental work by Brill (1970) has shown that samples of *keli*, the ash of the *chinan* plant which grows in the Syrian desert, is characterised by high soda levels (28 per cent), low potassium oxide (5.5 per cent) high calcium oxide (21.1 per cent) and low magnesia (0.5 per cent) (Brill 1970: table 2). Other analyses of soda-rich plant ashes contained considerably higher magnesia levels accompanying the soda. Glasses made in this way are referred to as 'high magnesia

Table 8.1b. *Electron probe analyses of 18th Dynasty coloured glass samples performed by J. Henderson taken from core-formed vessels in the Ashmolean Museum, Oxford, excavated by Petrie from Amarna, Egypt (expressed as the weight percentage of each of the elements in the glasses) For a full description of the vessels sampled see Table 8.1*

Analysis no.	1	2	3	4	5	6	7
Colour	Trans turq	opaque yellow	opaque white	Trans turq	opaque yellow	opaque blue	Trans turq
Na_2O	18.7	15.6	17.8	18.3	12.9	21.6	17.5
MgO	4.8	4.1	4.2	4.2	5.1	3.9	4.0
Al_2O_3	0.5	0.8	0.7	1.2	1.1	5.9	1.2
SiO_2	63.0	61.1	63.0	64.0	56.1	55.9	62.7
P_2O_5	0.1	0.2	ND	0.2	0.2	0.3	0.2
SO_3	0.3	0.5	0.5	0.3	0.4	0.7	0.2
CI	0.7	0.8	0.7	1.3	0.9	1.8	1.3
K_2O	2.7	3.2	3.0	1.3	3.0	0.9	1.7
CaO	6.4	7.0	6.9	8.6	8.9	5.8	8.8
TiO_2	0.04	0.1	0.06	0.11	0.1	0.1	0.1
Cr_2O_3	0.02	ND	ND	ND	ND	ND	ND
MnO	0.05	0.04	0.03	0.07	0.04	0.3	0.05
Fe_2O_3	0.27	0.5	0.29	0.63	0.8	1.1	0.69
CoO	ND	ND	0.02	0.03	ND	0.21	0.02
NiO	ND	ND	ND	ND	ND	0.08	ND
CuO	1.4	ND	ND	0.7	0.1	0.5	0.86
ZnO	ND	0.17	ND	0.02	0.2	0.31	ND
As_2O_3	0.02	ND	0.12	0.03	ND	0.04	0.02
SnO_2	0.17	0.1	ND	0.06	ND	ND	0.04
Sb_2O_3	0.02	0.39	3.43	0.04	0.9	0.7	ND
BaO	ND	ND	ND	ND	ND	ND	ND
PbO	0.04	6.6	ND	0.06	9.4	0.08	0.06

Analysis No.	8	9	10	11	12	13
Colour	opaque blue	opaque white	opaque green	opaque white	Trans purple	opaque yellow
Na_2o	19.5	18.2	18.7	16.2	16.9	17.0
MgO	3.3	4.2	4.5	4.3	4.0	4.5
Al_2O_3	3.4	0.6	0.6	0.8	1.1	0.6
SiO_2	62.8	61.9	61.6	56.8	65.2	59.7
P_2O_5	0.1	0.2	0.2	0.1	0.1	0.1
SO_3	0.37	0.4	0.5	0.5	0.4	0.4
Cl	1.5	1.1	0.9	0.7	0.9	0.9
K_2O	0.9	3.0	2.6	2.0	1.9	2.5
CaO	5.7	8.0	6.6	11.2	9.0	8.4
TiO_2	0.06	0.04	0.05	0.06	0.06	0.02
Cr_2O_3	0.02	ND	0.02	ND	0.02	ND
MnO	0.31	0.01	0.01	0.01	0.80	0.03
Fe_2O_3	0.57	0.24	0.4	0.37	0.42	0.46
CoO	0.15	0.02	ND	ND	0.02	ND
NiO	0.04	0.04	0.02	0.01	0.02	0.01
CuO	0.83	0.01	1.29	ND	ND	0.08
ZnO	0.11	0.03	ND	0.03	ND	0.25
As_2O_3	0.03	0.12	0.04	0.24	0.06	ND
SnO_2	0.01	ND	ND	0.01	ND	ND
Sb_2O_3	1.21	2.49	0.63	7.56	ND	0.69
BaO	ND	ND	ND	ND	ND	ND
PbO	0.03	ND	1.56	0.01	ND	4.33

Analysis No.	14	15	16	17	18	19
Colour	opaque white	Trans blue	opaque turq	opaque yellow	opaque white	opaque yellow
Na_2O	15.7	18.8	18.4	18.9	13.8	16.5
MgO	4.1	3.6	4.6	4.9	4.7	4.0
Al_2O_3	0.5	3.4	0.7	1.2	2.6	0.8
SiO_2	61.2	62.5	62.3	60.8	63.7	62.7
P_2O_5	0.1	0.1	0.02	0.2	0.2	0.1
SO_3	0.4	0.2	0.21	0.5	0.5	0.2
CI	0.6	0.6	0.68	1.0	1.1	0.5
K_2O	2.2	0.7	1.6	3.1	3.1	2.7
CaO	12.8	6.8	7.7	8.1	8.9	5.3
TiO_2	0.06	0.06	0.04	0.02	0.06	0.06
Cr_2O_3	ND	0.02	0.02	ND	0.02	ND
MnO	0.03	0.7	0.01	0.04	0.03	0.05
Fe_2O_3	0.27	0.56	0.3	0.35	0.34	0.99
CoO	ND	0.19	0.02	ND	0.02	ND
NiO	ND	0.03	ND	ND	ND	ND
CuO	0.06	0.22	1.51	0.01	ND	0.01
ZnO	0.02	0.14	ND	0.09	ND	0.02
As_2O_3	0.08	ND	0.05	0.05	0.06	ND
SnO_2	ND	0.01	ND	ND	ND	ND
Sb_2O_3	0.91	0.33	1.37	ND	1.92	0.95
BaO	ND	ND	ND	ND	ND	ND
PbO	ND	0.11	ND	1.5	0.1	5.25

Analysis No.	20	21	22	23	24	25	26
Colour	Trans blue	opaque turq	opaque white	Trans blue	opaque red	opaque white	Trans blue
Na_2O	18.6	19.1	20.4	19.1	19.0	19.7	19.9
MgO	3.8	4.5	6.2	5.0	5.2	4.5	4.3
Al_2O_3	0.9	0.9	1.6	2.4	2.7	0.9	3.3
SiO_2	62.4	62.2	62.2	62.9	57.5	63.5	60.3
P_2O_5	0.1	0.1	0.1	ND	ND	0.1	0.1
SO_3	0.2	0.3	0.2	0.2	0.1	0.3	0.5
Cl	0.7	0.6	0.6	0.5	0.4	0.8	0.6
K_2O	3.3	4.0	2.7	2.3	2.9	2.1	1.8
CaO	5.2	5.5	5.2	4.7	5.2	7.4	6.1
TiO_2	0.04	0.04	ND	ND	0.1	ND	0.1
Cr_2O_3	0.02	ND	ND	ND	ND	ND	ND
MnO	0.05	0.04	0.07	0.08	0.16	ND	0.4
Fe_2O_3	0.62	0.54	0.4	0.3	7.6	0.4	0.5
CoO	0.12	0.02	ND	0.08	0.18	ND	0.29
NiO	0.02	0.02	ND	ND	ND	ND	0.06
CuO	0.36	1.27	ND	0.1	1.2	ND	0.06
ZnO	0.02	0.02	ND	ND	ND	ND	0.37
As_2O_3	ND	0.07	0.05	ND	0.4	0.07	0.07
SnO_2	0.08	ND	0.1	ND	ND	ND	ND
Sb_2O_3	0.17	1.0	1.3	0.2	0.3	1.5	1.4
BaO	ND	ND	ND	ND	ND	ND	ND
PbO	1.01	0.04	ND	0.3	0.3	ND	ND

Note: Trans = translucent; turq = turquoise (soda–lime) glass' (HMG; see Sayre and Smith 1967: 285, 287) to distinguish them from 'low magnesia (soda–lime) glasses', which were later made in Egypt (LMG); the levels of magnesia (MgO) are given in Table 8.1b. The most likely mineral used for the later LMGs was natron (Forbes 1957, 142). Analysis of twelve samples of natron taken from Wadi Natrun and chemically analysed revealed its true crystalline identity to be 'trona', which is a sodium sesquicarbonate, $Na_2CO_3.NaHCO_3._2H_2O$ (Brill pers. comm.). Trona also occurs in the Beheira province of Lower Egypt, a source which was certainly worked in antiquity. During the New Kingdom, however, it has been suggested that ready-made glass was imported from the Middle East (Oppenheim 1973: 260; and see p. 195, this volume). It is worth noting that trona was not only used for glass production but also medically as a detergent and in the process of embalming (see Turner 1956a: 283; see also Chapter 16, this volume). The sodium (kα) X-ray peak is visible at 1.041 KeV in Figures 8.8–8.10. The range of soda (Na_2O) levels detected is given in Table 8.1b.

Silica

Silica in glass-making is provided by sand or quartz pebbles. To locate sand sources obviously does not pose a problem, but to locate sources which have low mineral impurities, such as iron-bearing minerals, is more difficult (Highley 1977). Lucas (1948), among others, has noted the presence of shell fragments in sand which would potentially have provided a major source in the glass batch. Turner (1956b) studied the mineralogical composition of sand from Amarna, from the shore of the river Nile opposite Luxor, and from the Belus river by Haifa in Israel. All the samples contained variable levels of quartz (the silica source), calcite (a calcium source), feldspars, pyroxenes and ilmenite; the sand from Thebes was the only one to contain mud and mica. The sand from Amarna contained between 50 and 55 per cent quartz, 30 and 33 per cent calcite, 5 per cent feldspars, 5 per cent pyroxenes and 1 per cent ilmenite, and can thus be considered a relatively 'clean' sand source.

Lead

Lead (in the form of lead antimonate, $Pb_2Sb_2O_7$) was used from the Eighteenth Dynasty (1550–1307 BC) onwards in Egyptian glasses, specifically for decorative opaque yellow glasses which were normally applied to core-formed vessels. The presence of lead was detected by Turner and Rooksby (1959: 18, table 1B) in glass from Thebes dated to *c.* 1450–1425 BC using X-ray diffraction and confirmed by Sayre (1964). Lead has also been detected in faience (Kaczmarczyk and Hedges 1983). The earliest historical reference to lead can be found in Mesopotamian texts dated to the seventh century BC but thought to have originally derived from a source dating to the twelfth century BC (Brill 1970: 121). *None* of the translucent glasses in Table 8.1b, nor any other translucent glasses dated to periods before the eighth century BC, appears to have been made from lead-rich glasses. Lead is always present in glass as an oxide; although there is no actual archaeological evidence for lead being used as a primary raw material in Egyptian glass production, it must have been added at some point in the production cycle and converted into an oxide.

Crystalline lead antimonate, which can be prepared by heating the oxides of lead and antimony together would have been added directly to the glass as an opacifier (see Fig. 8.7 and p. 208). Work by Brill and co-workers using lead isotope analysis (Brill *et al.* 1993) has shown that characteristic sources of lead (galena) used for Eighteenth-Dynasty glasses (for example) presumably existed somewhere in the Eastern Desert, or possibly along the coast of the Arabian Peninsula (Brill 1993: 59). An X-ray spectrum for an opaque yellow glass from Amarna is given in Figure 8.9. Two lead (Pb) L peaks are visible, as is a series of antimony (Sb) K peaks.

Calcium

Typically, Eighteenth-Dynasty glasses contain calcium oxide levels of between about 6.5 and 9.0 per cent (Table 8.1b), and this indeed is also a common level of calcium oxide found in other soda–lime glasses in the first millennium BC and the first millennium AD (Turner 1956b: 45; Henderson 1985: 277, 1995). Calcium oxide is essential in glass as a network stabiliser; a soda–silica glass would tend to dissolve easily in water.

The surprising feature of Egyptian (and other ancient) soda–lime–silica glasses is that the calcium oxide level is almost invariably between about 6.5 and 9.0 per cent; the analyses in Table 8.1b are no exception. Had the ancient Egyptians used sand sources which were rich in shell fragments, would we expect this repeatable and consistent level of calcium oxide to enter the glass melt? Brill (1970: 109) has suggested that the proportion of shell fragments is always the same in the sand source, resulting in a repeatable glass composition. It is however, much more likely that, as with ancient metallurgy where consistent proportions of mineral-bearing ores would have been purified and melted, the different constituents of the sand were separated so that the shell fragments could be used as a calcium source, but that they would have been added in measured quantities to the glass batch.

Impurities

As to the impurity levels detected in the glasses, the expected high magnesia was detected in all the glasses analysed; however another impurity, potassium oxide, likely to have been introduced with the plant ash used as an alkali, is present at elevated levels in almost all the glasses. Three chemical analyses of blue glasses all contain relatively low potassium oxide levels at levels of 0.9 per cent (analysis 6), 0.9 per cent (analysis 8) and 0.7 per cent (analysis 15); these blue glasses contain the lowest magnesium levels of all the glass samples analysed strongly suggesting that they were fused using a different plant ash source of alkali.

The alumina levels in the glasses are mainly below 1 per cent, except, as expected, in blue glasses (see p. 215). However, three other glasses also contain somewhat higher levels: analysis 18 at 2.6 per cent (opaque white), analysis 22 at 1.6 per cent (opaque white) and analysis 24 of 2.7% (opaque reddish-brown). Again these glasses have evidently been prepared in a slightly different way from the rest and these elevated alumina levels are very unexpected in glasses of this age, especially sample 18, which contains an alumina level more typical of Hellenistic or Roman glass technology. The most likely interpretation of these elevated alumina levels is that they were introduced as an impurity in the sand used as a silica source (Matson 1951: 841); the low alumina levels present in the other glasses is thought to be due to the use of quartz as a silica source. Turner (1954: 441) and Saleh *et al.* (1972) indicate that corrosion of a glass-melting crucible could contribute impurities such as silica, alumina, iron oxide, lime, magnesia and alkalies to the glass melt. However, the generally consistent impurity levels in glass from Tell el-Amarna link to the use of different glass colours suggests that crucible corrosion may only make a minor contribution to the final glass composition: obviously the volume of the melt and consequently the size of the crucible involved will determine whether or not crucible corrosion makes a significant contribution to the chemical composition of the glass.

Glass colour

As noted above the principal colorants detected are as follows: cobalt in both opaque blue (Table 8.1b, analyses 6 and 8) and translucent blue glasses (Table 8.1b, analyses 15, 20, 23 and 26); copper (cupric) in translucent turquoise (Table 8.1b, analyses 1, 4 and 7) and opaque turquoise glasses (16, 21) and manganese in the translucent purple glass analysed (Table 8.1b, analysis 12). The colorants detected in the opaque glasses are calcium antimonate in opaque white glass (Table 8.1b, analyses 3, 9, 11, 14, 18, 22 and 25) and this opacifier combined with other colorants: with cobalt in opaque blue (Table 8.1b analyses 6 and 8), and with copper in opaque turquoise (Table 8.1b analyses 16 and 21). Lead antimonate is the crystalline colorant in opaque yellow glasses (Table 8.1b, analyses 2, 5, 13, 17 and 19). The 'apple' green colour of sample 10 is probably a combination of yellow lead antimonate and a copper (cupric) green glass matrix. The brownish-red sample (24) is coloured and opacified by cuprous oxide; the high level of iron oxide detected (7.6 per cent) will have been added as an internal reducing agent and will also have allowed the copper to dissolve with greater ease (Guido *et al.* 1984: 248). The generation and control of colour in ancient glass is by no means simple. The chemical environment, the redox equlibria in the furnace and subsequent heat treatment of the glass being amongst the determining factors.

Cobalt blue The chemical analyses of Eighteenth-Dynasty glasses presented in Table 8.1b include blue samples with elevated levels of aluminia of *c.* 5.9 per cent; the X-ray spectra for translucent and opaque blue glasses are shown in Figures 8.10–8.11. This is a factor of five or six lower than found in other translucent glass colours. It is also significant that these cobalt-blue glasses, present as Co^{4+} ions (Bamford 1977: 42) are associated with the impurities which Sayre (1964) and Kaczmarczyck and Hedges (1983) have detected in New Kingdom vitreous materials, such as the oxides of manganese, iron, nickel, copper and variable zinc and lead. Peaks for manganese, iron, nickel, copper and antimony are visible in Figure 8.11, in addition to the zinc. In addition to these, zinc and silver are shown to be present in the X-ray spectrum for the opaque blue glass (Fig. 8.10).

Turquoise blue and red-brown opaque glasses The two ionic states of copper produce two correspondingly different colours in Egyptian glasses: a turquoise-blue colour when the cupric (Cu^{2+}) ion is present (Brill 1970: 120) and a dull brown-red colour when the cuprous (Cu^{+}) ion is present (Hughes 1972; Freestone 1987; Guido *et al.* 1984). Weyl (1953: 164–5) notes that the 'green' colour is only produced in the presence of lead oxide in the glass, however several examples of copper-green (translucent turquoise-green) glasses with no detectable lead have been found (Table 8.1b). After brass is introduced, copper and zinc are often found to be associated in ancient turquoise glasses, where scrap brass has been introduced as a colorant.

All Egyptian opaque red glasses which pre-date the ninth century BC contain lead levels of less than 3 per cent oxide; after this date the lead oxide levels generally rise and a brighter (sealing-wax) red glass colour is produced (Freestone 1987) with the development of different, dendritic, cuprous oxide crystals in the glass rather than globular particles.

Iron and manganese Egyptian glasses were coloured 'deliberately' by the probable use of minute quantities of manganese-bearing minerals such as pyrolusite (MnO_2). The chemical compositions of translucent purple Eighteenth-Dynasty glasses (e.g. Table 8.1b, analysis 12) show an elevated manganese oxide level, apparently with few other accompanying impurities, implying that a relatively pure mineral source of colorant, like pyrolusite, was used. The purple colour would be produced by the trivalent Mn^{3+} ion in the glass (Weyl 1937: 118). Manganese, which in later periods is used as a decolorant in glass (Henderson 1985), is present in blue glasses as an impurity and in the purple glass as a colorant, but in the balance of glasses analysed it has either not been detected or only detected at very low levels.

Iron oxide is often present in Egyptian glasses, and may be used to produce a translucent dark brown colour, but generally it occurs only as an impurity which is eclipsed by the addition of colorants like cobalt and copper to the glass melt. The common iron-green glass of later periods is produced by a mixture of ferrous ($Fe2+$) and ferric ($Fe+$) ions in the glass melt (Weyl 1953: 91; Bamford 1982: 6; Sellner *et al.* 1979). Newton (1978) was of the opinion that Medieval glassmakers were 'at the mercy of the furnaces they used', so little direct control existed over the available free oxygen. Egyptians, on the other hand, apparently controlled tightly the addition of trace or minor quantities of colorants deliberately.

Other opacifiers The use of opacifiers in Egyptian glass is discussed above (see pp. 207–8). The electron-microprobe analyses in Table 8.1b provide data which conform with the results produced by other workers: opaque yellow glasses were opacified with lead antimonate (analyses 2, 5, 13, 17 and 19), opaque white glasses with calcium antimonate (analyses 3, 9, 11, 14, 18, 22 and 25), opaque blue, green and turquoise with a combination of calcium antimonate crystals and cobalt, copper and iron, and copper respectively. Often the translucent matrices in which the opacifying crystals sit have a colour which may be modified by the presence of other impurities associated with the colorant or other raw materials. Figures 8.8–8.10 are X-ray spectra produced using proton-induced X-ray emission for opaque white, opaque yellow and opaque blue Amarna glasses. It can be seen that there are major peaks for calcium and antimony in all three glasses because calcium antimonate is the opacifier present. Lead is at higher levels in the opaque yellow glass because lead antimonate is present and cobalt is present in the opaque blue glass.

The working properties of Egyptian soda–lime glasses

The chemical compositions of Egyptian glasses determine their working properties (Doremus 1994, 99 figure 1). As we have seen, most Egyptian translucent glasses are soda–lime–silica in composition. The liquidus temperature for a soda–lime–silica glass containing 18.8 per cent soda, 7 per cent calcium oxide and 74.2 per cent silica is 867 °C, which rises to 1,060 °C for a glass containing 17.6 per cent soda, 15 per cent calcium oxide and 64.7 per cent silica (Morey 1964). The former composition is closest to that for second millennium BC Egyptian glasses, however a closer comparison is provided by the work of Brill (1988) where, despite the fact that the glass dates to the fourth century AD, the basic composition is similar to other, earlier, soda–lime glasses (with some important differences in impurity patterns). Brill (1988, 278–81) showed that for a typical soda–lime glass of *c.* 68–73 per cent silica, *c.* 14–17.4 per cent soda and *c.* 7.4–10 per cent calcium oxide ('lime') the liquidus temperarure was *c.* 900 °C, the softening temperature at which the glass could be moulded was *c.* 1,000 °C and the marvering and gathering temperatures were *c.* 1,000–1,100 °C. It is therefore a perfectly valid assumption that the softening and working temperatures for an Egyptian soda–lime–silica glass of the second millennium BC were between *c.* 1,000 and 1,100 °C. The glass would therefore have a relatively short working time, but since the vessels are made with cores, the length of time it took for the wound trails of glass to fuse would not have been a problem. On the other hand a range of (generally opaque) glasses were used in the decoration of the core formed vessels. Some of these had a high lead oxide level (see Table 8.1b) and would therefore have had a much longer working time and a lower softening temperature of *c.* 750 °C, depending on the level of lead oxide involved. The opaque white glasses used for decorative trailing would have been more difficult to work because they contain no detectable lead oxide, or low levels. These glasses would have been applied as opaque rods to the surface of the core-formed vessels (Gudenrath 1991), and would have been continuously re-heated in order to soften them. This, in turn, could have led to distortions of the patterns, but the most difficult part of the operation would have been to avoid distorting the glass vessel while at the same time keeping the rod of decorative glass sufficiently soft to work. The complete decorated core-formed vessels very rarely display any signs that the artisan who made them had problems decorating them.

Chemical analysis and the interpretation of Egyptian glass technology

It is evident from the above discussion of analytical techniques that great strides have been made in the development of both quicker and less destructive techniques. The interpretation of the results has enabled the analyst to contribute to archaeology in a range of new ways. Some of the earliest analytical work, by Farnsworth and Ritchie (1938) showed that even qualitative analyses could enable the investigator to classify the glasses chemically and to suggest a possible source for the cobalt-rich mineral used to colour Eighteenth-Dynasty Egyptian glasses. Even then it was possible to indicate that the glass technology of the Eighteenth Dynasty was well-formed and involved a range of procedures which were standardised by that time.

Any analytical investigation of Egyptian glass before about 1960, and during the time when Lucas was working, tended to be time-consuming and destructive, using techniques such as arc-source emission spectrometry. Consequently, the number of chemical analyses of Egyptian glass was relatively restricted, and the questions asked of the data were connected to the fact that statistical rigour in assembling compositional groupings tended to be lacking. However, some seminal work was carried out by Rooksby and Turner for example (Rooksby 1962; Turner and Rooksby 1959, 1961, 1963) in the investigation of the compounds used to opacify ancient glasses using X-ray diffraction and identified for the first time some compounds only used in ancient glasses. In spite of Neumann's (1929: 835) claim that the opaque colours found in trailed-on decoration was due to tin oxide this is most unlikely in view of the work by Rooksby, Turner and others. Not a single second millennium BC specimen of Egyptian opaque glass has provided further evidence of the use of tin oxide as an opacifier. Nevertheless Neumann (Neumann and Kotyga 1925: 192) did establish the basic chemical characteristics of Egyptian glasses.

Turner (1956c) carried out a further review and substantiated the basic quantitative characteristics of Egyptian glasses and from this he was able to suggest strongly the kinds of primary raw materials that were used for making Egyptian glass (Turner 1956a). He even refers to the chemical analysis of potential sand sources for Egyptian glasses in order to establish some of the potential impurities that could be introduced into the glass (Turner 1956a: 280–1, tables I–III). Turner's investigation of the glass technology at Amarna (Turner 1954) was the first real study of what can be described as an Egyptian glass production site. This involved the relationship of glass chemical composition to working properties and even the ceramic materials used for crucibles. Publication of later Egyptian glass analyses (Turner 1956c: 169, Table III) dating to *c.* 200–100 BC from Elephantine and 'Alexandrian' glasses showed that while the soda–lime–silica glass technology had persisted in use, 'Roman' glass technology had been introduced to Egypt by this time. The main compositional differences from glasses of the second millennium BC was the use of glasses containing markedly lower magnesia and potassium oxide levels due to the probable use of a mineral source of alkali, like natron, instead of a plant ash. The other difference is the occurrence of a generally much higher level of alumina in the later glasses, which is likely to be due to the use of a sand source rich in an alumina-rich mineral impurity such as feldspar or epidote (Matson 1951: 84; Henderson 1985: 271). Although tin oxide is unusual in opaque glasses of the second to first century BC outside Europe, an opaque white glass of this date from Elephantine contained 0.54 per cent tin oxide (and no copper), and therefore may have been opacified by tin oxide (Turner 1956c: table III, 169); only X-ray diffraction analysis of the glass would provide unambiguous evidence for the presence of tin oxide crystals. Bimson and Freestone (1988: 13–15) published the chemical and structural analyses of glass foundation-deposit plaques of Ptolemy III and Queen Berenice dated to between 246 and 221 BC. These analyses also showed that a low magnesia soda–lime glass was in use which was characterised by elevated alumina levels in the 'Roman' tradition.

The use of a far more automated technique, neutron activation analysis (NAA), led Sayre (1964) and Sayre and Smith (1961) to show how soda–lime Egyptian glasses fitted into other ancient glass technologies in a global context. Because the technique allowed Sayre to examine relative levels of glass impurities in detail, he was able to pinpoint Egyptian glass compositions with unusual characteristics (Sayre 1964). Sayre and Smith (1967) also enlarged Turner's (1954) study of raw materials used in Egyptian glasses by examining the impurity levels introduced by different raw materials in detail; he was able to do this because NAA enabled him to carry out a larger number of analyses (although only fifteen glass samples from the second millennium BC were analysed) and thus he was able to establish compositional variability for individual chemical groupings and also to indicate any exceptions from the norm.

The chemical analyses of Egyptian glasses by Fleming and Swan (1986) using a proton probe (PIXE), provided new data which supported the patterns established by Turner (1954) and by Sayre (1964), emphasising, for example, that very small quantities of colorant-bearing materials must have been introduced in the ancient glass melts (Fleming and Swan 1986) in order to bring about a controlled colouring effect in the glass (Henderson 1985: 283). PIXE is an ideal system for this study because it is capable of detecting very low levels of materials.

Electron microprobe analysis, a micro-destructive technique which can produce high quality results, became a relatively widely used analytical technique in the 1970s. The alumina levels detected in the electron probe analyses of Eighteenth-Dynasty opaque glasses published here suggest that the recipe used for making glass at Amarna was not always the same, and indeed the low levels of magnesia in the cobalt-blue glasses detected (Table 8.1b) suggests that a different source of alkali was used in making them (and see Lilyquist and Brill 1993: 41). Other chemical analyses of Amarna glasses have been published by Kühne (1969).

Many of Brill's analyses of Egyptian glasses involved the use of AAS (atomic absorption spectroscopy; see Lilyquist and Brill 1993). Important compositional similarites were noted for glass dating to between the late sixteenth and fourteenth centuries, underlining both that the glass used was the product of a relatively well-established industry, given a relatively low level of compositional variation, and that while the mineralogy of ceramics can sometimes provide a means of 'fingerprinting' them, glass can be far more difficult to characterise as to its regionalised production technology.

Complete chemical analysis of blue and turquoise glass ingots from the fourteenth-century BC Ulu Burun shipwreck, undertaken by Brill, has not yet been published (*cf.* Bass 1986: 282 n. 55; see also section on secondary processing p. 200). In any case it is not yet clear as to whether glass was made from raw materials in Egypt *and* in Mesopotamia in the fourteenth century BC, or imported from Mesopotamia. Although glass was intentionally manufactured in Western Asia from at least as early as *c.* 1500 BC (Moorey 1994: 201) no incontrovertible evidence has been found for the fritting of glass from primary raw materials in either Egypt or Mesopotamia, this being the only certain evidence for primary glass-making at a specific location. Although the earliest glass has been found in Mesopotamia, this does not preclude the possibility that glass was fused from primary raw materials in Egypt later. Further archaeological and scientific investigations need to be carried out in order to investigate this.

If we compare the impurity patterns of magnesia and potassium oxide detected in the Amarna glasses listed here with those from glasses of the late fifteenth to fourteenth centuries BC and thirteenth to twelfth centuries BC from the site of Pella in Jordan (Henderson in preparation) and of fourteenth-century BC date from Tell Brak in Syria (Henderson 1998), as well as Minoan glasses of *c.* fourteenth century BC (Henderson, unpublished analyses), it can be seen that the Amarna glasses form a relatively tight compositional group when compared with the glasses from Tell Brak (see Fig. 8.13). It will be noted that there is also a very interesting compositional distinction between low magnesia thirteenth- and twelfth-century Pella glasses and the earlier high magnesia late fifteenth- and fourteenth-century Pella glasses which, apart from one, fall close to the Amarna glasses. Thus, although from an early period Egyptian glass displays signs of being a conservative technology (Lilyquist and Brill 1993: table 2; see also Table 8.1b and Fig. 8.13 here), and to some extent this is also true of Amarna glass, there is nevertheless some compositional variation, with some relatively high alumina levels occurring in translucent non-cobalt glasses as early as the reign of Thutmose III (Lilyquist and Brill 1993: fig. 57).

The fusion of glass raw materials at high temperatures of up to *c.* 1,400 °C, and the introduction of minute quantities of colorants to the glass in highly controlled ways, are both a testament to the extremely high degree of skill which was involved in glass manufacture in Egypt. Further detailed analytical investigations need to be carried out in order to establish whether glass was made independently from an early period in Egypt; questions still remain as to whether all early Egyptian glass was imported from Mesopotamia and where the glass ingots found on the Ulu Burun shipwreck were originally made, as distinct from being poured into moulds. It is worth noting however, that the moulding of ingots of foreign glass in Egypt, for export to a third country would seem an odd practice unless they were being altered in some way, for example by the addition of a local colorant (see section on secondary processing p. 199). Given the potential variation in the impurity levels of glasses of the second millennium BC in the circum-Mediterranean region (Fig. 8.13), further analytical research is essential.

Acknowledgements [Nicholson]

I would like to thank the Egypt Exploration Society and Mr Barry Kemp for their suppport of my work at site O45.1 at Amarna. The work has been funded by the Wainwright Fund for Near Eastern Archaeology to whom I am indebted, while analytical work by myself and Dr Caroline M. Jackson has been supported by the Leverhulme Trust, grant F/407/J whose support is gratefully acknowledged.

Rene Cappers and Mary Anne Murray kindly provided information on the distribution of glass-making plants and Dr Delwen Samuel gave information on alkali plants. Mr Ian Mathieson carried out geophysical survey at site O45.1 and I am indebted to him. Ms Susan Cole, Mr Ian Dennis, Dr Jackson, Professor Michael S. Tite and Dr Katharine M. Trott have all worked for the 'Amarna Glass Project', and

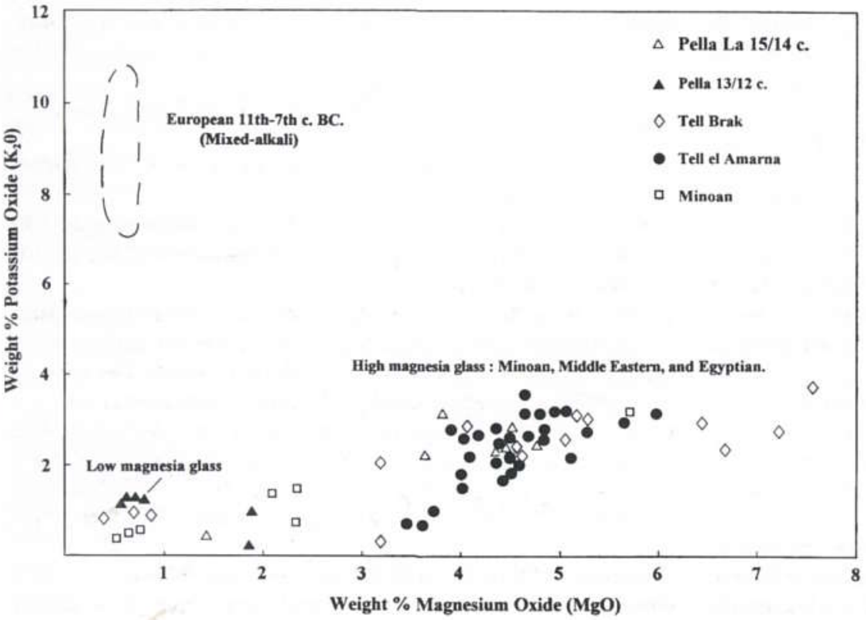


Figure 8.13 A bivariate plot of weight percent of potassium oxide (K_2O) versus weight per cent magnesia (MgO) in glass samples dating to between the fifteenth and twelfth centuries BC from Pella (Jordan); Tell Brak (Syria); Amarna (Egypt); and Minoan samples from Crete. The relative magnesia and potassium oxide levels of some eleventh to seventh century BC glasses from Europe are also plotted to illustrate that an entirely different (mixed-alkali) glass technology also existed slightly later the these soda–lime glasses plotted.

their hard work is gratefully acknowledged. The work at Amarna would not have been possible without the kind cooperation of the Egyptian Supreme Council for Antiquities to whom I am indebted.

Ms Janine Bourriau and Dr Carol Andrews kindly commented on an earlier draft of my section of this chapter and I am indebted to them for their comments.

Acknowledgements [Henderson]

I would like to thank Dr Roger Moorey and Dr Helen Whitehouse of the Ashmolean Museum, Oxford, for permission to sample glass from Tell el-Amarna in order to undertake electron probe microanalyses. I would also like to record my thanks to Dr Ian Freestone and Dr Norman Charnley for discussions over the years on the interpretation of glass analyses, and to both St Cross College, Oxford for a Junior Research Fellowship and the (then) SERC for a Post-doctoral Fellowship at the time when this research was carried out.

References

Bamford, C. R. 1977. *Colour Generation and Control in Glass.* Amsterdam: Elsevier Scientific Publishing.

1982. Optical properties of flat glass. *Journal of Non-Crystalline Solids*, 47 (1): 1–20.

Bass, G. 1986. A Bronze Age shipwreck at Ulu Burun (Kas): 1984 campaign. *AJA*, 90: 269–96.

1987. Oldest known shipwreck reveals splendors of the Bronze Age. *National Geographic*, 172 (6): 692–733.

Bass, G, Pulak, C., Collon, D. and Weinstein, J. 1989. The Bronze Age shipwreck at Ulu Burun: 1986 campaign. *AJA*, 93: 1–29.

Bayer, G. and Wiedmann, H.-G. 1976. Ägyptisch Blau, ein synthetisches Farbpigment des Altertums, wissenschaftlisch betrachtet. *Sandoz-Bulletin* 40, 20–39.

Beadnell, H.J.L. 1901. *Dakhla Oasis: Its Topography and Geology.* Egyptian Geological Survey Report 1899 Pt. 4.1. Cairo: GSE.

1909. *An Egyptian Oasis: An Account of the Oasis of Kharga in the Libyan Desert.* London: John Murray.

Beck, H.C. 1934. Glass before 1500 BC. *Ancient Egypt* (June 1934): 7–21.

Bianchi, R.S. 1983a. Those ubiquitous glass inlays from pharaonic Egypt, part I. *Journal of Glass Studies*, 25, 29–35.

1983b. Those ubiquitous glass inlays, part II. *BES*, 5, 9–29.

Bimson, M. and Freestone, I.C. 1988. Some Egyptian glasses dated by royal inscriptions. *Journal of Glass Studies*, 30: 11–15.

Bimson, M. and Shore, A.F. 1966. An Egyptian model coffin in glass. *BMQ*, 31: 105–9.

Bimson, M. and Werner A.E. 1969a. Two problems in ancient glass: opacifiers and Egyptian core material. In *Annales du* 4^a *Congrès International d'Etude Historique du Verre* (ed. J. Philippe). Liège: Journales Inernationales du Verre, pp. 262–6.

Bimson, M. and Werner, A.E. 1969b. Problems in Egyptian core glasses. In *Studies in Glass History and Design* (eds. R.J. Charleston, W. Evans and A.E. Werner). Sheffield: Society for Glass Technology, pp. 121–2.

Boyce, A. 1989. Notes on the manufacture and use of faience finger rings at Amarna. In *Amarna Reports* V (ed. B.J. Kemp). London: EES, pp. 160–8.

1995. Collar and necklace designs at Amarna: a preliminary study of faience pendants. In *Amarna Reports* VI (ed. B.J. Kemp). London: EES, pp. 336–71.

Breasted, J.H. 1906. *Ancient Records of Egypt* II. Chicago IL: University of Chicago Press.

Brill, R. H. 1963. Ancient glass. *Scientific American*, 209: 120–31.

1968. The Scientific investigation of ancient glasses. *Proceedings of the VIIIth International Congress on Glass.* Sheffield: The Society of Glass Technology, pp. 47–68.

1970. The chemical interpretation of the texts. In *Glass and Glassmaking in Ancient Mesopotamia* (eds. A.L. Oppenheim, Brill, R. H., Barag, D. and A. Von Saldern). Corning: The Corning Museum of Glass, pp. 105–28.

1972. Chemical-analytical round-robin of four synthetic ancient glasses. *Proceedings of the Ninth International Congress on Glass, Artistic and Historical Communications, Versailles 1971.* Versailles: The International Congress on Glass, pp. 93–100.

1988. Scientific investigations of the Jalame glass and related finds. In *Excavations At Jalame* (ed. G.D. Weinberg) Columbia: University of Missouri Press, pp. 257–94.

Brill, R.J., Barnes, I.L. and Adams, B. 1974. Lead isotopes in some ancient Egyptian objects. In *Recent Advances in Science and Technology of Materials Vol. 3* (ed. A. Bishay). London: Plenum, pp. 9–27.

Brill, R.H. and Moll, S. 1963. The electron-beam probe microanalysis of ancient glass. In *Recent Advances in Conservation* (ed. G. Thompson). Contributions to the International Institute of Conservation Conference, Rome 1961. London: Butterworth, pp. 145–51.

Brill, R.H., Shirahata, H., Lilyquist, C. and Vocke, R.D. Jr. 1993. Lead-isotope analyses of some objects from Egypt and the Near East. In *Studies in Early Egyptian Glass* (C. Lilyquist and R.H. Brill with M. T. Wypyski). New York: MMA, pp. 59–70.

Caley, E.R. 1962. *Analyses of Ancient Glasses 1790–1957.* Corning: Corning Museum of Glass.

Chase, W.T. 1971. Egyptian blue as a pigment and a ceramic material. In *Science And Archaeology* (ed. R.H. Brill). Leiden: Brill, pp. 80–90.

Cooney, J.D. 1960. Glass sculpture in ancient Egypt. *Journal of Glass Studies*, 2: 10–43.

1976. *Catalogue of Egyptian Antiquites in the British Museum IV: Glass.* London: BMP.

1981. Notes on Egyptian glass. In *Studies In Ancient Egypt, The Aegean and the Sudan* (eds. W.K. Simpson and W.M. Davis). Boston: MFA, pp. 31–3.

Daressy, M.G. 1902. *Fouilles de la Vallée des Rois 1898–9.* Cairo: Catalogue géneral des antiquités du musée du Caire.

Davis, T.M. 1907. *Excavations in the Biban el Moluk. The Tomb of Iouiya and Touiyou.* London: Archibold Constable and Co.

Dayton, J.E. 1981. Cobalt, silver and nickel in Late Bronze Age glazes, pigments and bronzes, and the identification of silver sources for the Aegean and Near East. In *Scientific Studies in Ancient Ceramics* (ed. M.J. Hughes). London: BMP, pp. 129–42.

Doremus, R. H. 1994. *Glass Science.* New York: Wiley.

Eisenberg, J. 1996. Archaeological news from San Diego.

Minerva, 7/2, 49.

Emery, W.B. 1967. Preliminary report on the excavations at North Saqqâra. *JEA*, 53: 141–5.

Farnsworth, M. and Ritchie, P.D. 1938. Spectrographic studies on ancient glass. Egyptian glass mainly of the 18th Dynasty, with special reference to its cobalt content. *Technical Studies in the Field of the Fine Arts*, 6/3: 155–73.

Fleming S.J. and Swan C.P. 1986. PIXE spectrometry as an archaeological tool. *Nuclear Instruments and Methods in Physics Research* A242, 626–31.

Forbes, R.J. 1957. *Studies in Ancient Technology* Vol. 5. Leiden: Brill.

Fossing, P. 1940. *Glass Vessels Before Glass Blowing*. Copenhagen: Munksgaard.

Foster, K.P. 1979. *Aegean Faience Of The Bronze Age*. New Haven CT: Yale University Press.

Freestone, I.C. 1987. Composition and microstructure of early opaque red glass. In *Early Vitreous Materials* (eds. M. Bimson and I.C. Freestone). London: British Museum Occasional Paper no. 56, pp. 173–91.

1991. Looking into glass. In *Science and the Past* (ed. S. Bowman). London: BMP, pp. 37–56.

Gadd, C.J. and Thompson, R.C. 1936. A Middle-Babylonian chemical text. *Iraq*, 3: 87–96.

Garner, H. 1956a. The use of imported and native cobalt in Chinese blue and white. *Oriental Art*, 2/3: 48–50.

1956b. An early piece of glass from Eridu. *Iraq* ,18: 147–9.

Geilmann, W. 1955. Beiträge zur Kenntnis alter Gläser III. Die chemische Zusammensetzung einiger alter Gläser, inbesondere deutscher Gläser des 10. bis 18. Jahrhunderts. *Glastechnische Berichte*, 28: 146–56.

Goldstein, S.M. 1979. A unique royal head. *Journal of Glass Studies*, 21, 8–16.

Gudenrath, W. 1991. Techniques of Glassmaking and Decoration. In *Five Thousand Years of Glass* (ed. Hugh Tait). London: BMP, pp. 213–41.

Guido, C.M., Henderson, J. Cable, C., Bayley, J. and Biek, L. 1984. A Bronze Age glass bead from Wilsford, Wiltshire: Barrow G42 in the Lake Group. *PPS*, 50: 245–54.

Hall, E.T. 1965. Recent research at the Research Laboratory for Archaeology and the History of Art, Oxford. *Application of Science in Examination of Works of Art*. Boston: MFA, pp. 105–13.

Hall, E.T., Schweizer, F. and Toller, P.A. 1973. X-ray fluorescence analysis of Museum objects: a new instrument. *Archaeometry*, 15: 53–78.

Hamza, M. 1930. Excavations of the Department of Antiquities at Qantîr (Faqûs district). *ASAE*, 30: 31–68.

Harden, D.B. 1956. Glass and glazes. In *A History of Technology* II (eds. C. Singer, E.J. Holmyard, A.R. Hall and T.I. Williams). Oxford: Clarendon, pp. 311–46.

1968. Ancient glass I: pre-Roman. *The Archaeological Journal*, 125: 46–72.

Harris, J.R. 1961. *Lexicographical Studies in Ancient Egyptian Minerals*. Berlin: Institut für Orientforschung Veröffentlichung 54.1.

Hatcher, H. Tite, M. S. and Walsh, J. N. 1995. A comparison of inductively-coupled plasma emission spectroscopy and atomic absorption spectrometry analysis on standard reference silicate materials and ceramics. *Archaeometry*, 37: 83–94.

Hedges, R. E. M. and Moorey, P. R. S. 1975. Pre-Islamic ceramic glazes at Kish and Nineveh in Iraq. *Archaeometry*, 28/2: 25–43.

Henderson, J. 1985. The raw materials of early glass production. *Oxford Journal of Archaeology*, 4/3, 267–91.

1988. Electron probe microanalyses of mixed-alkali glasses. *Archaeometry*, 30/1, 77–91.

1989. The scientific analysis of ancient glass and its archaeological interpretation. In *Scientific Analysis In Archaeology* (ed. J. Henderson). Oxford: Oxford University Committee for Archaeology, Monograph 19, pp. 30–62.

1995. Ancient vitreous materials. *AJA*, 99: 117–21.

1998. Scientific analysis of glass and glaze from Tell Brak and its archaeological implications. In *Excavations at Tell Brak Vol. I: The Mitanni and Old Babylonian periods*. (D. Oates, J. Oates and H. McDonald). (McDonald Institute Monographs.) Cambridge: The McDonald Institute for Archaeological Research and BSAI, pp. 94–100.

in preparation. Scientific analysis of the glass from Bronze Age Pella.

Henderson, J. and Warren, S.E. 1983. Analysis of prehistoric lead glass. *Proceedings of the 22nd International Symposium on Archaeometry*. Bradford: University of Bradford, pp. 168–80.

Henein, N.H. and Gout, J-F. 1974. *Le verre soufflé en Égypte*. Cairo: IFAO.

Heyworth, M.P., Hunter, J.R., Warren, S.E. and Walsh, N. 1989. The role of inductively coupled plasma spectrometry in glass provenance studies. In *Archaeometry: Proceedings of the 25th International Symposium* (ed. Y. Maniatis). Oxford: Elsevier, pp. 661–70.

Highley, D.E. 1977. *Silica. Mineral Dossier no. 18*. London: HMSO.

Howarth, J.T., Sykes, R.F.and Turner, W.E.S. 1934. A study of the fundamental reactions in the fomration of soda–lime–silica glasses. *Journal of the Society of Glass Technology*, 18, 290–306T.

Hughes, M.J. 1972. A technical study of opaque red glass of the Iron Age in Britain. *PPS*, 38: 98–107.

Hughes, M.J., Cowell, M.R. and Craddock, P.T. 1976. Atomic absorption techniques in archaeology. *Archaeometry*, 18, 19–37.

Hughes, M.J., Cowell, M.R. and Hook, D.R. (eds.) 1991. *Neutron Activation and Plasma Emission Spectrometric Analaysis in Archaeology*. British Museum Occasional Paper no. 82. London: BMP.

Jackson, C.M., Nicholson, P.T. and Gneisinger, W. 1998. Glassmaking at Tell el-Amarna: an integrated approach. *Journal of Glass Studies*, 40: 11–23.

Jenkins, R. 1988. *X-ray Fluorescence Spectrometry*. Chichester: Wiley-Interscience.

Jope, E.M. and Huse, G. 1940. Examination of 'Egyptian blue' by X-ray powder photography. *Nature*, 146: 26.

Kaczmarczyk, A. 1986. The source of cobalt in ancient Egyptian pigments. In *Proceedings of the 24th International Archaeometry Symposium* (eds. J.S. Olin and M.J. Blackman). Washington DC: Smithsonian Institution Press, pp. 369–76.

1991. The identity of *wšbt* alum. *JEA*, 77: 195.

Kaczmarczyk, A. and Hedges, R.E.M. 1983. *Ancient Egyptian Faience*. Warminster: Aris and Phillips.

Keller, C.A. 1983. Problems in dating glass industries of the

Egyptian New Kingdom: examples from Malkata and Lisht. *Journal of Glass Studies*, 25: 19–28.

Kühne, J. 1969 *Zur Kenntnis silikatischer Werkstoffe und der Technologie ihrer Herstellung im 2. Jahrtausend vor unserer Zeitrechnung*. Berlin: Abhandlung der Deutschen Akademie der Wissenschaften zu Berlin.

Labino, D. 1966. The Egyptian sand-core technique: a new interpretation. *Journal of Glass Studies*, 8: 124–7.

Lambert, J. B. and McLaughlin, C. D. 1976. Analysis of early Egyptian glass by atomic absorption and X-Ray photoelectron spectroscopy. In *Archaeological Chemistry* II, (ed. G. F. Carter), Advances in Chemistry Series no. 171. Washington DC: The American Chemical Society, pp. 189–99.

Lilyquist, C. and Brill, R.H. 1993. *Studies in Early Egyptian Glass*. New York: MMA.

Löw, I. 1924–1934. *Die Flora der Juden*. Vienna and Leipzig: R. Lowit, Veroffentlichungen der Alexander Kohut Memorial Foundation 2–4, 6.

Lucas, A. 1933. Appendix 2: The chemistry of the tomb. In *The Tomb of Tut-ankh-amen* III (H. Carter). London: Cassell and Co., pp. 170–83.

1934. *Ancient Egyptian Materials and Industries*, 2nd edn. London: Edward Arnold.

1948. *Ancient Egyptian Materials and Industries*, 3rd edn. London: Edward Arnold.

1962. *Ancient Egyptian Materials and Industries*, 4th edn., rev. J.R. Harris. London: Edward Arnold.

Martin, G.T. 1971. *Egyptian Administrative and Private-name Seals*. Oxford: Griffith Institute.

Matson, F. R. 1951. The composition and working properties of ancient glass. *The Journal of Chemical Education*, 28: 82–7.

Mehlman, F. 1982. *The Phaidon Guide to Glass*. Oxford: Phaidon.

Moorey, P.R.S. 1994. *Ancient Mesopotamian Materials and Industries*. Oxford: Clarendon Press.

Moran, W.L. 1992. *The Amarna Letters*. Baltimore MD: Johns Hopkins University Press.

Morey, G. W. 1964. Phase-equilibrium relations of the common rock-forming oxides except water. *U.S. Geological Survey Professional Paper* no. 440–L, Chapter L.

Morgan, M.H. 1914. Vitruvius: *The Ten Books on Architecture*. Harvard: Harvard University Press.

Neumann, B. 1929. Antike Gläser IV. *Zeitschrift für angewandte Chemie*, 42: 835–8.

Neumann, B. and Kotyga, G. 1925. Antike Gläser, ihre Zusammensetzung und Färbung. *Zeitschrift für angewandte Chemie*, 38, 776–80 and 857–64.

Newberry, P.E. 1920. A glass chalice of Tuthmosis III. *JEA*, 6: 155–60.

Newton, R. G. 1978. Colouring agents used by medieval glassmakers. *Glass Technology*, 21/4: 173–83.

1980. Recent views on ancient glasses. *Glass Technology*, 21 (4): 173–183.

Newton, R.G. and Davison, S. 1989. *Conservation of Glass*. London: Butterworths.

Nicholson, P.T. 1993. *Egyptian Faience and Glass*. Aylesbury: Shire.

1995. Glassmaking and glassworking at Amarna: some new work. *Journal of Glass Studies*, 37: 1–19.

1996. New evidence for glass and glazing at Tell el-Amarna (Egypt). In *Annales of the 13th AIHV Congress*. Netherlands: AIHV, pp. 11–19.

Nicholson, P.T. and Jackson, C.M. 1998. Kind of blue: glass of the Amarna period replicated. In *The Prehistory and History of Glass and Glass Technology* (eds. W.D. Kingery and P. McCray). Columbus, OH: American Ceramic Society, pp. 105–20.

Nicholson, P.T., Jackson, C.M. and Trott, K.M. 1997. The Ulu Burun glass ingots, cylindrical vessels and Egyptian glass. *JEA*, 83, 143–53.

Noll, W. 1981. Mineralogy and technology of the painted ceramics of ancient Egypt. In *Scientific Studies in Ancient Ceramics* (ed. M.J. Hughes). London: BMP, pp. 143–54.

Nolte, B. 1968. *Die Glasgefässe im Alten Agypten*. Munich: Münchner Ägyptologische Studien, 14.

1977a. Glas. *LÄ* II, 614–17.

1977b. An Egyptian glass vessel in the Metropolitan Museum of Art. In *Ancient Egypt in the Metropolitan Museum Journal Vols. 1–11 (1968–1976)*. New York: MMA, pp. 25–9.

Oppenheim, L. 1970. The cuneiform tablets with instructions for glassmakers. In *Glass and Glassmaking in Ancient Mesopotamia* (eds. A.L. Oppenheim, R.H. Brill, D. Barag and A. von Saldern). Corning: Corning Museum of Glass, pp. 22–68.

1973. Towards a history of glass in the ancient Near East. *Journal of the American Oriental Society*, 93: 259–66.

Parodi, H.D. 1908. *La verrerie en Egypte*. Cairo: Khedival Technical School, Bulak. [Thesis at University of Grenoble]

Peltenburg, E.J. 1987. Early faience: recent studies, origins and relations with glass. In *Early Vitreous Materials* (eds. M. Bimson and I.C. Freestone). British Museum Occasional Paper 56. London: BMP, pp. 5–29.

Petrie, W.M.F. 1891. *Illahun, Kahun And Gurob*. London: Nutt.

1892. *Ten Years Digging in Egypt*. London: Religious Tract Society.

1894. *Tell el-Amarna*. London: Methuen & Co.

1909. *Arts and Crafts of Ancient Egypt*. London: Foulis.

1924. *Ancient Egyptians*. H. Spencer's Descriptive Sociology 11.1. London: Williams and Norgate.

1925. Glass found in Egypt. *Transactions of the British Newcomen Society*, 5: 72–6.

1926. Glass in the early ages. *Journal of the Society of Glass Technology*, 10, 229–34.

Pusch, E. 1990. Metallverarbeitende Werkstätten in Qantir/Piramesse-Nord. *Ägypten und Levante*, 1: 75–113.

Reeves, C. N. 1986. Two name-beads of Hatshepsut and Senenmut from the mortuary temple of Queen Hatshepsut at Deir el-Bahri. *Antiquaries Journal*, 66: 387–8.

1990. *The Complete Tutankhamun*. London: Thames and Hudson.

Rehren, T. 1997. Ramesside glass-colouring crucibles. *Archaeometry*, 39/2: 355–68.

Rehren, T. and Pusch, E. 1997. New Kingdom glass melting crucibles from Qantir-Piramesses, Nile Delta. *JEA*, 83.

Riefstahl, E. 1968. *Ancient Egyptian Glass and Glazes in the Brooklyn Museum*. New York: Brooklyn Museum.

Rooksby, H.P. 1962. Opacifiers in opal glasses. *GEC Journal of Science and Technology*, 29/1: 20–6.

Saleh, S.A., George, A.W. and Helmi, F.M. 1972. Study of glass and glass-making at Wadi-el-Natrun. *Studies in Conservation*, 17: 143–72.

Sayre, E.V. 1963. The intentional use of antimony and manganese in ancient glasses. In *Advances in Glass Technology II* (eds. F.R. Matson and G.E. Rindone). New York: Plenum, pp. 263–82.

1964. *Some Ancient Glass Specimens with Compositions of Particular Archaeological Significance.* New York: Brookhaven National Laboratory.

Sayre, E.V. and Smith, R. W. 1961. Compositional categories of ancient glass. *Science*, 133 (June 9): 1824–6.

1967. Some materials of glass manufacturing in antiquity. In *Archaeological Chemistry, a Symposium*, (ed. M. Levey). Philadelphia PA: University of Philadelphia Press, pp. 279–311.

Schuler, F. 1962. Ancient glassmaking techniques. The Egyptian core vessel process. *Archaeology*, 15: 32–7.

1963. Ancient glassmaking: methodology for attacking the Assyrian glassmaking texts. In *Advances in Glass Technology 2* (eds. F.R. Matson and G.E. Rindone). New York: Plenum, pp. 381–3.

Segnit, E.R. 1987. Evaporite minerals from the Dakhleh oasis. In *Ceramics from the Dakhleh Oasis: Preliminary Studies* (W.I. Edwards, C.A. Hope and E.R. Segnit). Melbourne: Victoria College Archaeology Research Unit Occasional Paper 1, pp. 97–102.

Sellner, C., Oel, H.J., and Camera, B. 1979. Untersuchung alter Gläser (Waldglas) auf Zusammenhang von Zisammensetzung, Farbe und Schmelzatmosphare mit der Elektronenspektoskopie und der Elektronenspinresonanz (ESR). *Glastechniche Berichte*, 52: 255–64.

Smith, S. 1928. *Early History of Assyria to 1000 BC.* London: Chatto and Windus.

Stern, E.M. and Schlick-Nolte, B. 1994. *Early Glass of the Ancient World 1600 BC–AD 50.* Ostfildern: Verlag Gerd Hatje.

Täckholm, V. and Drar, M. 1956. *A Student's Flora of Egypt.* Cairo: Anglo-Egyptian Bookshop.

Tatton-Brown, V. and Andrews, C. 1991. Before the invention of glassblowing. In *Five Thousand Years of Glass* (ed. H. Tait). London: BMP, pp. 20–61.

Thompson, R.C. 1925. *On the Chemistry of the Ancient Assyrians.* London: Luzac.

Tite, M.S. 1986. Egyptian blue, faience and related materials: technological investigations. In *Science in Archaeology* (eds. R.E. Jones and H.W. Catling). Fitch Laboratory Occasional Paper 2, London: British School at Athens, pp. 39–41.

Tite, M.S. and Bimson, M. 1987. Identification of early vitreous materials. In *Recent Advances in the Conservation and Analysis of Artifacts* (ed. J. Black). London: Summer Schools Press, pp. 81–5.

Turner, W.E.S. 1954. Studies of ancient glass and glassmaking processes, Part I. Crucibles and melting temperatures employed in ancient Egypt at about 1370 BC. *Journal of the Society of Glass Technology*, 38: 183, 436–44T.

1956a. Studies in ancient glasses and glassmaking processes. Part V. Raw materials and melting processes. *Journal of the Society of Glass Technology*, 40/194: 277–300T.

1956b. Studies of ancient glass and glassmaking processes, Part III: The chronology of glass-making constituents. *Journal of the Society of Glass Technology*, 40: 39–52.

1956c. Studies in ancient glasses and glass-making processes, Part IV: The chemical composition of ancient glasses. *Journal of the Society of Glass Technology*, 40: 162–86.

Turner, W.E.S. and Rooksby, H.P. 1959. A study of opalising agents in ancient opal glasses throughout three thousand four hundred years. *Glastechniche Berichte*, 32K, 8: 17–28.

1961, Further historical studies based on X-ray diffraction methods of the reagents employed in making opal and opaque glasses. *Jahrbuch des Römisch-Germanischen Zentralmuseums*, 8: 1–16.

1963, A study of the opalising agents in ancient glasses throughout 3400 years, part II. *Proceedings of the 6th International Congress on Glass: Advances in Glass Technology* (eds. F.R. Matson and G.E. Rindone). New York: Plenum, pp. 306–7.

Ullrich, D. 1979. Ägyptisch Blau ($CaCuSi_4O_{10}$): Bildungsbedingungen und Rekonstruktionsversuch der antiken Herstellungstechnik. Diploma dissertation. Freie Universität Berlin.

Vandiver, P.B. 1983. The manufacture of faience. In *Ancient Egyptian Faience* (A. Kaczmarkzyk and R.E.M. Hedges). Warminster: Aris and Phillips, pp. A1–A144.

Vandiver, P.B., Swann, C. and Cranmer, D. 1991. A review of mid-second millennium BC Egyptian glass technology at Tell el-Amarna. In *Materials Issues In Art And Archaeology II* (eds. P.B. Vandiver, J. Druzik and G.S. Wheeler). Pittsburgh: Materials Research Society, pp. 609–16.

Vassamillett, L.F. and Caldwell, V.E. 1969. Electron probe microanalysis of alkaline metals in glasses. *Journal of Applied Physics*, 40: 1637.

Veritá, M. Basso, R., Wypyski, M.T. and Koestler, R.J. 1994. X-ray microanalysis of ancient glassy materials: a comparative study of wavelength dispersive and energy dispersive techniques. *Archaeometry*, 36: 241–52.

Weatherhead, F and Buckley, A. 1989. Artists' pigments from Amarna. In *Amarna Reports* V (ed. B.J. Kemp). London: EES, pp. 202–40.

Weyl, W.A. 1937. The chemistry of coloured glass: II. *The Glass Industry* April 1937: 117–20.

1953. *Coloured Glasses.* Corning: The Corning Museum of Glass.

Wosinski, J.F. and Brill, R.H. 1968. A petrographic study of Egyptian and other cored vessels. *Studies in Glass History and Design*. Sheffield, pp. 123–4.

Part II.
Organic materials

Part II.
Organic materials

9. Papyrus

BRIDGET LEACH AND JOHN TAIT

Introduction

The writing material made from the papyrus plant *Cyperus papyrus* L. was the most important surface for recording written information used by the ancient Egyptians, and they themselves evidently regarded it as the primary writing-ground (general accounts of papyrus in the context of Pharaonic Egypt include Woenig 1886: 74–129; Täckholm and Drar 1950: 99–145; Černý 1952; Lucas 1962: 137–40, 364; Weber 1969: 1–13; Ragab 1980b; Drenkhahn 1982; Germer 1985: 248–50; Manniche 1989: 99–100; Parkinson and Quirke 1995). Various other materials were used for Egyptian scripts written with a pen, such as ostraca (that is, both potsherds and flakes of limestone), animal skins and tablets of wood (or occasionally of stone). The earliest extant papyrus is a blank roll from the Early Dynastic tomb of Hemaka (tomb 3035) at Saqqara, dating to the beginning of the third millennium BC: 'circular wooden box . . . A small flattened roll of uninscribed papyrus was the sole contents' (Emery 1938: 41, pl. 23a). Use of papyrus was continuous throughout Dynastic and Greco-Roman Egypt, into the Byzantine and early Islamic periods. The latest extant papyrus is an Arabic document dated AD 1087 (Pattie and Turner 1974: 7). Texts take the form of whole rolls, or sheets or strips cut from a roll, and, in later periods, codices (that is, books made up of folded sheets, or gatherings of folded sheets, much in the manner of a modern stitched hardback volume). Production of the writing material had declined by the seventh to eighth centures AD, when we see the increased use of animal skins (for example parchment) and of paper made from macerated plant residues.

Taxonomy and distribution of the papyrus plant

The taxonomy of the plant is complex and need not be discussed at length here. The genus name is *Cyperus*, of which there are more than 600 species, one of them being *C. papyrus*. The genus *Cyperus* belongs to the substantial family of *Cyperaceae*, or sedges, which in turn belongs to the larger classification of monocotyledons. These constitute one of the two great divisions of flowering plants: monocotyledons contain one seed leaf, and dicotyledons contain two. *Cyperus papyrus* L. is the botanical name given to the plant. The 'L' stands for Linnaeus, the Latin form of the name of the Swedish botanist Linné, who first classified the plant using the reproductive system in his work *Species Plantarum*, published in 1753 (Linnaeus 1753: I, 47). Various botanists since that time have described it, comparing samples from various geographical areas and naming or re-naming the different sub-species. There are minor botanical differences between these, but the exact sub-species used in antiquity for making the writing material cannot be assessed with any certainty. Ecological shifts over many centuries affecting the content of Nile water and the surrounding soil must have caused changes, small or otherwise, in the plants we are able to examine today. However, certain sub-species of the plant do make better papyrus sheets than others (see p. 228–9).

Today the plant in the wild is widely distributed over large swamplands in Central and East Africa, where it grows profusely (Carter 1953: 3) and also parts of West Africa (Nielsen 1985: 12). In addition it grows in Sicily, and has also been found in Palestine (Täckholm and Drar 1950: 136). It does not grow in the Egyptian Nile Valley today, other than modern horticultural or commercial reintroductions. However, travellers from medieval times until the nineteenth century reported seeing it still growing, particularly in the environs of Damietta and Lake Manzala in Lower Egypt (Täckholm and Drar 1950: 133–4). Because of its disappearance, there has been some debate as to whether papyrus was ever indigenous to Egypt, or might have been imported there as a cultivar (Täckholm and Drar 1950: 139). At the end of the eighteenth century, James Bruce, in his *Travels to Discover the Source of the Nile* (1790) argued against previous writers that neither the main stream of the Nile nor Egypt could have been the proper home of papyrus, remarking that it 'seems to me to have early come down from Ethiopia', that 'its head is too heavy', and that the 'stalk is small and feeble, and withall too tall, the root too short and slender to stay it against the violent pressure of the wind and current, and therefore I do constantly believe it never could be a plant growing in the Nile itself, or in any very deep or rapid river'. (Bruce 1790: V, 1–2; *cf.* Täckholm and Drar 1950: 139–40)

Bruce will have been influenced in his account by his quite incorrect belief that hieroglyphic writing fell into disuse before papyrus began to be employed. However, representational evidence in the numerous depictions of wild papyrus in marshes and hunting scenes, and the major role of the papyrus stem as a symbol, for example in temple architecture, make it implausible to reject the accepted view that the plant was both indigenous and, in the Pharaonic period, widespread in the Egyptian Nile Valley.

The disappearance of the plant from Egypt could perhaps be explained in several ways: ecologically, agriculturally and culturally. Firstly, the silting up and obstruction of the channels and waterways where the papyrus grew must have been a major factor. Täckholm and Drar (1950: 143) draw attention to the fact that certain branches of the Nile in the Delta had completely dried up 'within the Christian and Early Islamic periods', thus inhibiting the flow of fresh water to the papyrus and other plant habitats and depriving the roots of their essential supply of water. The papyrus root-stock is anchored very shallowly in the soil and it would be one of the first plants to disappear if its habitat were altered in such a way. Also, rising salination of the soil, a process which has increased over a long period of time, may have been a factor. As early as 1902, Alfred Lucas (1902: 8) conducted, for agricultural purposes, a survey of the soil and water in the Fayum Province, to determine the presence of injurious salts. Conditions in the Fayum will be different from those in the Nile Valley, but it is remarkable that Lucas found that the salt levels in some soils were indeed high: over ten times the level regarded to be harmful to crops (see p. 242). It is doubtful whether the character of the water of the Nile itself had any bearing on the plant's disappearance. The chemical content of water in the swamp habitats of Uganda, where papyrus still grows wild, is evidently suitable for papyrus growth. In 1953, G.S. Carter carried out an extensive survey of the chemical content of the waters of the papyrus swamps of Uganda (1953: 26). It is comparable to the chemical content of Nile water analysed by Lucas in the early twentieth century, when testing Nile water and soil from various locations in Egypt for the Survey Department in Cairo (Lucas 1908: 30–1). If the two sets of data are reviewed, chlorine content, absorbed oxygen and the presence of nitrogenous matter are comparable, even taking into account fluctuations due to the annual flood (in Egypt) or rains (in Uganda).

Secondly, the Egyptian sources of papyrus might well have simply become depleted, since it was used as a raw material for many items, such as matting, ropes, boats, sandals and numerous kinds of everyday object, quite apart from its decorative uses and its consumption as a food (Dixon 1972; Darby, Ghalioungui, and Grivetti 1977). Täckholm and Drar (1950: 141–2) point out that stocks of any wild plant utilised for centuries would eventually become exhausted, unless carefully cultivated.

Thirdly, as Täckholm and Drar (1950: 141) also note, papyrus habitats were located at the banks of the Nile and its subsidiary channels and waterways; therefore they would naturally be in populated areas. Here, demand for crops and possibly pasturing would eventually have superseded the demand for papyrus, and the land would have been put to other uses.

Aside from these ecological and agricultural reasons, the social and political climate must have played a part in its demise. There is evidence that the Greeks controlled papyrus production (Lewis 1974: 114), to the extent of destroying plants not within their official jurisdiction. This policy was perhaps continued by the Romans and the Arabs. It is difficult to tell if a failure in the supply of papyrus, or a new demand for paper was the more responsible for the fact that the use of paper began increasingly to supplant that of papyrus in the seventh and eighth centuries AD. Paper could be produced from the pulp of several different plants, and therefore its production was not limited to certain locations, as presumably was the case with papyrus. Once the demand for the writing material ceased, the few remaining plantations were perhaps given over to other uses.

The extent to which papyrus was cultivated for making a writing-ground or for other purposes in Pharaonic Egypt, as opposed to growing wild, is not known. Certainly the demand for writing materials in such a bureaucratic state must have been considerable, and it follows that there must have been some control over the way in which it was grown and harvested. Another question that arises is whether the uncultivated variety was suitable for making the writing material. It is possible that only cultivated plants were used for this purpose, while perhaps the wild plants might have been used for other items, such as rope, sandals and boats. The superb appearance of many papyrus rolls surviving from the Dynastic period suggests that great care must have been taken in choosing the correct plant, at the optimum time in its growth. Papyrus of excellent quality is known equally from the Egyptian Old, Middle and New Kingdoms. Although it has often been stated that the overall quality of papyrus worsened during the Greco-Roman and Byzantine periods, such a decline cannot be seen to have begun in Pharaonic Egypt, if attention is confined to the best surviving examples. However, inferior papyrus is also known from all periods. This must raise the question of whether papyrus was sometimes made from wild stock or even from a different sedge plant (see p. 229), thus producing a poorer quality product.

Also, although *Cyperus papyrus* L. is the general name for the plant species, there are many sub-species. They display only minor botanical differences, but these may affect the quality of the finished writing-ground. This was demonstrated in 1968 when a new sub-species of the plant was found growing wild in the Wadi Natrun, West of the Delta. Here, Dr el-Hadidi from the University of Cairo found a small population of *Cyperus papyrus* L., from which he and his colleagues subsequently manufactured some papyrus sheets. Although it was possible to make writing material from these plants, the process was much less successful than that employing plants cultivated from root-stock available in Cairo (Ragab 1980b: 85). It can be only a matter of conjecture whether the ancient Egyptians were aware of the advantages of using a particular sub-species for making the writing-ground, and cultivated it specifically for that purpose.

Papyrus is at present cultivated at several locations in Egypt, to supply the tourist trade in painted papyrus sheets. The first plantation of this type in Egypt was started by Hassan Ragab in 1962, beginning with root-stock from the Zoological Gardens in Cairo (Ragab 1980b: 52), and later with roots of the plant from the Sudan (Ragab 1988: 514–15). How similar this plant is to the ancient variety is difficult to tell, but samples of this material, made in 1975, appear to be of excellent quality: strong, flexible, opaque, of a creamy-white colour and comparable to much ancient papyrus. Unfortunately, mass-production by some manufacturers in recent times has led to the addition of chemicals (caustic soda and bleaches) in the manufacturing process (Ragab 1988: 518), producing poor-quality sheets that are dark, brittle and translucent. Microscopic (SEM) examination of ancient and modern papyrus has shown that it is possible to identify the plant used in some cases (Sturman 1987). It was found that in one modern sheet *Cyperus alopecuroides* Rottb., another sedge plant found plentifully in Egypt, had been used, producing a false papyrus sheet. Interestingly, when a comparison is made between the ancient papyrus samples and modern samples made from *C. papyrus* L., the ancient specimen proves to have a much more ordered and compact cell structure than that of its modern counterpart. In fact the ancient papyrus was as dissimilar from the modern papyrus, as the modern real papyrus was from the false, suggesting that, if these samples were typical, the plant, or the manufacturing process had been significantly different in ancient times.

Description of the plant

Papyrus is a perennial freshwater plant. In Egypt, propagation may be effected by root-stock division in spring or summer (Täckholm and Drar 1950: 100). In modern times, this has been the usual method of establishing new plantations, but plants have also been grown successfully from seed (Ragab 1980b: 55–63). The plant itself is tall, green and leafless. Much of Pliny's description (Nat. Hist. XIII.22 [71]; see Mayhoff 1909; Rackham 1968) is accurate. He says, 'It has a sloping root as thick as a man's arm, and tapers gracefully up with triangular sides to a length of not more than about 15 feet, ending in a head like a thyrsus' (Rackham 1968: 141; see Mayhoff 1909: 442). A thyrsus was 'a rod carried by worshippers of Bacchus [Dionysus] topped by a fir-cone or a cluster of grapes or figs' (Rackham 1968: 140, n. b). The 'head' to which he refers is the umbel, or flower head, and the 'root' is the basal sheath at the bottom of the stem which is about 8 cm thick when fully grown (see Fig. 9.1). Old branches die out continually, leaving a strangled mass of rhizomes. These mount to about 60 cm above soil level, and from them the new shoots grow. For anchorage the plant relies mainly on this heavy basal mass amongst which there is a rapid accumulation of dead plant material and sediment. The roots are soft and able to penetrate only water and water-saturated soil, rich in humus (Bailey 1963: III, 2,472–3). Papyrus, as a sedge, favours marshes and swamps. Shallow water hospitable to the plant occurs chiefly at the edges of quiet bodies of fresh water in sheltered areas, in sluggish rivers, or where the ground is at least waterlogged and free water accumulates on the surface for some period of the year. Hence ideal growing places for papyrus occurred along the banks of the Nile or along one of the numerous river branches and channels in the Delta.

If the stem of the plant, triangular in cross-section, is cut horizontally and the white pith inside exposed, it can be seen that the pith consists of ground-tissue in which fibres are embedded. The ground-tissue is made up of 'parenchyma' cells. In shape these are three-armed cells, and they are stacked in a honeycomb-like network, building up vertical intercellular air spaces called 'aerenchyma', running throughout the length of the stem. In cross-section the parenchyma cells appear to be circularly arranged around the air passages. The parenchyma cells often contain one or more calcium oxalate crystals, but are otherwise empty (Metcalfe 1969: 205–6). Oxalic acid is found in small amounts in nearly all plants, and solid crystals of insoluble calcium oxalate are often found in plant cells (Thatcher 1921: 126). The parenchyma cell walls are mainly cellulose and hemi-cellulose.

Parallel to the air passages run many fibres, or fibro-vascular bundles, embedded in the parenchymous material. These passages serve to carry food and water to the flower head and give the stem its rigidity and support. The fibres are made up of xylem cells which carry water and have lignified walls, and phloem cells which carry food and have cellulose walls (Metcalfe 1969: 205–6; Ragab 1980b: 37–9). It is these fibro-vascular bundles which to the naked eye are such a prominent feature of papyrus sheets, running vertically and horizontally, and it is the parenchymous material that fills and covers this fibre network. Also visible on a finished sheet of papyrus are transversal commissural bundles, also referred to as 'diaphragm cells', which connect the vascular bundles (Metcalfe 1969: 205–6; Ragab 1980b: 39–40). These can be seen very clearly by transmitted light,

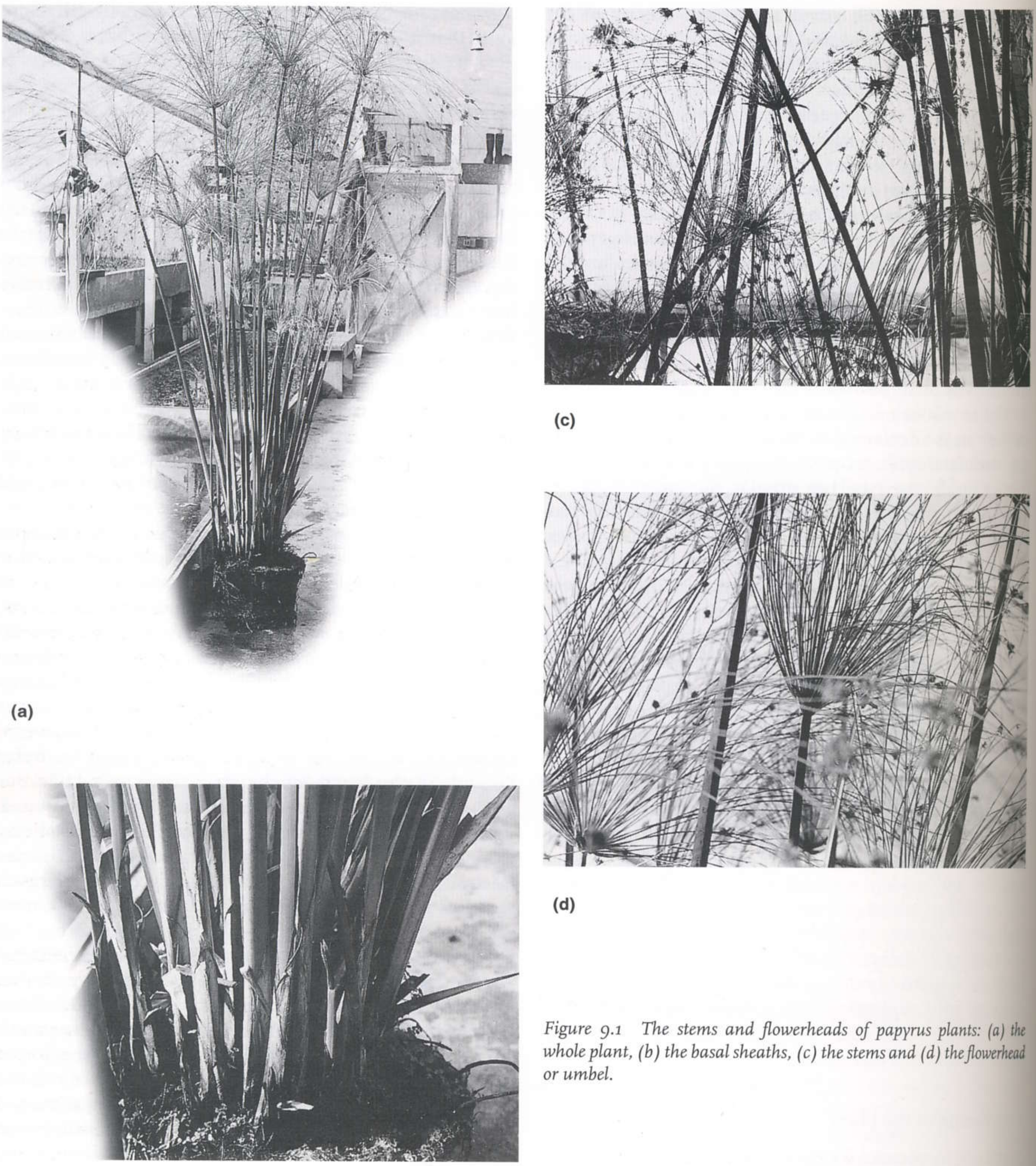


Figure 9.1 *The stems and flowerheads of papyrus plants: (a) the whole plant, (b) the basal sheaths, (c) the stems and (d) the flowerhead or umbel.*

and also with the naked eye, scattered throughout the material.

Manufacture of papyrus as a writing-ground

As can be appreciated from the structure of the plant, it is a very suitable species from which to process this particular kind of writing surface. The vascular bundles serve to give the sheet its strength by forming a structure, in this case a criss-cross network, and the parenchymous material fills and gives body to this framework. The lower portion of the stem is used for papyrus manufacture (see also p. 235). First, it is thicker and has more pith. Secondly, because the fibres run the length of the stem, which tapers at the top, it follows that the fibres are more densely packed at the top, making this part of the stem more fibrous.

The only surviving ancient account of the manufacture of papyrus is given by Pliny (*Nat. Hist.* XIII.23 [74–7]; see Rackham 1968: 142–5; Mayhoff 1909: 442–4). This problematic description has been much discussed (e.g., with bibliographies, Lewis 1974; Bülow-Jacobsen 1976; *cf.* Bülow-Jacobsen 1986). Many modern writers (e.g. Lucas 1962: 138–40; Lewis 1974: 34–69; Nielsen 1985: 58; Menci 1988) consider this account to be correct in basic method, but ambiguous in detail. However, from examination of the ancient examples, and from the experience of various individuals who have made papyrus sheets in more recent years, such as Bruce (1790: v. 5, pp. 9–10), and, in this century, Gunn, Ibscher, Lucas, Baker (Lucas 1962: 138–9), Ragab (1980b: 131–50), Basile (1972; cf. 1977), Leach (1975: 6–14), Owen and Danzing (1993: 36–8), and, most recently, Basile and Di Natale (1996) and De Bignicourt and Flieder (1996: 488–93), the basic method can reasonably be deduced to have been as follows (see Fig. 9.2):

- Cut the stems into manageable lengths and peel away the rind.
- Thinly slice the pith into strips longitudinally, along one of its three flat sides.
- Lay a series of the strips onto a board, side by side, just touching each other, or slightly overlapping, to make the first layer.
- Lay a second similar layer of strips over them at right angles.
- Press or beat the two layers together and allow them to dry.

The basic process seems uncommonly simple. However, questions of craft practice arise, unanswered by Pliny's account, or by the various papyrus-making experiments undertaken in modern times. First, there is still some discussion as to whether the strips were butted up to each other, or overlapped. Examination of ancient material by the authors suggests that both methods could be used, and that in any one papyrus roll the technique employed was fairly consistent. In some badly made ancient papyrus, occasional narrow gaps may be observed in one of the two layers of papyrus, where for a few centimetres the edges of two strips do not quite meet. This may have been due to the use of slightly damaged strips, rather than mere carelessness in laying the strips down.

In modern trials, both methods have been used, with seemingly similar results. In his experiments, Baker favoured butting up, possibly seeking to avoid ridges where the two layers overlapped (Lucas 1962: 139). However, papyrus strips, before pressing or beating, are made up of a considerable amount of air which is expelled during manufacture. The strip is reduced after pressing and drying to less than a quarter of its original thickness (Ragab 1980a: 116). This process allows plenty of scope for unevennesses to be reduced by the time that the papyrus has dried. Therefore the danger of forming ridges is almost negligible. Also, overlapping the strips would naturally reduce the possibility of the gaps that could result if the strips were not butted up to one another sufficiently closely. Baker, however, found that skill in laying down the strips could ensure that no gaps occurred.

Another recently proposed theory as to the manufacture of a papyrus sheet argues that the outer rind was first removed, and then a needle-like implement was used to peel off the pith in an unrolling action, thus obtaining one continuous slice. Two such layers would then be combined to produce a papyrus sheet. Hendriks was the first to investigate this possibility in detail, and it has become known among papyrologists as the 'Hendriks method' or the 'Groningen solution', as samples were used from Botanical Gardens of Groningen State University (Hendriks 1980; 1984; *cf.* comments by Turner 1980; Lewis 1981; Holwerda 1982; Lewis 1989: 16–21). Some experiments have been carried out with fresh papyrus stems using both the slicing and the unrolling methods and comparing them under SEM and a stereo microscope (Wallert 1989). The result was that the 'peeled' papyrus had an uneven surface texture that was identifiable under the microscope.

However, applying the knowledge gained to ancient material has been less successful and ultimately inconclusive. It also appears that it is not easy to peel the pith in this unrolling fashion. Both Wallert (1989: 5) and Owen and Danzing (1993: 37) found it difficult to accomplish without holes, tears and unevenness in the layer. However, it is not impossible that ancient craftsmen might have developed such a skill. Another objection that has been raised is that the stem of the papyrus plant tapers, however slightly, and thus it would be impossible by the Hendriks method to produce a continuous layer in which the fibres continued to run parallel with each other throughout the sheet. If strips are used, the tapering of each individual strip is minimal, and compensation can even be made for this by reversing the direction of alternate strips.

A few instances have been reported of the apparent manufacture of papyrus sheets in three layers. Budge

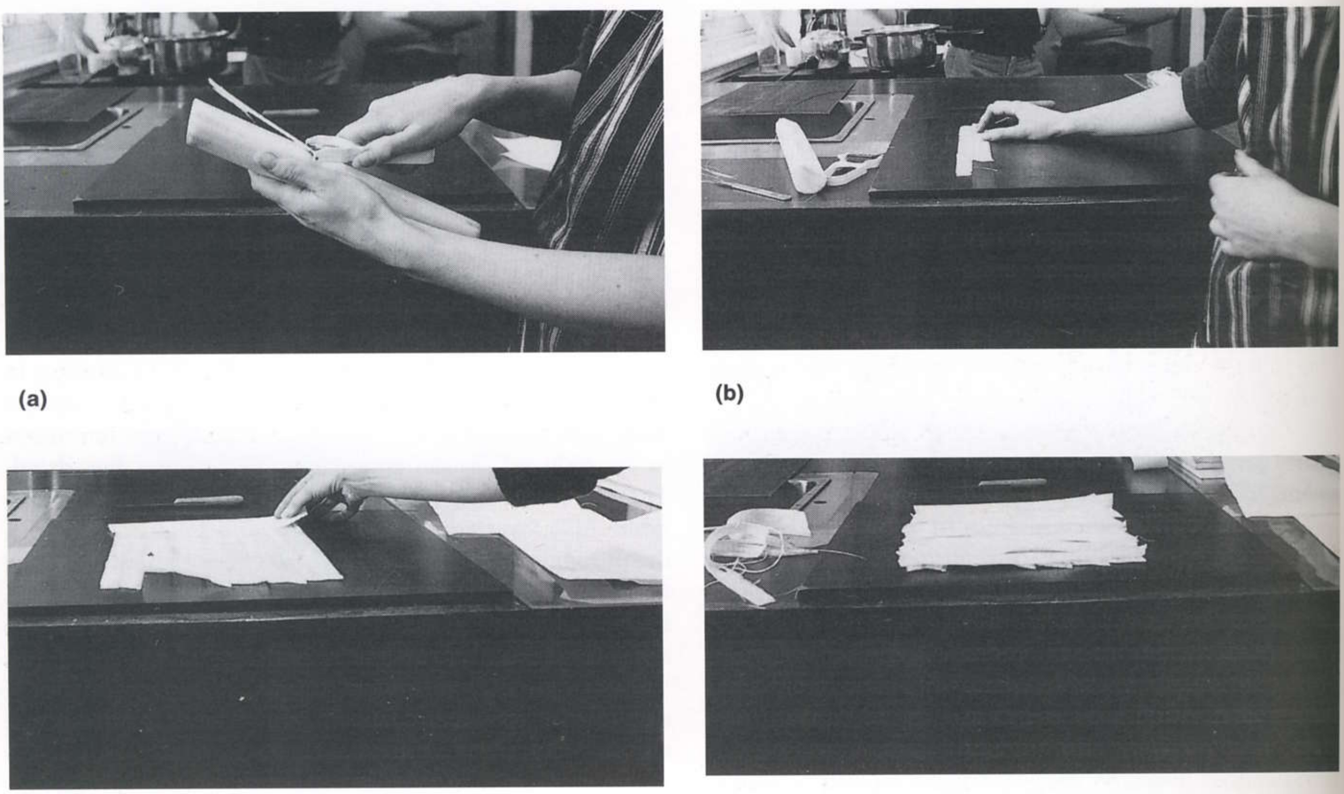


Figure 9.2 Stages of papyrus manufacture: (a) slicing pith into strips, (b) laying down the first layer of strips, (c) laying down the second layer at right angles, (d) two layers ready to be beaten, or pressed together.

claimed that the Greenfield Papyrus in the British Museum (see Fig. 9.3) was written upon papyrus of this kind: 'The material is composed of three layers of papyrus, supplied by plants which measured in the stalks about 4 inches in diameter' (Budge 1912: xxii–xxiii). Unfortunately the papyrus is mounted upon a paper backing, and the structure cannot be assessed from a surface examination. It would be necessary to remove the backing from the papyrus in order to examine it over transmitted light, or to lift up the layers. Neither interference can be justified in the case of a papyrus which is in particularly good condition and needs no conservation treatment. As mentioned by Černý (1952: 31, n. 10), Ebers, in his edition of the medical papyrus that bears his name, quoted Schenk (Professor of Botany at Leipzig) as stating that coarser papyrus was manufactured from three layers (1875: 3). Schenk seems to have examined very few samples, and to have noted three layers in a Book of the Dead in the Leipzig Library. Černý states that he himself had never encountered a three-layered papyrus. Bülow-Jacobsen (1978) describes a Greek literary papyrus, which is probably of the three-layered type.

No example has yet been reported of papyrus originally manufactured in more than three layers. It is necessary to distinguish other reasons that can make papyrus take on a multi-layered appearance. Users of papyri sometimes strengthened and repaired old papyri by pasting on an extra layer of ordinary papyrus. This might vary from a small repair patch to a backing sheet the size of a normal papyrus sheet. Sheet-joins (see pp. 236–7), can occasionally be abnormally wide, especially if they are the amateur work of a user, rather than made by the manufacturer. Although cartonnage (see p. 243) is often readily identifiable, fragments extracted from cartonnage and composed of two or more layers of papyrus still adhering together can give the impression of extremely thick papyrus.

A feature that is quite noticeable is the great thickness of certain papyri of the Late Period or Greco-Roman period. There are certainly only two layers but the strips themselves must have been sliced very thickly. It is widely accepted that the Greek style of reed pen (which in the Ptolemaic period quickly ousted the traditional Egyptian rush pen – even, eventually, for the writing of Demotic) was likely to puncture the thinnest qualities of papyrus, and that this led to a general increase in the thickness of papyrus. However, this characteristic has also been noted in papyri from a rather earlier period. For example, the funerary papyri of Pasheb-

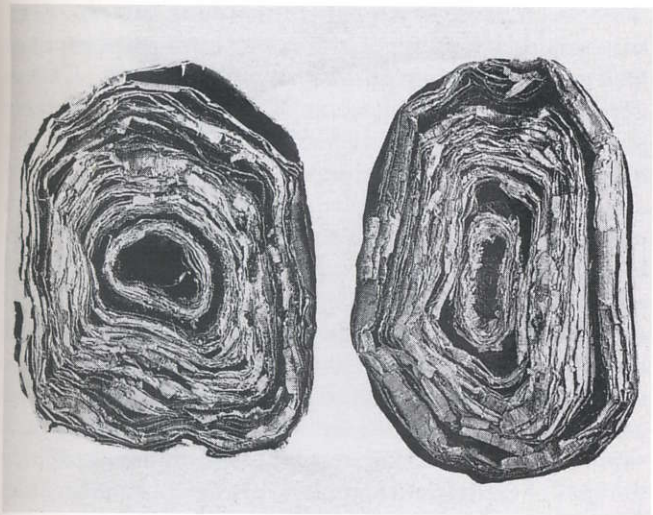


Figure 9.3 Views of each end of the Greenfield Papyrus (BM EA10554: the Papyrus of Nestanebtisheru, Third Intermediate Period).

mutwebkhet and Dimutiudu (BM EA10988 and BM EA74136; Quirke 1993: 57, 35), both from Thebes and dated to *c.* 950 BC, are notably thick in this way.

Apart from the method of forming the layers, the most contentious aspect of Pliny's account of papyrus manufacture is his reference to the practice of moistening the sheets with Nile water prior to pressing, in order to cause the layers to adhere together. Pliny inferred that Nile water contained an adhesive. In ancient practice, it may have been usual, if the papyrus became dehydrated during the cutting and laying down of the strips at right angles, to remoisten the sheet before pressing. Nile water might naturally be used for this, as workshops were likely to have been located near the plantations. Experiments in recent years have shown that the layers must be pressed while still moist. Pliny perhaps misunderstood what he saw, or what he was told. Now, the adhesive qualities of Nile water are discounted, and the reasons for the adhesion or bonding of the two layers are more fully understood.

Papyrus does contain natural gums in its cell-sap (see p. 234). Whether this is the principal cause of adhesion in papyrus is nevertheless open to question, and this issue has been much discussed. Recent experiments have all found that pressing the layers together was enough to ensure adhesion (Leach 1975: 8; Owen and Danzing 1993: 37; De Bignicourt and Flieder 1996: 489). Ragab (1980a, *cf.* 1980b: 151–60) proposed that physical bonding is the main reason for the lamination of the horizontal and vertical layers. The theory may be briefly outlined.

The pith of the papyrus stem is made up of ground tissue and fibres. The ground tissue consists of three-armed parenchyma cells with air spaces between them. When the two layers are pressed together during manufacture, the air is expelled, and the parenchyma cells are forced together, occupying the previous air spaces. They interlock in what Ragab describes as a dovetail effect. The ground tissue of the two layers is now effectively bonded together, with a much reduced bulk due to the expulsion of the air. Ragab states that, upon drying, the bulk is reduced even further. This shrinkage causes the dovetail bond to set and dry in a permanently locked position. The process could therefore be seen to have considerable similarity to that of traditional paper-making (that is, the manufacture of paper from pulp). Ragab measured the thickness of the papyrus strips in samples of papyrus of his own manufacture, before and after pressing, and also after drying. The strips after pressing were reduced by 75 per cent of their original thickness, with a further loss of 5 per cent on drying. The fibres remain embedded in the ground tissue throughout the manufacturing process and form the network around which it bonds.

Examination of the cell structure carried out by Roland and Mosiniak (1987) resulted in a similar view of the capability of the ground-tissue cells to bond mechanically, and also physio-chemically. They stated that the microfibrils which make up the cell walls are arranged in a series of spirals, which enables a highly effective bond to be made as the microfibrils interlock together under pressure. They further found the cell walls to be coated with polysaccharides, with chemical groups able to form hydrogen bonds with other cell walls.

If this is the case, it follows that the beating and/or pressing of the papyrus layers is a crucial part of the manufacturing process. Again, we know very little about ancient practices. Pliny says they are 'pressed in presses', and then 'dried in the sun' (Lewis 1974: 37). Modern-day experiments have involved beating the two layers together with a mallet, or using a roller for the purpose, or pressing by weights or other means, followed by drying, with or without pressure. If Pliny's account is to be believed, the ancient, or at least the classical, practice was to dry without pressure, having pressed the strips together first. One of the authors has made sheets by beating the layers together and allowing them to dry in the air. The air-drying was successful, in that the layers proved to have adhered well, and no subsequent distortion occurred during drying. Recent experiments at the Brooklyn Museum by Owen and Danzing (1993), however, found that air-drying alone, or just light pressing, was not sufficient to ensure a good bond, and heavy pressing was crucial. In fact, it seems, whether the sheets are beaten, rolled or heavily pressed, if this stage is accomplished efficiently, the papyrus can be air-dried. Once enough pressure has been applied to ensure the bond between the two layers, the papyrus can be dried in or out of a press. In procedure, this may have resembled the way in which a traditional bookbinder today will 'nip' a book in the press to ensure a good bond when, for example, pasting down the end papers. One firm application of pressure or twist of the press will seal the bond and it is then left to dry out under less pressure. In view of the extreme thinness and fine texture of some papyrus produced in ancient Egypt, it is difficult to imagine how this could have been achieved by direct beating with a mallet. The experience of one of the authors is that the fibres distorted a little and gaps and holes resulted where the papyrus had been beaten too heavily. It was difficult to achieve an even pressure over the sheet, although this has been accomplished very successfully in the case of much ancient papyrus. Owen and Danzing experienced the same difficulties, and found rolling a better alternative. However, the problems could perhaps be explained, in both cases, by a lack of acquired skill. It is also true that many extant papyri are not of good quality and show the gaps and holes of inferior manufacture. There is no evidence from Pharaonic Egypt for any kind of press, in the sense of a permanent mechanism designed to bring two flat surfaces together and maintain pressure between them (for the means employed to 'press' grapes, for example, see Chapter 23, this volume). Such an apparatus for papyrus could have employed the very simplest technology, and it is conceivable that large workshops (if they existed) were equipped with devices that were not available to smaller concerns. However, it must remain a possibility that even the finest quality papyrus that survives was produced by skilful beating with mallets.

Adhesion by physical and chemical bonding requires no extraneous adhesive. Papyrus contains natural gums in its cell sap, which were analysed by Hepper and Reynolds (1967) at the Royal Botanical Gardens at Kew. They found it to contain galactose and arabinose and a trace of rhamnose. These are simple sugars which occur in many vegetable gums and seaweeds, and are the main constituents of several natural adhesives such as gum arabic and tragacanth. They concluded that this must be the cause of the joining together of the two layers. Ragab (1980a: 114–15) disputed that the sap played any important part in the adhesion. He conducted various tests, including one in which he removed the sap from papyrus strips by rolling them, then smeared them with the original sap, and placed them in a press to dry. They did not adhere. In fact, the modern Ragab method, which successfully produces papyrus sheets in great quantity, involves soaking and rolling the sap out of the strips completely, to remove all soluble carbohydrates. They are then once more soaked with water, to cause the air ducts to swell again. The two layers are then formed, and pressed together. This must give weight to the theory that physical bonding is the main cause of adhesion. More experimentation would be necessary to come to a firm conclusion about how large a part the natural gums play in the adhesion of the two layers, but as yet no one making papyrus has needed to use extraneous adhesive.

A further question arises, however, because microscopic examination has found starch adhesive between the layers of ancient papyrus samples (Barrandon *et al.* 1975; Weidemann and Bayer 1983), indicating that the Egyptians could, at least on occasion, use extra paste as part of their manufacturing process. Whether or not this was necessary is another question. Weidemann and Bayer expressly state that starch *adhesive* was found between the horizontal and vertical layers, as opposed to starch grains, a quantity of which might be expected to be present in plant material. Barrandon *et al.* (1975: 9) observed an adhesive, which they state was probably paste, on the internal surface of one layer only. De Bignicourt and Flieder (1996: 490) undertook microscopic studies of ancient and modern samples of papyrus to try to establish whether the starch derived from within the plant, and therefore appeared as starch grains, or was added as paste, which would result in its being present as amorphous starch. In the case of the ancient samples, this was not a straightforward question, as starch grains break down over time, particularly because of the long-term effects of temperature and humidity, and thus are difficult to distinguish from amorphous starch. However, they concluded that there was *no* starch adhesive present except on samples which were either sheet-joins or cartonnage.

It is also to be noted that, during modern conservation processes which involve the treatment of papyrus in water, the vertical and horizontal layers do not delaminate, but remain firmly fused together. The adhesives that have been identified in the cell sap are water-soluble, and so also is starch paste. If the layers were caused to adhere by no other means than by one or both of these adhesives, some delamination would be expected. However, this does not happen. In addition, it is well-known that the older, harsh techniques for extracting papyrus from cartonnage, which included the use of acid (see p. 245), especially tended to cause the pasted sheet-joins to come apart, but did not affect the papyrus layers themselves.

Two final issues to be discussed here concerning the manufacture of sheets are (1) the optimum time for the harvesting of the plant, and (2) the optimum part of it to use. We have some information from the Greco–Roman period, outlined by Lewis (1974: 103–14), as to when plantations were leased out, and about certain conditions which were laid down to control the harvesting. The plant could be harvested throughout the year, and study of the documents led Lewis to deduce that the yield increased from March onwards, June to August being the most productive time of year. This might be explained by the fact that the Nile floodwaters were highest from September to March. By June, water-levels would have subsided sufficiently to give access to the plants without the use of boats, and harvesting would therefore have become more efficient and productive. Lewis, however, stresses that the evidence indicates that harvesting did continue throughout the year, even in the inundation season.

Lewis also states that in the Classical period the practice was to bundle the stalks into units of one armful or six armfuls. In fact, we have very few examples of representational evidence from Pharaonic Egypt, but one scene in particular from the early New-Kingdom tomb of Puyemra at Thebes (TT 39; Davies 1922: I, pls. vii–xix) shows papyrus being harvested. For what ultimate use the papyrus is being gathered is not indicated in the scene. However, a single stalk is shown being pulled up by a man who is standing on a shallow papyrus boat and who appears to have no instrument for cutting. A second male figure is tying together a bundle or load of stalks, from which the flower-heads seem to have been removed. Another carries on his back a load, shown with its flower-heads intact, towards the last figure in the scene, who is peeling with his fingers a strip, perhaps of the outer rind, from a single stalk. He does not appear to have cut the stalk into manageable lengths, but is peeling the entire length of it. Stephen Quirke (pers. comm. 1996) has suggested that he may merely be preparing a strip for use in tying together a bundle of stalks.

A much earlier scene from the Fifth-Dynasty *mastaba* of Ty at Saqqara (Wild 1953: pls. 76, 110) shows workmen carrying tied bundles hoisted onto their backs, similar to those in the tomb of Puyemra; one man has fallen under the weight of his load, and is being helped to his feet. The register immediately below depicts the lashing together of papyrus stalks to manufacture boats. It is thus possible that the bundles depicted above were specifically intended for boat-building. However, further registers below depict a variety of marsh scenes, and the top two registers need not be directly linked in subject matter.

Two scenes of papyrus-gathering survive in Middle Kingdom tombs at Meir (Blackman 1915a: 14, pls. 3–4; 21, 2; 25, 2; 26, 1–2; *cf.* 1915b: 12; pl. 4). It has often been suggested that the former of these two scenes (see Fig. 9.4) represents the gathering of papyrus for boat-building; but it might be noted that the clumps of papyrus are shown being carried *away* from the papyrus boat under construction. However, in all these tomb scenes (and in the others known), there are no grounds for supposing that the papyrus is being harvested for the manufacture of writing material.

As discussed above, the fibro-vascular bundles are spaced more widely apart towards the bottom of the stem. It is likely that it is for this reason that it has been recommended that this part be used for papyrus manufacture (Lucas 1962: 139; Ragab 1980a: 116; De Bignicourt and Flieder 1996: 489), where the ratio of fibres (fibro-vascular bundles) to ground-tissue (parenchyma) is the optimum for making fine papyrus. Experiments in modern times suggest that it is desirable to select the stalks harvested for papyrus manufacture. They should be neither too old nor too young. In young plant cells, the cell walls consist of practically pure cellulose, but as the stalk grows older it becomes permeated with more ligneous or woody material (Thatcher 1921: 74), and is also more likely to have been bent or bruised. For most modern individuals experimenting with papyrus-making there has been very little choice, and they have had to make do with whatever stalks they can procure. The papyrus made by one of the authors several years ago was made with stalks from a greenhouse in England. Although a sheet of papyrus resulted in which the layers adhered well, it was very brown in colour. Also, the pith had a dry feel about it which led to the suspicion that the stalks had been rather old.

In the absence of any ancient references, it is worth quoting the advice of Dr Ragab who is able to pick and choose his plants from a large plantation.

> Though papyrus is a perennial plant yielding one harvest a year (they harvest in summer), yet there is no definite age for the stalk best used for sheet making as this depends on many factors, amongst which, degree of richness of soil, amount of water level covering the rhizomes and lower coriaceous acuminate sheaths, density of the amount of stalk in one clump, the density of clumps in the field, the degree of nearness of clumps to hedges, dikes, etc. etc. From practical experience we can now judge from the appearance of the stalk whether it is suitable or not to yield good quality sheets.
> The main characteristics of a good quality stalk are the following
>
> i the stalk should be erect, not drooping or twisting.
> ii It should have nearly uniform cross-sections throughout its length: i.e. the normal tapering of the stalk should not be very pronounced in order to give

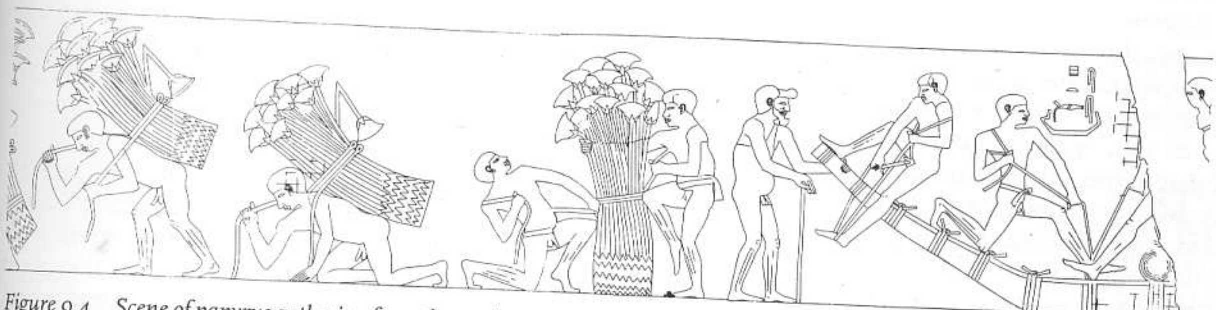


Figure 9.4 Scene of papyrus gathering from the tomb of Senbi's son Ukh-hotep at Meir, Middle Kingdom. Four men are seen making a papyrus skiff (right).

strips of uniform width instead of the normally tapering form of the ordinary stem.

iii The stem should have no bruises, bends or scratches, since a brown colour is certain to happen in the affected area.

iiv above all the skin should be tender and have a wax white colour of its lowest part when the acuminate sheaths are stripped out.

(H. Ragab, pers. comm. 1975; *cf.* Lewis 1989: 20)

Obviously, the higher up the stem the more fibrous the pith will become. Pliny mentions that 'the choice quality comes from the centre, and thence in order of slicing' (Lewis 1974: 37; *cf.* Mayhoff 1909: 442–3; Rackham 1968: 142–3). The meaning of this passage has been much debated, but, to judge from his precise wording, he may possibly mean the innermost portion or heart of the pith, rather than the middle section from the length of the stem. Thus he seems to have believed that the strips peeled from nearest the outer rind would be tougher than the material in the centre. However, Ragab states that, once the outer rind has been peeled away, the pith has a homogeneous structure, and that distance from the centre of the stem makes no difference; either the stalk is good or it is not (Ragab 1980b: 119).

In their experiments using plants from the Natural History Museum in Paris, De Bignicourt and Flieder (1996) found that the colour of the final sheet depended upon its thickness, and upon the speed of drying. When papyrus pith is exposed to air it darkens. This is because, in the presence of oxygen, enzymes contained in the plant catalyse a series of chemical changes in the phenols, also present in the plant, ultimately producing quinones. Quinones have the characteristic of being coloured. When the papyrus is dry, this action and the resulting discoloration stop. Consequently it was found that, the finer the sheet, the quicker it dried, and the lighter the colour.

Before leaving the question of papyrus manufacture, it should be noted that work on this subject has been taking place for many years in Sicily by Dr Corrado Basile, founder of the International Institute of Papyrus at Syracuse (Basile 1972; *cf.* Basile 1977; Basile and Di Natale 1996). The plant and its manufacture into a writing ground has a long history on the island, and a museum devoted to the subject is located at Syracuse (Basile and Di Natale 1994). Täckholm and Drar concluded that the plant was introduced by the Arabs during their domination of the island in the tenth century AD (1950: 135). However, Basile and Di Natale report that many authors writing in the eighteenth century AD believed that it was introduced into Sicily during the third century BC, their conclusions based upon archaeological evidence of communication between Egypt and Sicily at this time (1994: 7). Today, the plant grows along the River Ciani at Syracuse, giving the Papyrus Institute fresh material for use in trials to establish certain aspects of manufacture, particularly the treatment of the freshly cut papyrus strips before they are laid down in vertical and horizontal layers. Recent chemical analysis of ancient Egyptian papyrus samples, organised by the Papyrus Institute in Sicily, and presently unpublished, promises to yield much interesting data on these questions.

Manufacture of papyrus rolls

Once papyrus sheets had been made, they were joined together to form rolls. There is no evidence to suggest that papyrus was ever supplied in the form of separate sheets. From the late Old Kingdom onwards, the hieroglyphic script employed a rolled-up papyrus roll with mud seal as the 'determinative' (i.e. a sign indicating the general sense of a word) for words connected with writing. Later, a hieroglyph representing a loop of fibres or string served much the same purpose, and was widely used in the hieratic script: it is generally thought to represent the fibres prised from the outside of a papyrus roll, or a separate string, to secure the roll. Substantial papyri seem normally to have been kept in the form of rolled-up rolls, and not to have been stored in any folded form. However, rolls may sometimes have loosened or have become partially unrolled in storage, so that parts of damaged rolls may appear to have been folded (see Tait 1991a: 20). Letters or short documents appear regularly to have been kept as small packets, produced by a combination of rolling and folding; frequently, they appear to have been deliberately flattened. The pattern of the original folds is often conspicuous in surviving examples. Users who required a small piece of papyrus appear to have cut it from a roll, either before or after writing their text – and pieces of papyrus could also be salvaged from discarded documents. Apart from Pliny's statement that there are 'never more than twenty sheets to a roll' (Rackham 1968: 144–5; *cf.* Mayhoff 1909: 444), there is some evidence from Pharaonic Egypt to suggest that twenty sheets could form a standard length of roll (Borchardt 1889: 120; Černý 1952: 9; *cf.* Skeat 1982).

Rolls were manufactured when the sheets were dry by overlapping one sheet over the next by approximately one to two centimetres, and using an adhesive to join them together. Again, we have Pliny's account of how this was done (Lewis 1974: 40–1; *cf.* Mayhoff 1909: 445; Rackham 1968: 148–9). He states that paste was used, made from the finest flour, and allowed to stand for a day (Seider 1976), and also that carpenter's glue (probably an animal glue) and gum (probably a vegetable gum, such as gum arabic) were too brittle for the task. This makes sound sense, as anyone who has worked with paper-related materials or in the bookbinding trade could confirm. In their recent analyses of ancient papyri, De Bignicourt and Flieder (1996: 490) have identified starch paste on samples at sheet joins. Pliny then goes on to say that when the joins had been pasted down they were 'flattened with a mallet and lightly washed with paste, and the resulting wrinkles were again removed and smoothed out with the mallet' (Lewis 1974: 41). The phrase 'washed with paste' is a little puzzling. A practical interpretation could be offered: the paste was applied to one sheet along the edge to be overlapped, and the sheet to be attached was laid along the pasted edge, and beaten down. Next, to achieve a smooth join, particularly along the overlapping ridge, extra paste was applied along it before beating down again. However it was done, this task would have to be carried out skilfully in order to beat the four layers of papyrus strips that constitute the overlapping area of the join to a thickness at least comparable with that of the rest of the roll, and to ensure particular smoothness at the overlapping edge, without causing holes or weakening at the underside ridge (see Fig. 9.5). It is noticeable on numerous extant fragmentary papyri that this particular area is very vulnerable, and fractures have often occurred along this edge.

It has been pointed out several times in recent years that some papyri of the Late Period or Greco-Roman period display a refinement in manufacture, presumably designed to provide a smoother finish at the sheet-joins. First, in 1978 Turner reported that John Rea had observed that a then unpublished Oxyrhynchus papyrus of the fourth century AD had only three layers of papyrus for much of the width of the sheet-join (for 2.5 cm of a join 2.75 cm wide). In effect, it seemed likely that a single vertical strip of papyrus had deliberately been omitted at one edge of the sheet (Turner 1978: 20). The papyrus was subsequently published as P.Oxy.li.3624: see the remarks by Rea (1984: 61). Coles described a similar feature in three Rendel Harris papyri (P.Harr. 212, 214, 216) of the fourth century AD, stating that 'at least 3 cm' of vertical fibres are missing (Andorlini *et al.* 1985: especially p. 115). Coles stated that he and Rea had come to see this as a standard feature of papyri of the period. They have found many examples subsequently, and Coles would suggest that appearances hint that it is more likely that a vertical strip was omitted in manufacture than that one was torn away subsequently (R.A. Coles, pers. comm. 1996). One of the authors had independently noticed a slightly different feature in North Saqqara papyri to be dated at least five centuries earlier: frequently the sheets had been 'deliberately made with a short "fringe" of horizontal strips at their left-hand edge, protruding 2–8 mm beyond the last vertical strip' (Tait 1986: 70, with, in n. 56, a reference to Rea's observation). In the Saqqara examples, the only essential difference from the later phenomenon found among the Oxyrhynchus material is that the area of papyrus in the pasted-up roll that consists of only three layers is much narrower. Subsequently Ménei (1993) has independently observed a similar feature in papyri in the Louvre and elsewhere, mentioning a fringe of 1–1.5 cm. One of the authors has examined examples in the British Museum collection and has identified some instances of this type of join. However, without detailed examination, which would involve lifting the layers along the join and would therefore be a rather questionable procedure, it is not easy to say with certainty.

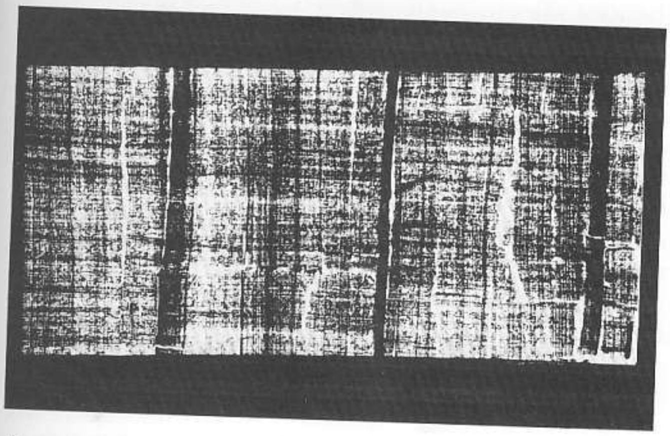


Figure 9.5 The Papyrus of Nesmin (BM EA10188/14, Late Period); the sheet joins are visible when it is seen through transmitted light. The extra thickness of the overlap at the join shows as a dark vertical strip.

One papyrus from the pharaonic period at the British Museum has exceptionally wide sheets, clearly identifiable on the light table. This is a Fifth-Dynasty document from Abusir (BM EA10735/8–9), with sheet widths of 66 cm and 66.5 cm. The well-known 'Hymns to Senusret II' among the Kahun papyri at the Petrie Museum of Egyptian Archaeology, University College London (Kahun, LV.1; UC. 32157) include exceptionally wide sheets measuring 51.5 and 49.5 cm (Griffith, 1898: 1; pls. 1–2). Robinson reports that, in the third century AD, the papyrus rolls used to produce some of the Nag Hammadi codices must have been manufactured with extraordinarily wide sheets, and he surveys the evidence that very wide sheets might have been used for the manufacture of codices at this period (1984: 61–70).

Once the papyrus sheets were pasted together to form a roll, the material was ready for writing. According to Pliny 'rough spots are rubbed smooth with ivory or shell' (Lewis 1974: 39; *cf.* Mayhoff 1909: 445; Rackham 1968: 146–7). However, Pliny then goes on to say that this makes the surface 'shinier and less absorptive'. Hepper and Reynolds (1967), in their account of papyrus-making, suggest that no advantage was to be found in burnishing as it seemed only to loosen the fibres and to make the surface more resistant to ink. However, it has been noticed on many funerary papyri that the inside surface of the roll is smoother than the outside. Indeed, when handling detached fragments from border areas, which bear no text, the inside can be identified by noting the smoother side. On the other hand, in the case of documents typically written on both sides, such as the Late Ramesside Letters, the papyri show no discernible difference between their two surfaces. Those who work with Ptolemaic and Roman papyri are used to seeing a superior finish on the inside surface of rolls.

The application of cedar oil as a preservative (Turner 1968: 3), or a coating of paste (Lewis 1974: 67–8) as a finish has been suggested by several people. It is true that papyrus does have a natural sheen on its surface, and some Demotic papyri in particular appear to have a yellow patina. However, there is no secure evidence for any such application, and on close inspection this can often be seen to be surface dirt or a natural graininess. One of the authors has examined four papyri under the stereoscopic microscope (× 30); a modern example made by Ragab in 1974, an illustrated Book of the Dead from the early Eighteenth Dynasty (BM EA10477/1, *c.* 1450 BC), the Late Period *Lamentations of Isis and Nephthys* (BM EA10188/1, *c.* 300 BC), and a Demotic text (BM EA10710/2, *c.* 550 BC). To the naked eye, the surfaces of all four appeared to have a different appearance. The Ragab example was cream and almost matt, the Book of the Dead darker with a slight sheen and the Late Period and Demotic examples had a yellow to brown, slightly shiny surface. The yellowness of the Demotic example was curious, as it had grains on the surface, particularly along the joins, and it was difficult to know if this was due to over-enthusiastic pasting of the joins, or to dirt, or even to the light paste wash mentioned by Pliny (Lewis 1974: 41). Otherwise, however, under the microscope the surfaces were all comparable, and the sheen appeared to be in the very structure of the material itself, deriving from the glutinous nature of the sap. Even though in his modern practice Ragab washes out the excess starch and gums from his papyrus, the plant still retains much glutinous material, thus imparting the characteristic lustre. The other author has observed a distinctive yellow patina on one surface of many Roman-period papyri from Tebtunis; it would have been the original inside surface of the roll, but was subsequently the outside surface when the roll was reused (see Tait 1977: xi). This surface often shows considerable signs of handling in use; but it is nevertheless possible that the basic overall yellow shade is due to the natural ageing of a layer of paste on the surface.

Media used on papyrus

The Egyptians regularly used black ink for pen-written material. Red ink was freely used alongside black in many kinds of text, for example to distinguish headings (Černý 1952: 24). Many papyri, chiefly religious (for example, the funerary Book of the Dead), are illustrated, and the colours used for this may range from simply black alone to a wide variety of colours. The pigments used for these purposes are covered in Chapter 4 of this volume, and it is necessary here to mention only features of the substances used that are relevant to the study of papyrus.

The black ink employed during the Pharaonic period has to date almost invariably been found to be carbon black (Lucas 1962: 339–40; Green 1995: 90). Carbon ink is made by partially burning organic materials (for example oil or wood; therefore the products obtained are rarely pure carbon, but all contain mineral impurities and hydrocarbons). The carbon derived from it is mixed with a binder, most probably a gum such as gum arabic (Lucas 1962: 6; Green and Leach 1993: 4), to make a solid cake or 'watercolour'. This ink is very stable, as anyone who has worked upon papyri in the many collections around the world can testify.

It is not certain when metallic ink, commonly called 'iron-gall ink', was first used, but Reed (1972: 55) reports that it was in common use by the seventh century AD. Iron-gall ink is made by mixing oak-galls (containing gallotannic acid) with iron sulphate (a liquid, also known as green vitriol or copperas) to produce a writing fluid (ferrous gallotannate) that on exposure to air produces a black colour through oxidation, and becomes ferric gallotannate (Gettens and Stout 1966: 122).

Some interesting analysis has been undertaken quite recently to ascertain the type of ink used on Demotic and Greek texts dating from 252–98 BC in the collection of the Louvre (Delange *et al.* 1990). The PIXE (Proton Induced X-ray Emission) method of analysis was employed, having the advantage of being a non-destructive method. Although the method is not sensitive to carbon, carbon ink could be deduced by its lack of metallic elements compared to iron-gall ink. The results of the analysis were surprising in that it was found that all the Demotic texts were written with carbon ink, and that all the Greek texts, apart from one, were written with metallic ink. One Greek text was dated as early as 252 BC. This is therefore the earliest analysed example of this type of ink on papyrus in Egypt. It was also interesting that the use of metallic ink was directly associated with the writing implement, i.e. a reed pen in the Greek texts, while the demotic texts were always written in carbon ink with a rush pen of traditional Egyptian type, somewhat resembling a brush (see Tait 1988). Also the content of these metallic inks was slightly unexpected, since many different metallic elements were found, suggesting that the ink had been made with a wide variety of components (Ménei 1990: v. 1, p. 64). One significant finding was that, unlike the more modern iron-gall ink which shows a substantial presence of iron and sulphur, these ink samples had a marked lack of sulphur, although it was expected to be found in the same proportion to iron or copper. There was also a predominance of copper as opposed to iron. This in turn led to speculation on the method of ink manufacture, and the effects of ageing, suggesting that perhaps carbonates instead of sulphates were used in manufacture. It has also been proposed that the sulphur may have been incorporated into a gas or liquid compound which could have disappeared over time. Iron-gall ink has, with age, a characteristic brownish appearance, unlike carbon ink, which appears much blacker.

The analysis referred to above found that conclusions drawn from close observation with the naked eye were borne out by scientific analysis. One of the authors has noticed examples of metallic-looking inks on Manichean papyri from the Chester Beatty Collection, dated from the third or fourth centuries AD, and also on BM EA10951, a papyrus dating to the period from the first century BC to the first century AD, in the British Museum collection. However, chemical analysis would be needed to confirm this.

The source of the red ink found on Egyptian papyri is, with rare exceptions, haematite. Haematite, or red iron oxide, Fe_2O_3, is discussed in Chapters 2 and 4, this volume, dealing with the rock and the pigment respectively. A rare exception to this rule is to be found in one example in the British Museum (BM EA9968; Quirke 1993: 29), the Book of the Dead of Ahmose from the early Eighteenth Dynasty. Here the text has the appearance of having been written in black and yellow, which is surprising, as the Egyptian tradition of using red ink was so firmly established. Analysis of the 'yellow' ink was carried out at the British Museum and it was identified as para-realgar (Green 1992), indicating that the original pigment used for the ink was realgar. Realgar, α-AsS, is an orange-red colour of very similar chemical composition to yellow orpiment (arsenic trisulphide, As_2S_3). Exposure to heat (and sometimes light) can bring about changes in this pigment (Green 1995: 88–9), causing it to turn to a yellow colour, 'para-realgar', γ-AsS. The exact chemical reactions, and their causes, are not as yet fully understood, but tests are currently being carried out at the British Museum to try to understand the mechanisms of this change, and the time period involved in it.

Finally it is worth bearing in mind that although vermilion (HgS: red mercuric oxide, from the mineral cinnabar) has not been identified in use as a writing ink, it has certainly been identified as an artist's pigment on a papyrus of the Late Period (BM EA9916/2A; Quirke 1993: 49: Papyrus of Nesmin). When it appeared on the Egyptian palette is not yet known. Gettens and Stout state that it was known in the Classical world (1966: 170–1).

Deterioration of papyrus

Papyrus will deteriorate like any other organic material. Despite this, it has shown remarkable powers of durability. Apart from the purity of the material, this has undoubtedly been aided by the dry climate of Egypt. Finds outside the modern country of Egypt are rare, although well-known discoveries have been made at Derveni, Dura Europus, Herculaneum, Nessana (Anja Hafir, Palestine) and Petra. A survey of these finds, with bibliography, is given by Rupprecht (1994: 7–10; for Petra, see for example Koenen 1996). Deterioration will occur through ageing, and the breakdown of constituents in the material itself, physical damage, insect attack and mould; all these factors are closely associated with the conditions in which the papyri have lain for many years before discovery, and the subsequent treatment they have received. Most forms of deterioration and mould growth take place in the presence of moisture, often with contamination from other organic matter also. Papyrus finds fall very broadly into two categories; those included in tomb assemblages and those excavated from archaeological sites. Tombs can provide relatively dry and stable conditions until discovery, whereas other excavated sites are much less likely to do so. However, because Egypt's water table was relatively low until the present century, and conditions are sometimes favourable, many papyri have also been preserved in non-funerary contexts, and carbonised rolls may survive in relatively damp townsites (see p. 243).

Breakdown of the constituents of papyrus

As we have seen, papyrus is made up of a ground-tissue embedded with fibres. The pith has been analysed by Grant (Wendelbø 1975: 44), and found to be 97 per cent carbohydrates in the form of cellulose, hemi-cellulose and lignin, the remaining 2–3 per cent being made up of proteinaceous material. Further analysis by Weidemann and Bayer (1983) of the cellulose and lignin content of four ancient samples found the cellulose content ranging from 53.29–62.04 per cent, and lignin content from 22.42–32.77 per cent. Recently manufactured samples from Egypt and Sicily showed comparable results, but the Egyptian papyrus sample had 68.96 per cent cellulose content, in contrast to 53.12 per cent in the modern Sicilian papyrus. Examination of the distribution of these constituents showed that the vascular bundles were predominantly lignin and the surrounding material predominently cellulose.

Cellulose is inherently very stable, but it can also break down due to reactions caused by hydrolysis or oxidation. For instance, the degradation of cellulose in modern paper is often caused by acid hydrolysis. Acid hydrolysis involves a chemical reaction catalysed by hydrogen ions. Acidic materials can be present, due to the substances used during paper manufacture, e.g. papermaker's alum, which produces hydrogen ions in the presence of water. Papyrus, being made up of a large proportion of cellulose, will be subject to breakdown, particularly if kept in poor storage conditions, or in contact with acid-producing materials (Thomson 1986: 143–4; 154–6).

The presence of lignin has long been established as one of the factors in the deterioration and discolouration of woodpulp paper (Greathouse and Wessel 1954: 391), particularly when exposed to heat and light. Lignin is a complex aromatic polymeric substance soluble in strong alkalis and converted to soluble form by bleaching agents such as chlorine. Except for mechanically produced woodpulp papers, it is removed, at least partially, from the paper pulp in the paper-making process using various chemical methods to break it down and wash it out. The lignin content of newsprint is 20–30 per cent, and that of chemically treated woodpulp paper commonly 0.5–2 per cent, while good quality paper, made of rag or cotton, contains 0 per cent. Strangely, papyrus contains a proportion of lignin to cellulose similar to that of newsprint, but, unlike newsprint, does not darken when exposed to light, but lightens dramatically. Reflectance measurements with Perkin-Elmer 5515 Ultraviolet-visible (UV-Vis) spectrophotometer taken before and after light ageing (twenty-eight days in Microscal light-fastness tester) of a strip of papyrus showed a 4.1 per cent increase in reflectance (lightening) at 436 nm (Green and Leach 1993: 14).

However, papyrus can discolour or darken with age. Reflectance measurements taken before and after heat ageing (twenty-eight days at 70 °C) showed a 3.6 per cent decrease in reflectance (darkening) at 436 nm. Weidemann and Bayer came to the conclusion that the darkening of papyrus is due to the higher polymerisation of the lignin content, as lignin is a less stable component than cellulose.

Micro-organisms

Being an organic material, papyrus is susceptible to microbiological degradation. Cellulose, lignin, and the sugars in the cell sap of papyrus can be used by micro-organisms for growth. In the early 1970s, Kowalik and Sadurska (1973) of the Institute of Industrial Organic Chemistry in Poland did extensive work on the study of microflora that grow on papyrus, using ancient samples from various museums in Cairo. A very wide range of moulds and fungi were found on the material. They concluded that certain fungi are specific for papyrus and also aspects of Egyptian climatic conditions. Many factors have an influence on fungal growth: moisture, temperature, acidity or alkalinity of the material or its environment, and the presence of nutrients, i.e. nitrogen compounds, from the material itself or from its environment – usually, in the case of papyrus, from the soil. The research carried out by Kowalik and Sadurska found that certain micro-organisms could grow within a wide pH (acid/alkalinity) range: pH 4–10.00 for those growing in the presence of ammonium nitrate and phosphate. The temperatures required for growth were, however, relatively high, 24–6 °C being suitable for many. Fungal growth is extremely destructive to papyrus, as it decomposes it. However, these tests only indicate the possibilities of rapid growth in certain prepared conditions. Although many micro-organisms were isolated from the papyri, spores will always be present on everything in the natural world. It is the actual growth of a fungus that presents a problem, and good environmental conditions will not encourage growth. Also a valid comment on these results was made by Nielsen (1985: 90), that the samples used for the tests had been in museum storage for approximately thirty years, therefore it was not clear whether contamination was due to the nature of the excavation site or museum storage.

Banik and Stachelberger (1987) state that the high salt content of Egyptian soil (see p. 242) has a preservative effect on papyrus, as the salts inhibit microbiological growth. They state that, where sodium chloride is present in a concentration of over 6 per cent, very few micro-organisms can survive. However, although the alkaline soil of Egypt may well have a preservative effect against micro-biological deterioration, mould growth has been found on papyri in various collections (Kowalik and Sadurska 1973; Weidemann and Bayer 1983; Owen and Danzing 1993).

Attack by insects

Papyrus is very vulnerable to insect attack. Most collections have examples of the results of the ravages of insects. The regular patterns of damage are indicative of activity taking place while the papyrus was still rolled. Cockle (1983: 157) states that ancient users of papyrus were aware of this danger and applied *cedrium*, a resinous extract from the juniper, to prevent bookworms from attacking the roll. Many papyri in the British Museum and Petrie Museum collections show evidence of insect attack (see Fig. 9.6); one of the authors, on unrolling a papyrus in 1992, found a dead insect still inside. Fortunately the problem is not a continuing one. Activity dies with the insect, perhaps even before discovery. If papyri are stored in good conditions there is no reason why they should be re-infested.

Deterioration during ancient use

Another factor which will have a bearing on the condition of papyrus rolls is the use to which they were put in ancient times. If the roll was consulted as a reference work, for example the Kahun Medical Papyrus in the Petrie Museum (Kahun, VI.1; UC. 32057; Griffith 1898: 5; pls. 5–6), it will already have been subjected to considerable wear and tear. Sometimes repairs made in ancient times, often with a strip of fresh papyrus, can be observed (see p. 232). A good example of this is the Rhind Mathematical Papyrus in the British Museum (BM EA10057 and BM EA10058; Robins and Shute 1987). Palimpsests are also found, both

Figure 9.6 A papyrus bearing a liturgy in hieratic (BM EA10819, Eighteenth Dynasty), which has been subjected to insect attack while rolled.

among more ephemeral material, such as accounts, and also in the case of a surprisingly large amount of literary material (Caminos 1986; Tait 1975: 263). In these examples, the surface of the papyrus can be damaged and the fibres disturbed by rubbing when the first text was removed: the 'tired' or 'dead' appearance of the surface of re-used papyrus has often been noted (e.g. Tait 1991b: 51). However, many extant papyri from Pharaonic times are Books of the Dead which have received hardly any use in antiquity, and which seem usually to have been written upon fresh papyrus.

The media applied to the papyri by the ancient Egyptians can cause deterioration. Fortunately the inks used throughout the Dynastic period, carbon black and red iron oxide (see pp. 238–9), are both extremely stable. Iron-gall ink which appears later, is by its nature acidic and can break down cellulose materials. There are numerous examples of this type of degradation on paper where the ink has eaten right through the paper (Watrous 1967: 73). However, judging from the papyrus examples with iron-gall ink seen personally by one of the authors, for example some of the Chester Beatty collection (ranging from the third to seventh centuries AD) and others in the British Museum collections, the iron-gall ink does not appear to have done any visible damage to the papyri, although the ink itself is very fugitive.* Of course at these early dates we do not know the exact constituents, or recipe, used for the ink, and these may differ considerably from the types well-known from later periods, which are found to damage paper. The situation is different in the case of the green pigment found on Egyptian papyri. Most collections of illustrated papyri (e.g. British Museum: Donnithorne 1986: 4; Louvre: Ménei 1990: II/iv, 23; Brooklyn: Owen and Danzing 1993; Leipzig: Weidemann and Bayer 1983) have examples of the degradation of copper-based pigment. The colour darkens to brown or black and causes staining in and around the pigment area similar to a 'burn', as it is frequently called, sometimes to the point of a complete disintegration of pigment and papyrus in the area. The process will have begun before the papyrus was unrolled, and consequently the stain may also have affected surrounding areas of the roll. This type of degradation is distinctive, and typical of the pigment verdigris, or copper acetate (Banik 1989). However, analysis of pigments on papyri at the British Museum has not yet resulted in the identification of verdigris as the green pigment used, and more specific analysis of these particular greens would need to be carried out to ascertain whether the degradation is in fact due to the presence of copper acetate.

Blue mixed with yellow has definitely been identified as a green pigment on papyrus, and so far the blue pigment has invariably been found to be Egyptian blue (Green 1995; and see also Chapters 4 and 8, this volume, for discussion of Egyptian blue). This green colour is copper-based, and it too can blacken, particularly around the edges of the painted area, but not with the characteristic 'burn' discussed above. A hypothesis that may go part of the way towards explaining this blackening is that, if orpiment, arsenic trisulphide (As_2S_3), is also present on the papyrus as a yellow pigment, the excess sulphur given off by it inside the papyrus roll may react with the copper pigment, and cause the blackening effect. This may explain the randomness of the blackening, as it occurs in a noticeably haphazard fashion, on some greens and blues, but not others. Indeed, the incompatability of orpiment with other colours containing copper or lead has been known by painters since the seventeenth century AD (see Harley 1970: 87). Tests are currently being carried out at the British Museum, in an attempt to understand the behaviour of orpiment, and more work is necessary before conclusions can be reached. However, initial experiments have shown that copper colours blacken in proximity to orpiment. A strip of papyrus, painted with copper colours and orpiment, was covered over, but half of the strip was left uncovered; this area did not display the blackening effect, suggesting that the sulphur had reacted with the copper colour only when unable to release itself into the atmosphere.

In general, all pigments are liable to cracking and flaking and general onset of brittleness due to the loss of binder over the years. Additionally, the pigments themselves were often coarsely ground and thickly applied, which is especially noticeable in the case of the blue pigment, and so the loss of the binder can make these pigments even more friable.

Deterioration caused by environment of find site

The conditions in which the papyri have been preserved before discovery will also affect their state of deterioration. Most finds of papyri can, very loosely, be divided into two types of context: firstly those found in tombs and burials, and secondly those found by excavation within the occupation layers of town sites, or in rubbish dumps. The exact provenances of papyri now in museum or private collections often remain uncertain.

Papyri found in tombs have on the whole fared better than those found by excavation. In general, it can be said that the only papyri that survive relatively intact are (1) funerary papyri preserved in the tomb and (2) archives or personal libraries deposited in exceptional conditions (sometimes a tomb). Because most tombs retain a reasonably stable relative humidity and temperature, they are, to an extent, protected both from human interference and from the environment. From the Eighteenth Dynasty on-

---

* 'Fugitive', with reference to media on graphic material, means that they are susceptible to movement if excess moisture is present; they are also sensitive to light, and exposure to this form of energy can cause the media to fade.

wards, rolled-up funerary papyri were often placed alongside the body, in the wrappings or upon the shroud. In burials of the Late New Kingdom and Third Intermediate Period, funerary papyri might be put in a separate container (a hollow Osiris figure of wood) or placed by the body. In the Roman Period, short funerary papyri were often placed within the coffin. The most common types of deterioration in these cases are insect attack and staining of the papyri. Stains are caused by resins used in the mummification and burial ceremonies, and perhaps excretions from the body. Some stains are blackened and almost tar-like, and unfortunately can obliterate part of the text. Examples of this type of stain can be seen on numerous late Books of the Dead (e.g. BM EA10048/1–2).

Papyri excavated from archaeological sites are found in a wide variety of conditions. In settlement sites, when conditions have been sufficiently dry, they tend to survive only in a fragmentary state, often having been used as scrap paper. Some have been discovered in houses and temple complexes (most notably the massive finds of the Greco-Roman period from the Fayum and Middle Egypt) while others have been found in refuse deposits. The Middle Kingdom Ramesseum Papyri (Quibell 1898: 3; Gardiner 1955; Barns 1956) were found in a box under mud-brick magazines at the rear of the New Kingdom mortuary temple of Rameses II (the Ramesseum) apparently deliberately deposited in a modest Middle Kingdom tomb-shaft, and not in one of its burial chambers. The Hekanakhte letters were found in a tomb-passage in the Eleventh-Dynasty cemetery at Deir el-Bahari, probably discarded there as rubbish (James 1962: 1), although Goedicke (1984: 3–7) sees them as a dossier discarded, unread, after having being stolen.

The condition of the material varies greatly. The Ramesseum Papyri are in extremely poor condition due to decomposition of the constituents of the papyri, probably caused by a damp atmosphere. Several fragments among the collection are best described as dust. In the case of all excavated materials, fungal and insect damage can occur, as well as contamination by dirt and debris. If the papyri have been torn up in ancient times before disposal, and then buried beneath successive layers of rubbish, those sheets or rolls compressed at the bottom of the mound become even more damaged.

However, one of the problems commonly associated with papyri found under the soil is contamination with salts. The presence of salts on papyri was first reported in the early twentieth century when crystals on the Rainiér Papyrus were analysed by Barth (Rathgen 1905: 155), who found a high percentage of potassium and sodium chlorides in the crystals. The presence of this kind of salt contamination manifests itself as crystals on the surface of the papyrus, where it can be seen with the naked eye or observed through the microscope as small encrustations, embedded in the material. When salt particles effloresce, due to the absorption of moisture from the air, it is very detrimental to papyrus, since the particles form within the physical structure of the material, thus destroying the surrounding tissue.

When Bridgeman (1973: 16) examined various samples of ancient (unprovenanced) fragmentary papyri by radiography, he suggested that the salt which he observed in one sample was 'within the very fibres of the plant material', and consequently had been there prior to manufacture, taken up through the roots of the plant itself. It is true that the Egyptian soil is high in salt content in certain areas, and that plants contain small amounts of chlorine in the cell sap, due to the absorption of soluble chlorides from the soil. Sodium is also present in small proportions in nearly all plants. However, judging from the analyses undertaken, the content was not large enough to account for the salt efflorescence (Nielsen 1985: 104–40). Nielsen undertook a great deal of work on the problem of salts in papyrus, and their possible source. She examined papyri from Fayum town-sites (including many deriving from rubbish-tips), which are now in the collections of the National Library in Austria and the Carsten Niebuhr Institute in Copenhagen, concluding that the salts in the papyri probably resulted from contamination by the soil in which they were buried. These papyri were found to be sometimes high in soluble salts, up to 13 per cent, particularly sodium chloride (Nielsen 1985: 125). That the soil of the Fayum itself is especially high in salt content was demonstrated as early as 1902, when Lucas undertook an investigation into the soil and water of the Fayum Province, for agricultural purposes, because the soil in certain areas had deteriorated sufficiently to cause concern. He found the soil to contain sodium chloride and sodium sulphate at various levels at concentrations of up to 5.3 per cent, over 0.5 per cent being considered injurious for crops. After his analyses, Lucas (1902) came to the conclusion that irrigation water in the Fayum was not the source of salt in the soil, but that the ultimate source was the desert sand, and the limestone and clays that underlie it.

Nielsen examined whether the manufacturing process of papyrus could have contributed to the presence of salts in it, most particularly if the strips were re-wetted prior to beating or pressing. If this was the case, and the source of the water was the Nile or one of its canals, then salts in the water could be the source. It is difficult to assess from this distance in time whether the Nile water contained soluble salts in any significant proportion. Nielsen states that, in published water analyses, no chloride content over 0.2 per cent is found. This is borne out by the studies carried out by Lucas (1902: 10, 1908: 26, 32). Thus we have no reason to think that the papyrus absorbs salts in this way. Nielsen also considered whether the source of the salt was the plant itself, and analyses showed this not to be the case in the sample that she examined. The stem of the plant contained only 0.3 per cent sodium and 0.2 per cent chlorine of dry weight (Nielsen 1985: 118).

Excavation has also unearthed many finds of cartonnage containing papyri. Cartonnage is the term used for a type of mummy casing, made of gesso incorporating layers of papyrus or linen or both. The layers are glued and moulded together, the outermost layer of gesso being painted. The papyri used for this purpose were old documents, with a wide variety of texts on them; consequently their value to the papyrologist was significant. The practice was largely confined to the Greco-Roman period, and so lies beyond the scope of this book. However, there are hieratic texts (difficult to date on palaeographical grounds) used in the making of some cartonnage, and the practice may have begun somewhat earlier. Apart from being subject to the normal forms of deterioration of organic material, the adhesive between the individual fragments of papyri, and between papyri and gesso make cartonnage especially attractive to insects (Wright 1980: 21).

The last type of damage concerns carbonised papyri. The largest set of such material was discovered outside Egypt at Herculaneum (see p. 239), but carbonised papyri have also been found at the Delta-site of Tanis, where Flinders Petrie found about 150 carbonised papyri in 1884. They had been placed in baskets, and most of them were about three-quarters burnt to white ash. Additionally, they were crushed by other material, and had cracked, as well as providing a nest for mice (Petrie 1985: 42). In 1993, further carbonised rolls were excavated at Tanis by the Mission Français des Fouilles de Tanis (e.g. Brissaud 1993: 2, 1994: 2–3; Ménei 1995).

Conservation

The chief tasks facing the conservator of papyrus in modern times concern three issues: repairing the damage done to papyri by unsatisfactory or deleterious methods of conservation and storage adopted in the past; addressing the problems that still arise in modern papyrus collections; and treating papyri that are newly excavated or otherwise discovered (modern surveys with bibliography include Cockle 1983 and Fackelmann 1985).

Early treatment

Collectors of Egyptian antiquities, including papyri, made their acquisitions in various ways in the eighteenth and nineteenth centuries, sometimes acquiring items during their travels and at other times obtaining them by means of direct excavations of tombs or town-sites. The details of the original transactions are mostly unrecorded, therefore the provenances and subsequent histories of these objects are not known. Papyri were frequently cut up and sold to one or more collectors, or coffins were separated from their contents, as is evident from the distribution of related sets of objects throughout the collections of the world. This type of handling could only encourage mechanical damage, fragmentation and loss. There was also a common practice of making 'false' rolls by pasting together disparate papyrus documents into a roll-shape (see Fig. 9.7) and selling them in that form, evidently in the expectation that an apparent roll would command a higher price than fragments. An early conservation register of work at the British Museum includes an entry for 1838 which states that, having removed the outer cloth from a roll, 'I find it to be a complete imposition being nothing than a parcel of fragments laid together to give the appearance of a perfect roll' (Quirke 1995: 170).

The primary interest of a papyrus roll for early collectors and scholars was the text it contained, therefore most papyri were unrolled as soon as possible after acquisition. The basic method was to dampen the roll, either by wrapping it in damp blotting-paper, linen, or cotton wool, or by applying steam, or by contriving some kind of humidifying chamber. When the outer convolutions were flexible enough, these were laid flat between dry blotting-paper under a glass or weight, and the next section was dampened in turn, and so on until the end of the roll was reached. Plenderleith and Werner (1971: 44–7) mention subsequent pressing between thymol-impregnated blotting-paper for several days (*cf.* Petrie 1904: 93–5; Rathgen 1905: 154–6; Lucas 1932: 130–7).

Some substantial collections of papyri awaiting detailed study have traditionally been kept in paper folders. This method of storage should never be considered as more than a temporary measure, since the papyri are inadequately supported and protected. Also, the material can be made accessible only to scholars with some experience in handling papyrus fragments.

Some early treatments of papyri cause problems for us today. This need imply no criticism of the methods used,

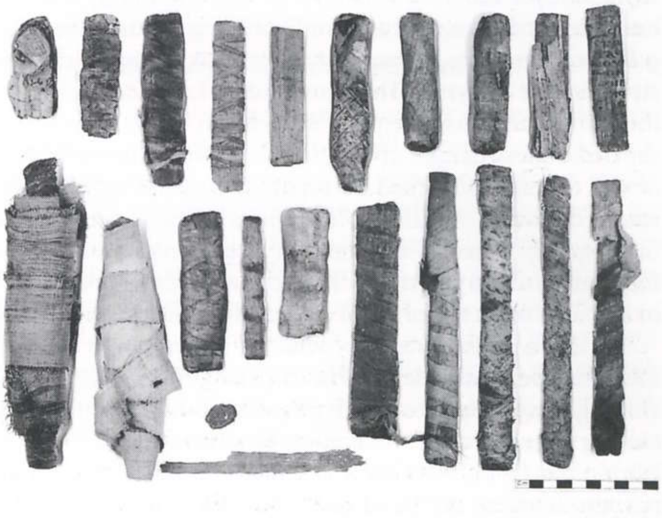


Figure 9.7 'Made-up' or 'false' papyrus rolls, some wrapped in linen (BM, unregistered; dates of constituent material range from the New Kingdom to the Coptic period).

since many items were saved with the materials and methods available at the time. Today we have better information and techniques at our disposal.

In the nineteenth century, the commonest treatment of papyri was to back them onto paper, card, or linen as they were unrolled, or soon after; they were then cut into convenient sizes for mounting between glass and board. Where there was text on the back, a gap would be left in the backing paper and the mounting-board, so that it could remain exposed, leaving this area unsupported and unprotected – although sometimes text on the back of a papyrus was overlooked (e.g. Andrews 1991). Unfortunately the materials used for this mounting were almost invariably deleterious. From the first half of the last century, the use of woodpulp instead of rags to produce large quantities of paper resulted in the production of much material of poor quality. The addition of various fillers and chemicals, particularly alum (papermaker's alum: aluminium sulphate) and rosin, which were used together as a size, tended to increase the acidity of the paper. Not all papyri were backed in such a way. Some were repaired with strips of gold-beater's skin (thin animal membrane), or with court plaster tabs (pieces of silk with an animal glue adhesive, the primary use of which was as first-aid sticking-plasters). Poor quality transparent papers of various types were popular for repairing papyrus, and many examples can be seen in collections today, in which the paper has become brittle and weak. Already at the beginning of the twentieth century, Spiegelberg (1917: v, n. 4) lamented the state of the Demotic Mythus Papyrus in the collection of the Rijksmuseum van Oudheden, Leiden, which had been completely overlaid with 'papier végétal' in the first half of the nineteenth century; this is now badly discoloured (see Raven 1982: 72; and *cf.* Griffith and Thompson 1904: 3, on P. London-Leiden). As backing paper deteriorates, it weakens and becomes sensitive to fluctuations in relative humidity and temperature, and cockling occurs (see Fig. 9.8); over time, the movement of the backing paper causes stress in the papyrus. This can lead to cracking and fractures, and can cause the papyrus to lift in some areas, with the consequent danger of the loss of small fragments. Many of the fragments backed or repaired by early techniques were misplaced, or else whole sections of the papyrus were misaligned. Subsequent attempts to arrive at a better arrangement of the fragments have often been made difficult or impossible by the original attempts at conservation.

We have little direct or detailed information on the methods and materials used in early papyrus conservation, although one early account, dating to 1838–42, has survived among the records of the British Museum (Quirke 1995). Also at the British Museum, a Late Period funerary papyrus, the Book of the Dead of Irtyru (BM EA9912; Quirke 1993: 42) is said to have been treated with an 'ethereal solution of hydrogen peroxide', to try to improve the legibility of the papyrus, after 'thymol paper' had been applied: this information comes from a note by Alan Shorter, who worked in the British Museum Laboratory (Shorter 1933). This particular example is in a very sorry condition, and the papyrus is cupping and flaking off the backing paper. As it had also been varnished, very possibly prior to the treatment mentioned, it is difficult to assess how much of the damage was done by the hydrogen peroxide.

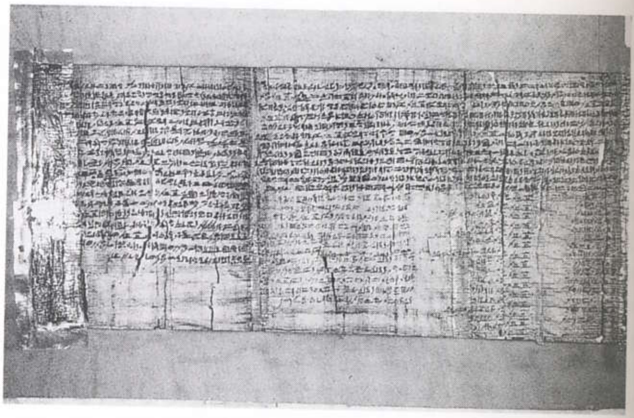


Figure 9.8 The Papyrus of Nesmin (BM EA10188/14, Late Period). This papyrus has writing on both sides; it has been inlaid into a piece of poor quality brown paper with strips of gelatin at each end. The papyrus is cracked and fractured as the brown paper has cockled.

Another treatment was to cause the papyrus to adhere to one side of the glass mount itself by rubbing warm wax on the glass and laying the papyrus upon it. According to Rathgen (1905: 155), the practice in Berlin was to coat both inner sides of the glasses with a thin layer of 'Vaseline'. The Ramesseum Papyri furnish examples of some of the worst types of treatment practised at one time. It has to be said that this material is particularly fragile, and has text on both front and back. The task of separating and mounting the fragments would have understandably presented problems for the famous Hugo Ibscher, to whom much of the material was entrusted (he worked on various papyri at the Berlin Museum from 1891, and also on various other European collections). Both Gardiner (1955: 2–3) and Barns (1956: xi) warmly praised the work he had been able to do. Two of the fragments were mounted on celluloid film (whether or not by Ibscher himself is not known), which subsequently ignited spontaneously, and they became badly disfigured. They now belong to the British Museum, although the damage was done before their arrival there. In view of this disaster, and the general fragility of the group, the British Museum accepted the papyri only on condition that Gardiner publish them first: hence the summary nature of Gardiner's volume (1955). Ibscher also used gelatin film to mount fragments, sometimes with cellulose nitrate adhesive. One of these documents (BM EA10754/C) has been analysed recently at the British Museum, and the adhesive identified as cellulose nitrate (Thickett 1992). It is certain that it was treated by Ibscher in 1905, as he etched his name and the date on the gelatin film. This type of adhesive with the trade name 'Zapon' was widely used at one time in the restoration of many museum objects (Rathgen 1905: 168–70B). In a solution of amyl acetate, it was used to 'strengthen' archival material. Lucas (1932: 132) refers to the strengthening of papyrus with a 'dilute solution of celluloid', in this case very probably meaning cellulose nitrate adhesive, although he mentions that this was rarely needed. The terms celluloid and cellulose nitrate are often used as if they were synonymous, but we here refer to the film as *celluloid*, and to the adhesive as *cellulose nitrate*. Film made from cellulose nitrate was marketed under the name 'Celluloid' in the USA (Koob 1982: 31). In its early formulation the film was particularly unstable chemically; hence the problem of the possibility of spontaneous combustion. The reactions are complex: in the first stages of degradation, nitrogen dioxide gas is given off, which itself speeds up the degradation. If the gas is able to build up, as in the case of early celluloid film stored in containers intended to be airtight, the reactions are accelerated further, sometimes resulting in combustion (Edge *et al.* 1990). Cellulose nitrate adhesive, being in a less concentrated form, is unlikely to react in this way, although it does become insoluble over time, thus causing other problems.

Of the Ramesseum Papyri treated by Ibscher (and later by his son, as the work went on into the 1920s and 1930s), only two were mounted on celluloid film. Most were attached to gelatin with cellulose nitrate adhesive, or were probably stuck by brushing the gelatin with a little warm water to make it tacky before laying down the papyrus, as no adhesive is visible. One example of the use of cellulose acetate film has been identified (Green 1993), but the rest were attached to waxed glass, or mounted between glass with no support or adhesive.

Salt contamination was observed as a problem from early on, and Rathgen (1905: 155) says that salt crystals were picked off with tweezers. Lucas (1932: 132) states that the only way to deal with salts was to soak the papyrus repeatedly in pure water until the wash water tested free of salt.

For cartonnage, all the early methods used to separate gesso from papyri involved the use of acids, which dissolved the gesso layer more or less completely. Lucas (1932: 134) records that 20 per cent acetic acid solution was employed; at the Sorbonne the use of hydrochloric acid is reported (Wright 1980: 27).

Carbonised papyri presented a particular problem in the past, as they still do. Although one might expect the material to be beyond repair, as indeed some of it is, carbonised papyri have frequently been unrolled, and text revealed. The black ink, in suitable lighting, is still legible against the background of the papyrus, which can take on a grey and 'metallic' colour when it has been subjected to very high temperatures. Many of the Herculaneum papyri were apparently unrolled by means of an elaborate machine, devised by Antonio Piaggio, not long after their discovery in 1752. If we understand correctly, the process involved slowly unrolling the layers onto a sheet of thin animal gut, dilute adhesive being used to relax the roll, and to attach the layers to the sheet (Gilberg 1988). This technique was not universally successful, as might be expected in the case of such fragile material, and sometimes large pieces of the roll broke away. Petrie (1904: 94) gives advice on the handling of finds of carbonised papyri, probably recording his experience at Tanis. He states that 'the objects should be removed from the site by undercutting the earth below and around it'. Later, the individual rolls can be separated using a fine knife and wrapped in soft paper, and 'wrapped thus carefully, a few to a box, they can be transported safely'. Two of the hieroglyphic papyri from Tanis came to the British Museum (Griffith and Petrie 1889), where there are also two small rolls and a box of untreated fragments. The section of the British Library which was formerly the British Museum Department of Manuscripts still has untreated material from Tanis, but the present location of approximately fifty frames of unrolled fragments is unknown. There is some documentation of the treatment received by this material:

> The papyrus fragments have been mounted in frames formed by two sheets of glass, held apart by a thin piece of cardboard round the edges to allow for wrinkles in the papyri; both sides of which can thus be seen. The fragments are kept in place under the glass with shell-lac. The task of mounting the papyri was a simple, although a delicate one. The rolls had been crushed flat, and so consisted of a series of flakes, each the same breadth as the crushed roll. The flakes were removed with a paper-knife from each side of the roll alternately, the order thus obtained being fairly correct. In some cases it was found more convenient to divide the roll in the middle, and, beginning from the centre, to take flakes alternately from each half. (Griffith and Petrie 1889: 2)

Papyrus collections: ongoing deterioration

When papyri have been in museums or private collections for many years their condition will have been affected by the environment in which they have been stored or displayed. All forms of deterioration, whether inherent in the material itself, or due to the nature of the conditions in which they survived before modern discovery, or mechanical handling, or previous treatment, will be accelerated by unstable environmental conditions. One form of deterioration, namely over-exposure to high light-levels, will actually catalyse breakdown of the papyri and some writing or painting media.

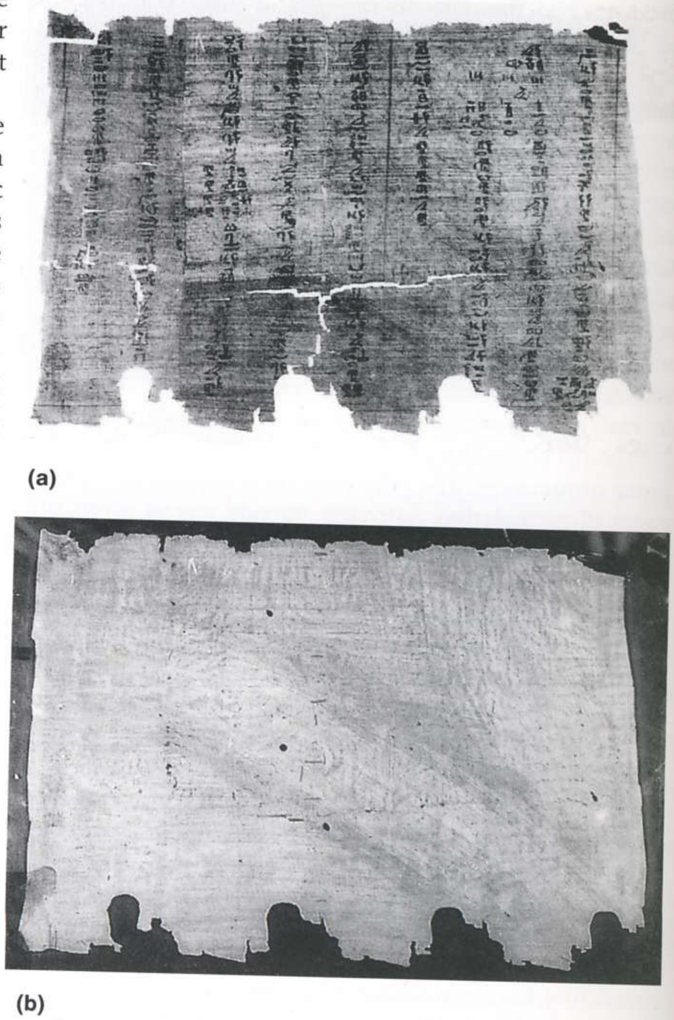
We have already seen that exposure to light, particularly ultraviolet light, causes papyri to lighten or 'bleach' (Green and Leach 1993: 11). This is due to photo-oxidation; light as a form of energy will cause chemical breakdown of the cellulose molecule (Thomson 1986: 193–5). Papyri that have been subjected to this type of degradation become irreversibly weak; at worst the fibres and the inter-fibrillar cellulose material readily turns to dust at the slightest movement.

Light can also affect the media used on papyrus. The inks on Egyptian papyri, being carbon black and red iron oxide, remain stable, but iron-gall ink, being an acidic product, ferric gallotannate, is less stable. Most pigments found on Egyptian papyri are mineral pigments and are light-fast, although vermilion and verdigris are known to darken (Thomson 1986: 12). The most light-sensitive pigment is orpiment, arsenic trisulphide, As_2S_3 (see pp. 239, 241). This has long been known, and tests currently being undertaken at the British Museum confirm that orpiment fades extremely quickly, and will eventually lose all colour when exposed to light. The relationship between the amount of light needed to effect the change, and the time factors involved has yet to be established. Orpiment degrades photochemically to arsenic trioxide, As_2O_3, which is almost white in appearance (Green 1995). There are examples of papyri in the British Museum which have lost all the yellow borders commonly drawn above or below the texts of the Books of the Dead. The fact that this is directly caused by exposure to light can be seen when one compares one frame that has been on display with another that has not, from the same papyrus roll: the yellow pigment has invariably faded. Realgar, an orange-red sulphide of arsenic very similar to orpiment, is also subject to photo-degradation (see p. 239).

Relative humidity plays a large part in the efflorescence of salts in those papyri which are contaminated. It manifests itself as small deposits imbedded in the papyrus, or as crystals on the surface, or, when the papyrus is contained in a mount, as a 'bloom' on the glass mount, roughly matching the shape of the mounted fragment (see Fig. 9.9). Analysis of this bloom on the glass has indicated that it consists essentially of sodium chloride (Nielsen 1985: 104–17; V. Daniels, pers. comm., 1996), and other summary examinations known to us have led to the same conclusion.

This 'bloom' forms because of salt migration, as the papyrus takes up moisture from the air. If the papyrus takes in more moisture than it can absorb, it will pass through the material, in its aqueous state, dissolving and carrying salts with it, ultimately to the surface of the papyrus, where it will come into contact with the glass or backing paper. Sometimes it passes through the backing paper to the glass. This is what we see as a 'halo' or 'bloom' on the glass mount.

Thus constant changes in relative humidity (RH) will encourage salt efflorescence. Light and temperature will also play a part in this as they alter the RH (Nielsen 1985: 104–17). Nielsen did tests to establish how far the bloom was caused by these three environmental factors, and found that although a high RH predictably resulted in a bloom on the glass, light exposure also had an effect by causing changes in temperature of up to +11 °C and in turn changes in RH of up to 42 per cent. Bloom resulted on all samples exposed to light even at a low RH setting. Thus papyri displayed for many years at high light levels will be subjected to variations of temperature and RH that can only encourage this type of salt migration. Nielsen's tests involved mounting papyrus fragments between glass and placing them in an environment with the RH at a constant low, constant high, or at a fluctuation, all at 20 °C. She then set the RH at 30, 50 and 80 per cent respectively, and trained direct light on the mounts from lamps switched on and off at six-hourly intervals.


(a)

(b)

Figure 9.9 Papyrus bearing Coffin Texts (BM EA10676/24, Middle Kingdom). Photograph (a) shows it inside a mount, which has developed a bloom on the inside of the glass. Photograph (b) shows the inside of the dismantled mount, with the bloom on the glass corresponding to the outline of the papyrus.

Papyri with salt efflorescence do not always display this 'bloom' on the mount, but salt deposits or crystals are visible under the microscope and sometimes to the naked eye. Aside from the amount of salt in the papyri when they arrive in a museum, the reason for their different behaviour may be due to the rate of drying during a fall in RH. In the case of objects which dry out slowly over a long period of time (i.e. the RH falls slowly and steadily), salts tend to migrate to the edges, or deposit themselves on material in contact – in the case of many papyri, glass. However, if the RH falls rapidly and an object dries quickly, salts are more likely to crystallise centrally, or on the surface of the object (D. Thickett, pers. comm., 1995). Whatever the reasons, some papyri can have a very marked bloom on the glass while the papyrus itself seems to show no salt efflorescence, and *vice versa*. In the latter case the danger is not always immediately visible as the crystals can be very small, but salt crystals repeatedly reforming with changes in RH, and over a number of years, will eventually damage the tissue and shatter the surface irreversibly.

Modern conservation procedures

The approach towards archaeological collections today, has, of course, changed since the time when most objects in our collections were acquired. The tendency is now towards minimum interference, in order to maintain the integrity of the object and of any evidence it can yield. Much repair work continues to be needed, the difference now being that the materials used must conform to conservation standards; this means that they must be chemically stable and have good ageing properties, and that their application should be reversible.

Great emphasis is now placed on 'passive conservation' by endeavouring to achieve satisfactory environmental conditions for storage and display. The recommended environment for pictorial art is 50–60 per cent RH and a temperature of 19 °C (±2 °C) (Bradley 1993: 79). Although 45–55 per cent RH is satisfactory for papyrus, damage can be caused by fluctuating conditions, particularly when those fluctuations are rapid. Light levels also are of crucial importance. Papyrus is subject to photo-degradation when exposed to high light levels, and some pigments used on illustrated papyri are light-sensitive, particularly orpiment. It is recommended that such pigments should not be exposed to light levels above 50 lux, and that the UV content of the light should be less than 75 micro-watts per lumen (Bradley 1993: 79).

The principal reasons for the deterioration of papyri have been outlined in the previous section, but of course all collections are different and will have different problems. Large, well-preserved Books of the Dead need a different approach from that appropriate to badly-preserved and fragmentary excavated material. Early treatments and subsequent museum environments, architecturally and climatically, will vary enormously.

Fungus and insect attack can be a serious problem for conservators and curators alike. Fortunately, this is not often a major problem for collections in temperate climates. However, infestation can occur when new objects are acquired which are already infested, or mould can develop if high RH micro-climates build up in particular areas. Most fungal growth will only occur above an RH of 65 per cent and a temperature of 20 °C (Daniels and Rae 1991: 4), although the spores found on papyri appear to prefer higher temperatures and higher RH (Kowalik and Sadurska 1973: 19), therefore environmental control is very important in order to discourage both insect activity and mould growth.

Many fungicides that have been used in the past are today considered unacceptable for Health and Safety reasons. In the past, after unrolling a papyrus, it was placed between thymol-impregnated blotting paper for several days prior to mounting (Plenderleith and Werner 1971: 46). However, the effectiveness of thymol is questionable (Kowalik and Sadurska 1973: 19), and there is evidence to show that it can yellow both paper and Perspex in the presence of light (Daniels and Boyd 1976). As far as pesticides are concerned, the British Museum, which still acquires much organic material, now uses methyl bromide gas, one of the permitted pesticides, or nitrogen anoxia. Freezing is also a method used for certain artefacts in the British Museum and other museums, although it is not advisable for unstable waxes and glues (Daniels and Rae 1991: 5). Tests prove that papyrus and mounts can be frozen if certain measures are taken (Leach 1995: 158), but as yet this rather drastic action has never been necessary for use on papyrus. More recently, argon gas was used in the Library at Mount Athos (Koestler and Matthews 1994); the gas is used to create a low-oxygen, or anoxic, environment, which kills the insect pests by suffocation. The use of inert gases is not new: nitrogen has been used for many years, most notably in the agricultural industry. Experiments using helium gas are currently planned at the Metropolitan Museum, New York.

The most effective way to guard against both forms of bio-deterioration is basic good housekeeping and staff awareness. Regular inspection of the collections and cleanliness, if done methodically, will ensure minimum risk of infestation or mould growth. Even in difficult climates, and in the case of collections which have no environmental control, much can be achieved by creating airflow. This reduces RH and prevents the formation of micro-climates.

When it comes to dealing with papyri which have evidence of mould growth, the mould deposit should be brushed away (a mask and rubber gloves should be worn for Health and Safety reasons). If the material is very fragile it may be taken away with fine tweezers or a scalpel; the use of magnification (a magnifying lamp, magnifying goggles, or microscope) is always helpful and the conservator can ensure that all the deposits have been removed. This operation should be done in a separate area with dust extraction. As yet, mould has never been encountered on any papyri in the British Museum collections, but unsorted excavation material may have deposits. Evidence has been noted of previous mould growth (or a better term would be microbiological deterioration) on papyri from other collections, where partial dampness at some time in the past has caused a mouldy stain. However, if dried out thoroughly after repair and stored in the correct environmental conditions, the papyrus should not deteriorate further.

Papyri that have been subjected to insect attack are characterised by holes or tunnels where the insect has been, and they may sometimes have very large areas of loss. Occasionally this proves useful for re-orientating fragments of a roll, when the insect has created a regular pattern in the convolutions of the roll while eating its way through the papyrus (Hoffmann 1994). In some instances the insect appears to have confined its movements to a single layer of papyrus (e.g. Tait 1991a: 20).

In the British Museum collection there are still several 'made-up' rolls: that is, papyrus fragments from disparate documents that have been stuck together into a roll shape (see p. 243). They usually present a larger, intact, piece around the outside to cover the scraps inside; other examples are known which are made up of fragments masking a stiff core of some other material. Three of these have been 'unrolled', or separated by the British Museum Department of Conservation in recent years. The method is very simple and involves the introduction of controlled humidity, followed by drying and pressing of the material. The aim is to introduce enough moisture to solubilise the adhesive between the papyrus layers, without harming the inks and pigments, so that the layers can be physically separated. A certain amount of moisture is also needed to 'relax' the papyrus, that is to make it flexible enough to realign and to flatten it out into its original shape. Separation of the layers is accomplished with tweezers or with whatever tool suits the conservator, and the individual pieces can gradually be eased away. It is necessary to rehumidify from time to time as the outer layers are removed. The fragments are then laid between two pieces of blotting paper with an interleaving layer of 'Bondina' or similar material, to act as a support and to stop the papyrus from adhering to them, under a piece of plate glass and weight. The blotting paper can be changed at regular intervals until the papyrus is dry. Much dirt, discolouration and old adhesive can be removed in this way, as it is drawn out of the papyrus into the blotting paper in its aqueous form. Straightforward rolls are approached in very much the same way, which is not unlike the early method of wrapping in damp blotting paper or linen, and leaving perhaps overnight, except that the introduction of moisture is much more controlled.

To achieve controlled humidification of papyrus, two aids have been found particularly useful: the use of an ultrasonic humidifier and the application of a material known by its trade name of 'Gore-Tex'. The ultrasonic humidifier produces water vapour by splitting the water into very fine droplets. The equipment consists of a small water tank with the sonic apparatus below, and a funnel running from it, carrying the water vapour. This produces moisture in a much gentler way than even the finest of sprays. Papyrus can be humidified slowly and gently either by directing the vapour flow directly onto the object, or by creating a humidity chamber and channelling the mist inside. The other method mentioned uses a layer of polytetrafluorethylene membrane (Gore-Tex), which is laminated onto a polyester felt backing. This membrane allows only gases and vapour to pass through it, so that, when it is laid over a damp layer (damp blotting paper or capillary matting), water vapour can pass through to the papyrus, which is laid on top. Again, a humidity chamber can easily be made by placing the layers in a tray and covering with a piece of glass, or by clipping a polythene sheet over it. This is particularly useful for small fragments, as they can be picked out one at a time to be cleaned and repaired. It is also valuable for small rolls or layers of laminated papyrus, as they can be separated in stages and replaced in the tray as more humidification is necessary. For larger papyri that will not fit in a tray, the same layers are used but a piece of glass can be laid on top. The amount of moisture passing through can be controlled by more or less extensive wetting of the damp layer. Distilled water is always used in papyrus conservation, to avoid the various impurities present in tap water.

Papyri that are not too fragile – by which is meant that the material is substantial enough to withstand a minimal amount of handling without disintegration – can be repaired. Small fragments can be picked up with tweezers, but larger pieces are always moved by holding firmly between two sheets of plate glass, with an interleaving layer between the papyrus and the glass as a support. If discoloured, dirty, fractured, misaligned, cockled, creased, or brittle, the papyri can be treated fairly straightforwardly. Humidification to relax the papyri is preceded by testing the inks for fugitivity. The inks are usually stable; only a slight fugitivity is sometimes found, but with proper care in humidification and physical handling this is not a problem. Before humidification, surface dirt can be removed with a soft brush. Once relaxed, if the papyrus is creased, cockled or misaligned it can be gently manipulated into shape. This is often done over a light table, where the fibres of the vertical and horizontal strips can be seen. At this point, any dirt or deposits may be removed. This should not include stains or resinous deposits, e.g. from a burial, which may be regarded as forming part of the object. Lumps of dirt, if necessary, can be picked off with tweezers. Once the papyrus is realigned, it can be repaired. Repairs are made with small pieces, 'tabs', of Japanese paper and wheat-starch paste. Long-fibred, good quality Japanese paper is strong; it can be toned with water colours if desired so that the tabs are not over-noticeable when attached to the papyrus. Gluten-free wheat-starch paste is widely used in conservation and is a good reversible adhesive. Small tabs can be laid over the fractures to rejoin them in the correct position and the papyrus is then pressed until dry. Again, much dirt and discolouration is removed by absorption into the blotting paper during drying. Where dirt or deposits obliterate the text, which is more likely with excavated material, careful use of tweezers and very gentle rolling of damp cotton-wool buds over the area, in the direction of the fibres, can successfully reveal the text. It is always advisable not to over-clean, firstly in order to avoid damage to the ink, and secondly because the absorption of dirt into the blotting paper very often means that on drying-out the text is much clearer than it may have appeared while wet.

Fragments of papyrus often become displaced. This can be due to the condition of the roll itself; if it has been subjected to insect attack it may have fallen into fragments. In addition, separating the layers of a made-up roll only leaves us with a considerable number of fragments which may, or may not, come from the same document. The philologist may be able to judge from the text which fragments may join up, but fortunately it is also possible to match up the horizontal and/or vertical fibres of the papyrus in order to re-orientate the roll or document, even when there has been a certain amount of loss. Because of the way in which papyrus is manufactured, each sheet has a fibre-pattern which can be seen through transmitted light, with or without magnification. Even papyri which are too thick to be viewed through transmitted light can have a visible surface fibre pattern. By lining up matching fibres either horizontally or vertically, it is sometimes possible to get an exact placing of a fragment, although the area immediately around it may be lost. The sheet-joins may also prove helpful. If we know the approximate dimensions of one or two sheets already, we can assume for the purposes of orientation that the remaining sheets will be of approximately the same size (e.g. Tait 1975: 263). Sheet-joins are normally easily recognised, as the horizontal fibre pattern changes, and the join is slightly thicker and darker when viewed by transmitted light because of the overlap. However, sheet-joins can be very difficult to identify in damaged material.

Many papyri in collections have been backed by paper of inferior quality, which has led to cockling, the lifting of small fragments, and fractures. If necessary, and where possible, these backings are removed. In most cases the papyri are very fragile and need to be relined with archival quality materials (Japanese paper and wheat-starch paste), with the advantage, at least, that the fibre pattern can be observed through the new lining. If they are strong enough, the papyri are not re-lined, but may be repaired with tabs only. To effect the safe removal of a backing, the papyrus must be adequately supported during the removal and while applying new repairs. A facing technique has been developed at the British Museum (Walker 1988), which has made it possible to remove backings safely. The technique has also proved satisfactory for illustrated papyri (Leach and Green 1995).

Very friable papyri sometimes need to be consolidated. Often this can be done effectively by humidifying the papyrus slightly, just enough to reactivate the gums, followed by pressing. Another successful method has been to spray on an aqueous solution of funori (0.5 per cent), followed, again, by pressing. Funori is a glutinous extract of three seaweeds, which contains galactose, also found in the natural cell sap of papyrus (Levring *et al.* 1969: 335). Funori has been used in Japan as an adhesive for many centuries, and is widely employed in paper conservation (Winter 1984: 119).

The pigments on an illustrated papyrus may be flaking or crumbling. In this case a suitable consolidant must be applied to reattach the pigment particles to each other and to the papyrus. The consolidants used in conservation such as Klugel G, Paraloid B72, and isinglass have all been tested at the British Museum in recent years: isinglass was found to be the most effective (Leach and Green 1995). It is almost pure collagen, the UK supply being made from the swim bladders of various tropical fish (Foskett 1994: 11). It is a good adhesive, and has a matt appearance which does not alter the colour of the ancient pigments when applied.

When salts are found to be present on papyri, they can, if crystallised on the surface, be removed with fine tweezers, working under magnification. Water-soluble salts may be removed using distilled water, followed by pressing between dry blotting paper to remove the solubulised salt; but this is not necessarily possible if the papyrus is very fragile. Again, not all salts are soluble, and the only safe practice, if the salts cannot be removed or removed completely, is to store or display the papyrus in stable conditions of temperature and RH, with suitable light levels. Salt manifesting itself as a 'bloom' inside a glass mount containing papyrus can be remedied by dismantling the mount, wiping the bloom off the glass, and re-mounting. However, this is not always practicable, or safe for the papyrus. Allowing a little air to circulate inside the mount is helpful in combatting this problem. At the Austrian National Library in Vienna, a small gap is left in the binding tape at the corner of each glass papyrus-mount, and the mount is then placed within a paper folder, as a dust cover. These particular mounts are comparatively small; therefore the method is feasible as well as successful. For collections with much larger papyri, enclosed in correspondingly larger glass mounts, where the papyri are constantly consulted, and the mounts subjected to considerable handling, this method is unfortunately not practicable.

It is widely – although not universally – agreed that papyrus is best stored between two sheets of glass, held together by some form of adhesive tape binding. Glass has several advantages. It has been used for the storage of papyrus for almost two centuries without any apparent harmful effects. It does not normally adhere to the papyrus in any way, and, if necessary, it can easily be cleaned or replaced. It allows the papyrus to be examined and photographed just as it has been stored. Indeed, photographers generally prefer to photograph papyri under glass. The disadvantages of glass should not be disregarded, however. It is heavy, and large collections of papyri when glassed can become very bulky. Sheet glass of three-millimetre thickness is perfectly adequate for small fragments, but the larger the papyrus, the heavier the weight of glass that must be used, and very large papyri require substantial wooden frames, if glass is to be employed with safety. If an accident causes both sheets of a glass mount to break, the papyrus usually remains undamaged, but may be cut, although fortunately the broken edges of the glass usually act in the manner of a guillotine, and sever the papyrus very cleanly. Obviously, care always needs to be taken in the handling of glass and of glass frames.

Papyri stored between sheets of glass should normally be held in place with tabs of Japanese tissue, made to adhere to one side of the glass. If unsupported in this or any other way, small fragments (especially when several pieces of differing thickness are stored in the same frame) can slip or move about. This is, at the least, an annoyance, and greatly increases the risk of damage to the fragments. The effect is exacerbated when the frames are shelved standing vertically, which is the method of storage most commonly adopted. Glass frames cannot be stacked in piles either conveniently or safely, and more elaborate methods of storing papyri horizontally are both expensive and greedy of space.

In modern times, the chief rivals to storage in glass have been various types of transparent plastic folders and Perspex sheets. They have several disadvantages. It is not known whether plastic or Perspex might harm the papyrus as they degrade, plastic folders are not sufficiently rigid to protect papyrus, and Perspex can warp. There is also anecdotal evidence that the static generated by Perspex can tear apart the two layers of a papyrus sheet when the mount is opened; one of the authors has witnessed a papyrus starting to be damaged in this way.

Conclusions

Much experimental and analytical work has been undertaken in recent years to attempt to identify the constituents of papyrus as a writing-ground, and to establish the methods used in the manufacturing process, and the mechanisms of deterioration. Much, however, is still not understood: for example, the type or types of sub-species of papyrus used, and the details of craft practice in the preparation of papyrus sheets (how the strips were cut and pressed together), in joining sheets, and in the finishing processes. In the absence of any Egyptian written sources, these questions may yet be clarified by closer examination and by modern analytical techniques. Much can be deduced from observation, particularly if a substantial corpus of papyri is available for study. However, early methods of mounting papyri, often encountered in long-established papyrus collections, can impede investigation. In the area of conservation, treatments still need to be found for certain problems, such as the insolubility of old cellulose nitrate adhesive used as a repair material at the beginning of this century.

Many papyri in existing collections remain quite unstudied. At the same time, papyri continue to be found in excavations, presenting a wide range of conservation problems. In the last few years, the use of computer scans has rapidly become feasible and almost commonplace, both in the publication of reproductions of papyri, and as a tool in reading them. This topic lies outside the scope of this book, but it is to be expected that computer techniques will play an increasing role in the study and the conservation of papyri: one application already being discussed is the matching of papyrus fibre-patterns, and other new approaches will undoubtedly be developed.

Acknowledgements

We should like to thank Dr V. Daniels, Dr S. Quirke, Mrs G. Roy, Mr T. Springett and Dr M. van der Veen for their help.

References

Andorlini, I., Baccani D., Barbi, R., Baroncelli, V., Bassi, E. and twenty others 1985. *The Rendel Harris Papyri* II. Studia amstelodamensia ad epigraphicam, ius antiquum et papyrologicam pertinentia 26. Zutphen: Terra.

Andrews, C.A.R. 1991. Postscript to PBM 10380A/B. *Enchoria*, 18: 175–6.

Bailey, L.H. 1963. *Standard Cyclopaedia of Horticulture* (3 vols). New York: The Macmillan Company.

Banik, G. 1989. Discoloration of green copper pigments in manuscripts and works of graphic art. *Restaurator*, 10: 61–73.

Banik, G. and Stachelberger, H. 1987. Salt migration in papyrus fragments. In *Recent Advances in the Conservation and Analysis of Artefacts: University of London, Institute of Archaeology Jubilee Conference 1987* (ed. J. Black). London: Summer Schools Press, pp. 199–201.

Barns, J.W.B. 1956. *Five Ramesseum Papyri*. Oxford: Griffith Institute.

Barrandon, J., Irigoin, J. and Schiffmacher, G. 1975. Nouvelles techniques applicables à l'étude du livre de papyrus. In *Proceedings of the XIV International Congress of Papyrologists, Oxford, 23–31 July 1974* (Graeco-Roman Memoirs 61). London: EES, pp. 7–10

Basile, C. 1972. A method of making papyrus and fixing and preserving it by means of a chemical treatment. In *Conservation of Painting and the Graphic Arts*, IIC Lisbon Conference Preprints, pp. 901–5.

1977. Metodo usato dagli antichi Egizi per la fabbricazione e la preservazione della carta-papiro. *Aegyptus*, 57: 190–9.

Basile, C. and Di Natale, A. 1994. *Il Museo del Papiro di Siracusa* (Quaderni dell' Associazione, Instituto Internazionale del Papiro – Siracusa IV). Siracusa: Associazione, Istituto Internazionale del Papiro.

1996. Un contributo alla manifattura dei papiri: esperienze, teorie, nuove ricerche. In *Atti del II Convegno Nazionale di Egittologia e Papirologia, Siracusa, 1–3 Dicembre, 1995* (Quaderni dell'Istituto Internazionale del Papiro – Siracusa VII). Siracusa: Istituto Internazionale del Papiro, pp. 85–135.

Blackman, A.M. 1915a. *The Rock Tombs of Meir II: The Tomb-chapel of Senbi's Son Ukh-hotp (B, No. 2)*. London: EEF.

1915b. *The Rock Tombs of Meir III: The Tomb-chapel of Ukh-hotp Son of Ukh-hotp and Mersi (B, No. 4)*. London: EEF.

Borchardt, L. 1889. Bermerkungen zu den ägyptischen Handschriften des Berliner Museums. *ZÄS*, 27: 118–22.

Bradley, S. (ed.) 1993. *A Guide to the Storage, Exhibition and Handling of Antiquities, Ethnographia and Pictorial Art*. London: BMP.

Bridgeman, C.F. 1973. The radiography of museum objects. *Expedition* (University Museum, University of Pennsylvania), 15 iii: pp. 2–14.

Brissaud, P. 1993. Premières nouvelles de la xl^{e} campagne – 1993. *SFFT Newsletter: Bulletin périodique de la Société Française des Fouilles de Tanis* 13: pp. 1–10.

1994. Une campagne intermédiaire. *SFFT Newsletter: Bulletin périodique de la Société Française des Fouilles de Tanis* 14: pp. 1–6.

Bruce, J. 1790. *Travels to Discover the Source of the Nile, in the Years 1768, 1769, 1770, 1771, 1772 and 1773* (5 vols). Edinburgh: Printed by J. Ruthven for G.G.J. and J. Robinson. [Vol. 5 has title: *Appendix: Select Specimens of Natural History, Collected in Travels to Discover the Source of the Nile in Egypt, Arabia, Abyssinia, and Nubia*].

Budge, E.A.W. 1912. *The Greenfield Papyrus in the British Museum: the Funerary Papyrus of Princess Nesitanebtåshru*. London: BMP.

Bülow-Jacobsen, A. 1976. Principatus medio: Pliny, N.H. XIII, 72 sqq. *ZPE*, 20: 113–16.

1978. Papyrus in three layers? P.Haun. 1, inv. no. 5n. *CdE*, 53/105: pp. 158–61.

1986. A short bibliography of papyrus-making. In *Papyrus: Structure and Usage* (ed. M.L. Bierbrier). London: BMP, p. 90.

Caminos, R.A. 1986. Some comments on the reuse of papyrus. In *Papyrus: Structure and Usage* (ed. M.L. Bierbrier). London: BMP, pp. 43–61.

Carter, G.S. 1953. *The Papyrus Swamps of Uganda*. Cambridge: Heffer.

Černý, J. 1952. *Paper and Books in Ancient Egypt*. London: University College (also repr. Chicago: Ares. 1977).

Cockle, W.E.H. 1983. Restoring and conserving papyri. *Bulletin of the Institute of Classical Studies*, 30: 147–65.

Daniels, V. and Boyd, B. 1986. The yellowing of thymol in the display of prints. *Studies in Conservation*, 31: 156–8.

Daniels, V. and Rae, A. 1991. *Guidelines for the Prevention and Control of Bio-Deterioration*. British Museum, London, Conservation Research Section, Internal Report no. 1991/31.

Darby, W.J., Ghalioungui, P., and Grivetti, L. 1977. *Food: the Gift of Osiris* (2 vols). London: Academic Press.

Davies, G. 1922. *The Tomb of Puyemrê at Thebes*. New York: MMA.

De Bignicourt, M.-C. and Flieder, F. 1996. L'Analyse des papyrus. In *Preprints of ICOM Committee for Conservation, 11th Triennial Meeting, Edinburgh, Scotland, 1–6 September 1996*. London: James and James, pp. 488–93.

Delange, E., Grange, M., Kusko, B., and Ménei, E. 1990. Apparition de l'encre métallogallique en Égypte à partir de la Collection de Papyrus du Louvre. *RdE*, 41: 213–17.

Dixon, D.M. 1972. Masticatories in ancient Egypt. *Journal of Human Evolution*, 1: 433–49 (repr. in *Population Biology of the Ancient Egyptians*; ed. D.R.Brothwell and B.A. Chiarelli. London, Academic Press, 1973).

Donnithorne, A. 1986. The conservation of papyrus in the British Museum. In *Papyrus: Structure and Usage* (ed. M.L. Bierbrier). London: BMP, pp. 1–23.

Drenkhahn, R. 1982. Papyrus, -herstellung. *LÄ* 4: 667–70.

Ebers, G. (ed.) 1875. *Papyros Ebers: das hermetische Buch ber die Arzeneimittel der alten Ägypter in hieratische Schrift*. Leipzig: Engelmann.

Edge, M., Allen, N., Hayes, M., Riley, P., Horie, C. and Luc-Gardette, J. 1990. Mechanisms of deterioration in cellulose-nitrate base archival cinematographic film. *European Polymer Journal*, 26 vi: 623–30.

Emery, W.B. 1938. *Excavations at Saqqara: The Tomb of Hemaka*. Cairo: Government Press.

Fackelmann, M. 1985. *Restaurierung von Papyrus und anderen Schriftträgern aus Ägypten*. Studia amstelodamensia ad epigraphicam, ius antiquum et papyrologicam pertinentia 23. Zutphen: Terra.

Foskett, S. 1994. An investigation into the properties of isinglass. *Scottish Society for Conservation and Restoration (Edinburgh) Journal*, 5/iv: 11–14.

Gardiner, A.H. 1955. *The Ramesseum Papyri*. Oxford: Griffith Institute.

Germer, R. 1985. *Flora des pharaonischen Ägypten*. DAIK, Sonderschrift 14. Mainz am Rhein: von Zabern.

Gettens, R.J. and Stout, G.L. 1966. *Painting Materials, a Short Encyclopaedia*. New York: Dover Publications.

Gilberg, M. 1988. Antonio Piaggio and the conservation of the Herculaneum Papyri. In *Early Advances in Conservation* (Occasional Paper 65). London: BMP, pp. 1–6.

Goedicke, H. 1984. *Studies in the Hekanakhte Papers*. Baltimore MD: Halgo.

Greathouse, G.A. and Wessel, C.J. 1954. *Deterioration of Materials*. New York: Reinholt.

Green, L.R. 1992. Analysis of pigments from the Papyrus of Anhay, EA 10472 and yellow used for hieroglyphs on papyrus EA 9968. British Museum, London, Conservation Research Section, Internal Report No. 1992/10.

1993. Analysis of mounting medium of fragments of papyrus, EA 10770/5. British Museum, London, Conservation Research Section, Internal Report no. CA 1993/4.

1995. Recent analysis of pigments from Egyptian artefacts. In *Conservation in Ancient Egyptian Collections: Papers given at the Conference of the United Kingdom Institute for Conservation, Archaeology Section, and International Academic Projects, London, 20–21 July 1995*; eds. C.E. Brown, F. Macalister, and M.M. Wright. London: Archetype Publications, pp. 85–91.

Green, L. and Leach, B. 1993. Investigation of consolidants and facing adhesives for pigments on papyrus. British Museum Conservation Section, Internal Report, 1993/21.

Griffith, F.L. 1898. *Hieratic Papyri from Kahun and Gurob, Principally of the Middle Kingdom* (The Petrie Papyri). London: Quaritch.

Griffith, F.L. and Petrie, W.M.F. 1889. *Two Hieroglyphic Papyri from Tanis* (The EEF, Extra Memoir). London: Trübner and Co.

Griffith, F.L. and Thompson, H. 1904. *The Demotic Magical Papyrus of London and Leiden*. London: Grevel (also issued Oxford: Clarendon Press, 1921).

Harley, R.D. 1970. *Artists' Pigments c. 1600–1835*. London: Butterworths.

Hendriks, I.H.M. 1980. Pliny, *Historia Naturalis* XIII, 74–82 and the manufacture of papyrus. *ZPE*, 37: 121–36.

1984. More about the manufacture of papyrus. In *Atti del XVII Congresso Internazionale di Papirologia*. Napoli: Centro Internazionale per lo Studio dei Papiri Ercolanesi, vol. 1, pp. 31–7.

Hepper, F.N. and Reynolds, T. 1967. Papyrus and the adhesive properties in its cell sap in relation to paper making. *JEA*, 53: 156–7.

Hoffmann, F. 1994. Die Länge des P.Spiegelberg. In *Egitto e Vicino Oriente 17: Acta Demotica: Acts of the Fifth International Conference for Demotists, Pisa, 4th–8th September 1993* (ed. E. Bresciani). Pisa: Giardini, pp. 145–55.

Holwerda, D. 1982. Plinius über die Anfertigung von 'Charta'. *ZPE*, 45: 257–62.

James, T.G.H., 1962. *The Hekanakhte Papers and Other Early Middle Kingdom Documents* (Publications of the Metropolitan Museum of Art Egyptian Expedition 19). New York, MMA.

Koenen, L. 1996. The carbonized archive from Petra. *Journal of Roman Archaeology*, 9: 177–88.

Koestler, R. and Matthews, T. 1994. Application of anoxic treatment for insect control in manuscripts of the Library of Megisti Laura, Mount Athos, Greece. In *Environment et conservation de l'écrit, de l'image, et du son: Proceedings of the ARSAG Conference, Paris, 16–20 May 1994*. Paris: Association pour la Recherche Scientifique sur les Arts Graphiques, pp. 59–62.

Koob, S.P. 1982. The instability of cellulose nitrate adhesives. *The Conservator*, 6: 31–4.

Kowalik, R. and Sadurska, I. 1973. Microflora of papyrus from samples of Cairo Museums. *Studies in Conservation*, 18: 1–24.

Leach, B. 1975. Papyrus. Unpublished student thesis, Camberwell School of Art, London.

1995. Papyrus conservation at the British Museum. In *Il rotolo librario: fabbricazione, restauro, organizzazione interna* (ed. M. Capasso) (Papyrologica lupiensia 3). Lecce: Università degli Studi di Lecce, Dipartimento di Filologia Classica e Mediaevale, Centro di Studi Papirologici, pp. 137–61.

Leach, B. and Green, L. 1995. Removal of unsuitable linings from illustrated papyri: an investigation into suitable consolidants and facings. In *Conservation in Ancient Egyptian Collections: Papers given at the Conference of the United Kingdom Institute for Conservation, Archaeology Section, and International Academic Projects, London, 20–21 July 1995* (eds. C.E. Brown, F. Macalister and M.M. Wright). London: Archetype Publications, pp. 29–35.

Levring, C.T.C., Hoppe, H.A., and Schmid, O.J. 1969. *Marine Algae: A Survey of Research and Utilisation*. Hamburg: Cram DeGruyter.

Lewis, N. 1974. *Papyrus in Classical Antiquity*. Oxford: Clarendon Press.

1981. Open letter to I.H.M. Hendriks. *ZPE*, 42: 293–4.

1989. *Papyrus in Classical Antiquity: a Supplement*. Papyrologica bruxellensia 23. Bruxelles: Fondation Egyptologique Reine Elisabeth.

Linnaeus, C. 1753. *Species plantarum* , 2 vols. Holmiae: Impensis Larentii Salvii.

Lucas, A. 1902. *A Preliminary Investigation of the Soil and Water of the Fayum Province*. Cairo: Public Works Ministry, Survey Department.

1908. *The Chemistry of the River Nile* (Survey Department Paper 7). Cairo: Ministry of Finance.

1932. *Antiquities: their Restoration and Preservation*. London: Edward Arnold.

1962. *Ancient Egyptian Materials and Industries*. 4th edn., rev. J.R. Harris. London: Edward Arnold.

Manniche, L. 1989. *An Ancient Egyptian Herbal*. London: BMP.

Mayhoff, C. (ed.) 1909. *C. Plini Secundi Naturalis historiae libri xxxvii* . . . II. Leipzig: Teubner (repr. Stuttgart, 1967).

Menci, G. 1988. Fabbricazione, uso e restauro antico del papiro: tre note in margine a Plinio, NH XIII 74–82. In *Proceedings of the XVIII International Congress of Papyrology, Athens, 25–31 May 1986*. Athens: Greek Papyrological Society, vol. 2, pp. 497–504.

Ménei, E. 1990. Le Papyrus: conservation, restauration, 2 vols. Unpublished thesis for the Diploma of the Institut Français de Restauration des Oeuvres d'Art, Paris (vol. 2 entitled: 4 Dossiers de restauration).

1993. Remarques sur la fabrication des rouleux de papyrus: precisions sur la formation et l'assemblage des feuillets. *RdE*, 44: 185–8.

1995. Les papyrus carbonisés de Tanis: première étude en vue de la mise au point de méthodes de conservation. *Bulletin de la Société française des Fouilles de Tanis*, 9: 39–50.

Metcalfe, C.R. (ed.) 1971. *Anatomy of the Monocotyledons, V: Cyperacae*. Oxford: Clarendon Press.

Nielsen. I. 1985. Papyrus structure, manufacture and deterioration. Doctoral dissertation. School of Conservation, Copenhagen.

Owen, A. and Danzing, R. 1993. The history and treatment of the papyrus collection at the Brooklyn Museum. *Journal of the American Institute of Conservation, Book and Paper Group*, 1993: 36–43.

Parkinson, R. and Quirke, S. 1995. *Papyrus* (Egyptian Bookshelf series). London: BMP.

Pattie, T.S. and Turner, E.G. 1974. *The Written Word on Papyrus: [Catalogue of] an Exhibition held in the British Museum, 30 July–27 October 1974*. London: BMP.

Petrie, W.M.F. 1885. *Tanis, Part I, 1883–4*. London: EEF.

1904. *Methods and Aims in Archaeology*. London: MacMillan.

Plenderleith, H.J. and Werner, A.E.A. 1971. *The Conservation of Antiquities and Works of Art*, 2nd edn. London: OUP.

Pliny (the elder): see Mayhoff, C. 1909 and Rackham, H. 1968.

Quibell, J.E. 1898. *The Ramesseum*. London: Egyptian Research Account.

Quirke, S.G.J. 1993. *Owners of Funerary Papyri in the British Museum* (Occasional Paper 92). London: BMP.

1995. An early conservation register of work undertaken on Egyptian papyri for the British Museum 1838–1842. In *Il* *rotolo librario: fabbricazione, restauro, organizzazione interna* (ed. M. Capasso). Lecce: Università degli Studi di Lecce, Dipartimento di Filologia Classica e Mediaevale, Centro di Studi Papirologici, pp. 163–86.

Rackham, H. (transl. and ed.) 1968. *Pliny (the Elder): Natural History*. IV 2nd edn. Loeb Classical Library. Cambridge MA: Harvard University Press.

Ragab, H. 1980a. A new theory brought forward about the adhesion of papyrus strips. *Institute of Paper Historians: Yearbook*, 1980: 113–24.

1980b. *Le Papyrus*. Cairo: Dr Ragab Papyrus Institute.

1988. The quality of recently manufactured papyrus. In *Proceedings of the XVIII International Congress of Papyrology, Athens, 25–31 May 1986*. Athens: Greek Papyrological Society, vol. 2, pp. 513–23.

Rathgen, F. 1905. *The Preservation of Antiquities*. Cambridge: CUP.

Raven, M.J. 1982. *Papyrus, van bies tot boekrol, met een bloemlezing uit de Leidse papyrusverzameling*. Zutphen: Terra.

Rea, J.R. 1984. *The Oxyrhynchus Papyri* LI. Graeco-Roman Memoirs 71. London: EES.

Reed, R. 1972. *Ancient Skins, Parchments, and Leathers*. London and New York: Seminar Press.

Robins, G. and Shute, C. 1987. *The Rhind Mathematical Papyrus: An Ancient Egyptian Text*. London: BMP.

Robinson, J.M. 1984. Introduction. In *The Facsimile Edition of the Nag Hammadi Codices, Introduction*. Leiden: Brill, pp. 1–102.

Roland, J.C. and Mosiniak, M. 1987. Sur l'ultrastructure et la cytochimie des parois cellulaires du papyrus en relation avec la malléabilité, la resistance et l'autoadhésivité des interfaces dans le support d'écriture. *Institute of Paper Historians: Information*, 1987: 133–8.

Rupprecht, H.A. 1994. *Kleine Einführung in die Papyruskunde*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Seider, D. 1976. Pliny on the manufacture of paste for papyrus. *ZPE*, 22: 74.

Shorter, A.W. 1933. Manuscript note entitled: 9912, treatment of in laboratory, to improve legibility. Archives of the Dept. of Scientific Research, BM, London.

Skeat, T.C. 1982. The length of the standard papyrus roll and the cost-advantage of the codex. *ZPE*, 45: 169–75.

Spiegelberg, W. 1917. *Der ägyptische Mythus vom Sonnenauge (der Papyrus der Tierfabeln Ä 'Kufi'), nach dem Leidener Demotischen Papyrus I 384*. Strassburg: Schultz.

Sturman, S. 1987. Investigations into the manufacture and identification of papyrus. In *Recent Advances in the Conservation and Analysis of Artefacts: University of London, Institute of Archaeology Jubilee Conference, 1987*. London: Summer Schools Press, pp. 265–7.

Täckholm, V. and Drar, M. 1950. *Flora of Egypt* II. Bulletin of the Faculty of Science 28. Cairo: Fouad I University Press.

Tait, W.J. 1975. The physical characteristics of the [Saqqara Demotic] papyri. In *Proceedings of the XIV International Congress of Papyrologists, Oxford, 24–31 July 1974* (eds. P.J. Parsons, J.R. Rea, E.G. Turner and R.A. Coles). London: EES, pp. 262–4.

1977. *Papyri from Tebtunis in Egyptian and in Greek*. Texts from Excavations 3. London: EES.

1986. Guidelines and borders in Demotic papyri. In *Papyrus: Structure and Usage* (ed. M.L. Bierbrier). London: BMP, pp. 63–89.

1988. Rush and reed: the pens of Egyptian and Greek scribes. In *Proceedings of the XVIII International Congress of Papyrology, Athens, 25–31 May 1986* (ed. B.G. Mandilaras). Athens: Greek Papyrological Society, vol. 2, pp. 477–81.

1991a. P. Carlsberg 207: Two columns of a Setna-text. In *Demotic Texts from the Collection* (ed. P.J. Frandsen). CNI Publications 15; Carlsberg Papyri 1; Copenhagen: Museum Tusculanum Press, pp. 19–46.

1991b. P. Carlsberg 230: eleven fragments from a demotic herbal. In *Demotic Texts from the Collection* (ed. P.J. Frandsen). CNI Publications 15; Carlsberg Papyri 1; Copenhagen: Museum Tusculanum Press, pp. 47–92.

Thatcher, R.W. 1921. *The Chemistry of Plant Life*. New York: McGraw-Hill.

Thickett, D. 1992. Analysis of adhesive from Papyrus EA 10754/C. British Museum, London, Conservation Research Section, Internal Report No. CA 1992/54.

Thomson, G. 1986. *The Museum Environment*. 2nd edn. London: Butterworths, in association with the International Institute for Conservation of Historic and Artistic Works (also repr. (paperback edn.) Butterworth-Heinemann, 1994).

Turner, E.G. 1968. *Greek Papyri: an Introduction*. Oxford: Clarendon Press.

1978. The terms recto and verso: the anatomy of the papyrus roll. In *Actes du XV^{e} Congrès International de Papyrologie* I. Papyrologica Bruxellensia 16. Brussels: Fondation Egyptologique Reine Elisabeth.

1980. An open letter to Dr I. Hendriks. *ZPE*, 39: 113–4.

Walker, A. 1988. The use of a facing technique in the treatment of fragile papyri. In *Conservation of Ancient Egyptian Materials: Preprints* (eds. S.C. Watkins and C.E. Brown). Bristol: UKIC Archaeology Section, pp. 51–3.

Wallert, A. 1989. The reconstruction of papyrus manufacture: a preliminary investigation. *Studies in Conservation*, 34: 1–8.

Watrous, J. 1967. *The Craft of Old-Master Drawings*. Wisconsin: University of Wisconsin Press.

Weber, M. 1969. Beiträge zur Kenntnis des Schrift- und Buchwesens der alten Ägypten. Inaugural-Dissertation zur Erlangung des Doktorgrades der Philsophischen Fakultät der Universität zu Köln.

Weidemann, H.G. and Bayer, G. 1983. Papyrus, the paper of ancient Egypt. *Analytical Chemistry*, 55 (12): 1220A–1230A.

Wendelbo, Ø. 1975. The freeing of papyri from cartonnage. *Restaurator, International Journal for the Preservation of Library and Archival Material*, 2: 41–52.

Wild, H. 1953. *Le tombeau de Ti, II: La chapelle (première partie)*. Cairo: IFAO.

Winter, J. 1984. Natural adhesives in East Asian paintings. In *Adhesives and Consolidants, IIC, Preprints of the Contributions to the Paris Congress, 2–8 September 1984* (eds. N.S. Bromelle, E.M. Pye, P. Smith and G. Thomson). London: International Institute for Conservation of Historic and Artistic works, pp. 117–20.

Woenig, F. 1886. *Die Pflanzen im Alten Aegypten*. Leipzig: Friedrich.

Wright, M. 1980. The extraction of papyri from cartonnage. Thesis. Institute of Archaeology, University College London.

10. Basketry

WILLEMINA Z. WENDRICH

Introduction

Making baskets has a long tradition throughout the world. In Egypt the traditional technology shows clear parallels with the ancient basketry. Watching a twentieth-century basket-maker helps us to realise that artefacts and assemblages were produced and used by actual people. On the other hand, present-day basketry is not an exact copy of ancient Egyptian basketry. Through the ages basketry techniques have shown a clear development and a definite local variety. A detailed description of techniques employed in making baskets and mats is vital for understanding these developments.

In this chapter the section on materials, tools and techniques gives a general introduction to the materials and technology. Some attention is then given, in the section on representations and imitations, to skeuomorphs of baskets in other materials and the way in which baskets and mats are depicted in tomb paintings. A deeper insight will be given in classification criteria of techniques in the section dealing with classification and terminology and the relations between technique, material, shape and function will be surveyed in the section on function. Some remarks are made on the producers and users of basketry. With the subsequent discard and preservation of basketry objects, the cycle is complete. First of all, however, it is necessary to give a definition of basketry.

Many authors have tried to define what basketry is, only to find that they stumble upon discrepancies between a consistent definition and that which 'common sense' tells them to be basketry (Mason 1904: 193; Lehman 1907: 2; Vogt 1937: 2; Lucas 1962: 128; Leroi-Gourhan 1971: 268, 272; Balfet 1952: 260; Crowfoot 1954: 414; Emery 1980: 210; Forbes 1964: 178; Seiler-Baldinger 1979: 4; Adovasio 1977: 1; Larsen and Freudheim 1986: 38). Basketry and matting are often described as 'textile techniques', but while a cloth and a basket are clearly distinguishable, there is a grey area of objects which can be arbitrarily considered to be made in a textile or a basketry technique. Examples of criteria used in the discussion are the use of tools (looms in various degrees of complexity), the type of raw materials, the shape or the function of the objects. A more extensive discussion of definition, classification and other aspects occurring in this chapter can be found in *The World According to Basketry* (Wendrich, forthcoming).

In this chapter basketry (which includes baskets, bags and mats; sieves, pot stands and nets; brushes and brooms; boxes and coffins; furniture and sandals) is defined as: 'objects made of plant parts of limited length often with a shape specific to that particular plant part'. In other words: what makes basketry techniques fundamentally different from textile techniques is the fact that the basket-maker has to make amends for the often irregular shape of the raw materials and the short strands he or she is working with. Textiles, on the other hand, are made of long yarns, which in theory are uniform in size along the entire length. Mats woven or twined out of string are thus defined as textiles, but nevertheless they will be considered in this chapter. Making a distinction between 'textile' and 'basketry' techniques helps to consider the criteria important for capturing the 'basketness' of objects. Once aware of these criteria, we no longer have to maintain a strict separation. Since string mats are generally considered more 'basket' than 'textile' (here the arbitrariness, not of the definition, but of common sense, becomes clear) they have been included in this chapter.

Basketry materials, techniques, and tools

The term *technology* refers to the knowledge and craftmenship of making basketry, while *basketry technique* is used in a more limited sense to indicate the different interactions of strands making up baskets, mats, bags, nets, brooms or sandals.

Materials

The number of materials from which baskets and mats are made is quite limited, but not quite as limited as the designation 'reed' (which tends to be applied to baskets in publications), might suggest. Very few excavators have made the effort to identify the materials used, but nevertheless have not refrained from publishing ill-founded specifications. In many cases it is impossible to discern the different species macroscopically and a microscopic study of the cross-section or the epiderm patterns to identify plant parts, and the shape and size to identify fibres, is necessary. The work of Greiss (1957) resulted in the most important publications on the subject of plant materials used for basketry. The specification, not only of the plant species, but also of the plant part is of great importance. Thus the term 'palm fibre' which is frequently encountered in the literature, might refer to date-palm leaf, leaf-sheath fibre of the date palm, shredded fruit stem of the date palm, or to dom-palm leaf.

Palm leaf and grass are by far the most important materials for making baskets and mats. The leaves of two palm species are used: the side-leaflets of the large feather-shaped leaves of the date palm (*Phoenix dactylifera*), and strips of the fan-shaped leaves of the dom palm (*Hyphaene thebaica*). A third indigenous palm species, *Medemia argun*, seems not to have been used for basket-making, note also that for Latin names Germer (1985) is followed; alternative names and the extension indicating the botanist who named the plant can also be found in Germer. The long rigid midribs of the date-palm leaves are used for making roofs, doors and screens. At present there is an entire industry making the so-called *gereed* into crates, cages and furniture, but this does not occur until the late Roman period. Similarly, the fibrous leaf-sheaths of the date palm, the most important material for rope-making at present, were not used widely until the Greco-Roman period. In the Predynastic and Pharaonic periods, grass was used instead, being employed widely, not only for making rope, but also for the bundles and strands in twined matting and the bundles in coiled basketry. These tall tough grasses are often referred to as *halfa*, an Arabic term used for both the species *Desmostachya bipinnata* and *Imperata cylindrica*.

Among the less common materials used for making basketry are reeds, sedges and rushes. The culms of reeds are used for matting and making stools, tables and screens. Both the culms of ordinary reed *Phragmites communis* and a tall bamboo-like reed, *Arundo donax* have been identified (Greiss 1957: 148–9), but the former occurs much more often than the latter. *Arundo donax* is nowadays used for making shopping baskets which are light yellow and have a glossy appearance. These baskets, made of the split culms in a stake-and-strand technique, are a relatively recent development. Not only the culms of *Phragmites communis*, the common reed, are used, but also the leaves, identified by Greiss in a matting fragment from el-Omari (Greiss 1957: 107). The leaves of a third type of reed, *Saccharum spontaneum* are used also for making soft mats (*cf.* Greiss 1957: 149, who uses the indication *Saccharum biflorum*) this reed should not be confused with sugar cane, which has been introduced and cultivated in Egypt in modern times.

There is a wide variety of sedges used for making basketry and matting, the best-known being *Cyperus papyrus*, of which the thick triangular culm or just strips of the epiderm are employed in making baskets, boxes, coffins, simple furniture and sandals. Other species, mostly identified in matting, are: *Cyperus alopecuroides, C. articulatus, C. conglomeratus* and *C. schimperianus*. Sedges have long, leafless stems which are quite spongy inside, thus making them eminently suitable for making mats.

Rushes are less flexible than sedges and were used from the Predynastic period through to the present for making floor mats. The split culms are also used in coiled basketry. In the Roman period a whole new set of techniques were being executed mainly with rushes. The species occurring in Egypt are *Juncus rigidus* and *J. acutus*.

The shrub-like plant *Ceruana pratensis* was used mainly in the Early Dynastic period for making basketry coffins and brushes. Other materials, used especially in the production of mats, furniture webbing and nets, are yarn made of flax (*Linum usitatissimum*) or, from the Greco-Roman period onwards, cotton (*Gossypium species*). For a list of identified applications of each plant species as known at the time of publication see Täckholm *et al.* (1941–69).

The preparation of the raw materials varies from hardly any (*Ceruana pratensis*, leaf-sheath fibres of the date palm, rushes, sedges and grasses), minimal (palm leaf which is cut into strips, soaked and sometimes boiled with dyes) to extensive (flax and cotton).

Techniques

Surveying basket-making in the different periods of Egyptian history involves discerning different techniques, based on basketry found in museum collections, in the literature, and items recorded on site, at excavations of widely varying date. Artefacts in museum collections are often badly provenanced. It is hazardous to draw conclusions from descriptions of the techniques and materials in the literature, because the terminology used is often inconsistent and the identification of the raw materials inaccurate. The terms *plaiting* or *weaving*, for instance, are often used as synonyms for basket-making and may refer to a number of different techniques which bear no relation to plaiting or weaving in the technical sense of the word, e.g. 'straw plaiting' for what seems to be a twined grass mat, 'a small plaited basket' describing twined bags made of grass string, 'woven grass platters or lids' which are in fact made in the coiling technique (respectively: Petrie *et al.* 1913: 13; Bonioanni 1987: 112 and Caton-Thompson and Gardner 1934, caption with pl. xxviii). Other indications such as 'an oval basket of the usual kind' (Peet and Woolley 1923: 74) are not misleading, but just uninformative, although the photographs were clear enough to reveal that the baskets usually found in the Amarna Workmen's Village were coiled baskets. Other authors are much more trustworthy. Carter, for instance, gives quite good, although not very detailed, descriptions of the baskets in the tomb of Tutankhamun (cited by Reeves 1990: 204).

There are nine major basketry techniques in Egypt: coiling, weaving, twining, continuous plaiting, sewn plaits, looping around a core, looping, piercing and binding (see Fig.10.1). Knotted string is often used in making baskets, mats or brooms (for details on rope and knotting see Wendrich 1996). More will be said under **terminology** about the distinction between the different techniques, the classifications and the terminology used, but for the moment a concise description suffices.

Coiling is a technique in which a bundle of material is fixed in a coil, by wrapping the bundle with a strand which holds the bundle in place (Fig. 10.1a). The same technique is used for sandals, but then the term 'coiling' is, strictly speaking, not appropriate. Sandals were not made by laying out one bundle in a coil, but rather by fastening a number of parallel bundles with a wrapping strand.

Weaving is a technique in which a number of strands, usually fixed in a loom, are made into a fabric by interlacing them with crossing strands (Fig. 10.1b).

Twining is a technique in which a number of parallel bundles are held in place by fixing them with two strands which twist around the bundles and around each other (Fig. 10.1c).

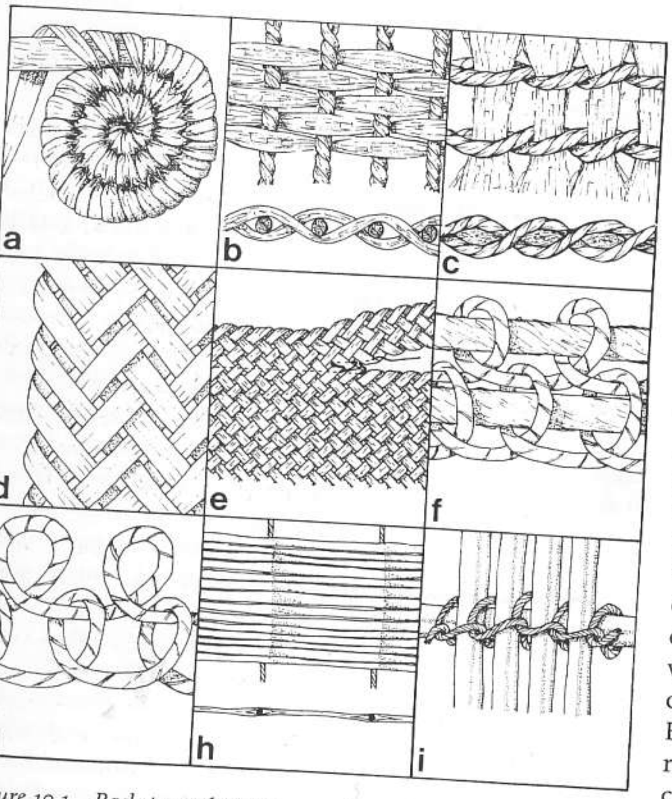


Figure 10.1 Basketry techniques occurring in Egypt: (a) coiling, (b) weaving, (c) twining, (d) plaiting, (e) sewn plaits, (f) looping around a core (g) looping/knotless netting, (h) piercing/sewing, (i) binding.

Plaiting is a technique in which a number of strands, which have not been fixed, are made into a fabric by interlacing them with crossing strands. Usually the strands make a sharp turn at the edge of the fabric and are folded back into the fabric (Fig. 10.1d).

Sewn-plaits technique involves two stages: first long strips are plaited, which are then sewn into a seemingly ongoing fabric (Fig. 10.1e). For rectangular mats a number of strips are fastened parallel to each other, baskets are sewn from one spiralling strip.

Looping (Fig. 10.1g) is a knotless netting technique by linking a row of loops to the previous row. Mats or baskets are made by linking the loops around bundles of grass, which is referred to as looping around a core (Fig. 10.1f).

Piercing involves rigid stems which are connected by yarns or sticks pushed through pierced holes. A similar technique, in which a row of parallel stems or strings are connected, is a form of piercing with needle and thread and therefore perhaps better indicated as 'sewing' (Fig. 10.1h).

Binding involves a number of strands or sticks which are layed out either crosswise or in a coil and fastened with a separate strand (Fig. 10.1i).

Within all these techniques a large number of varieties occur in the pattern or in the spacing. This variation is determined, for instance, by the materials used, by the function of the object, or by local traditions.

Although the continuity in basketry techniques is striking, there are also changes and differences in regional traditions. Although basketry is known from very early periods – and despite the fact that the preservation of organic materials in Egypt, and especially in the desert sites, is unsurpassed – there are no finds pre-dating the Neolithic period. The earliest baskets found are by no means new 'inventions' of mankind. The fine craftmanship shows that the knowledge of basket-making is much older and it is tantalising that we do not know anything about Palaeolithic basketry.

Finds show that by the Neolithic most of the techniques which came to be used throughout the Pharaonic period were already fully developed. In the Fayum A culture (5500 BC) coiling was the most important technique for making containers. Coarse-coiled grain silos (the bundles of grass fastened with winders which, most probably, consisted of palm leaf) were buried in the ground (Caton Thompson and Gardner 1934: pl. xxvii). The winders were lost in most cases, which led Caton Thompson originally to the conclusion that the grain-silos were pits 'lined with coiled wheat straw' (Caton-Thompson 1926: 314). Finely made coiled containers occurred in the settlement (Fig. 10.2). Badarian basketry of roughly the same period, but in the region of Upper Egypt also consisted entirely of coiled containers. The matting was woven, twined and perhaps bound (Brunton and Caton-Thompson 1928: pls. lx, lxi).

The Naqada I period shows a continuity of the basketry techniques. At Merimda (5000–4500 BC) no household

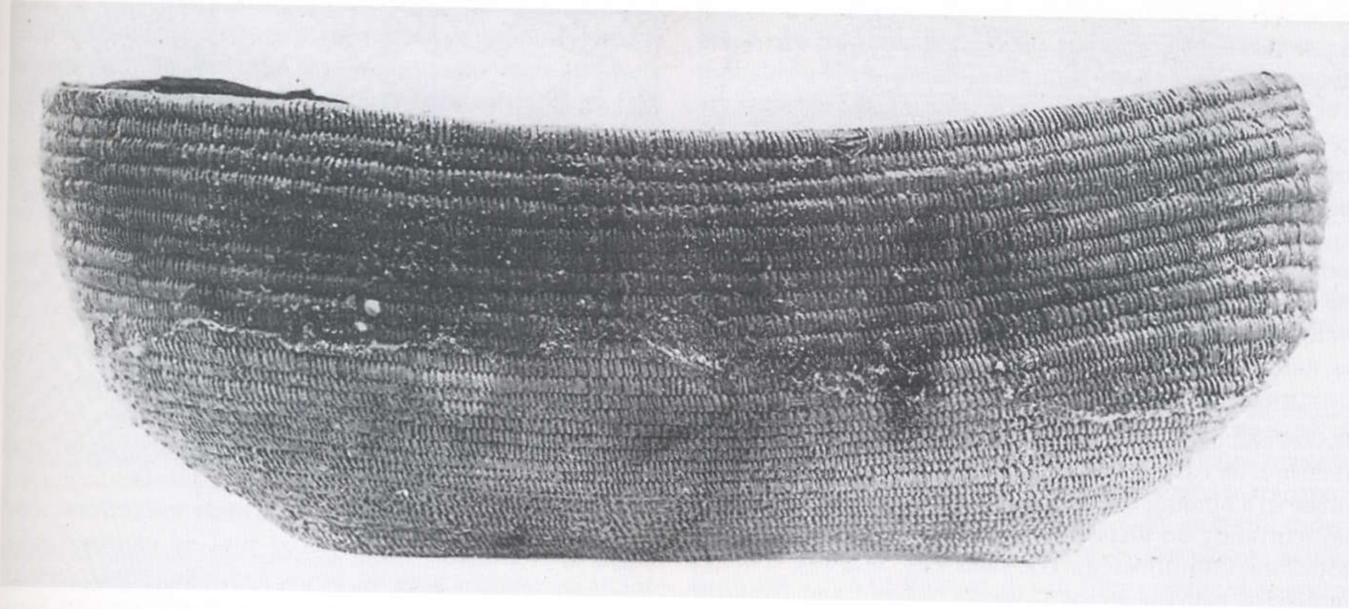


Figure 10.2 Neolithic coiled basket from the Fayum.

basketry was found, but the basketry and matting techniques incorporated in the architecture show the same techniques as the earlier periods. The descriptions and photographs published in Junker's (1929) preliminary reports leave some doubt as to the exact technique and materials, but the large grain silos, buried in the ground were probably made in the coiled technique. The identification of the bundle material as *Arundo donax*, a stiff bamboo-like reed, is puzzling, however, because this species cannot be bent into coils as small as those visible in the photographs (Junker 1929: pl. Vb). Greiss apparently doubted this identification too, because he states that confirmation of the identifiation is required (Greiss 1957: 148–9). Although the text seems to refer to the culms, it is possible that only the leaves of this large reed species were used for making silos. It seems likely that the silos were covered with coiled lids (Junker 1930: 44, pl. IIIa). Housing seems to have been made largely of oval pits built up with matting screens, of which Junker found remains in 1932 (Junker 1932: 52, 53, pl. IIIb). For this type of screen, made in a binding technique, both palm fronds and reeds are eminently suitable. The culms are laid out parallel, or put vertically in the soft mud-plaster and are made into a coherent wall by tying them to two or more levels of horizontal culms, thus forming cross connections in the middle and at the top of the vertical, closely spaced culms (Fig. 10.1i).

Many basketry finds in museum collections, which are supposedly from the Predynastic period, show extremely fine workmanship that is unsurpassed in any later period. A very fine matting fragment, allegedly from the Predynastic period and presently on display in the Egyptian Museum in Cairo (provenance and date are unknown, no registry number is visible, but the fragment is on display in the Predynastic section, room R/U 53, together with the twined fragment JE54546), is made in the pierced technique: culms of rushes have been pierced and a flax yarn has been pulled through the parallel stems (*cf.* Fig. 10.1h). From the same general period dates an extremely finely made twined matting fragment made of grass. The rows of twining, in S-direction, are widely spaced (five centimetres apart). Fragments of coiled basketry from Maadi show an equally fine workmanship (Rizkana and Seeher 1989: pl. VI,1).

Most basketry and matting remains from the Predynastic and Early Dynastic periods are, however, from funerary contexts. In many older publications mat-burials are listed, unfortunately seldom specifying the materials and techniques used (e.g. Petrie and Quibell 1896: 15, 23, 25, 27). In many cases culms of reeds or sedges seem to have been used, which are connected with supple strands by either binding or twining (e.g. Emery 1958: pl. 121b and 122a, Greiss 1957: 107).

The walls of a funerary chapel in the First-Dynasty tomb 3505 at Saqqara (Emery 1958: 10, pl. 26), were not made of reeds, but of much more flexible grass matting, in which bundles of grass were made into a fabric by widely spaced rows of twining. Since S3505 was thought to be an élite tomb, the occurrence of simple twined grass matting as wall cover for the chapel is surprising.

Via the sequence dates of Petrie a number of basketry techniques, also from a funerary context at Tarkhan, occurring in the Early Dynastic period, can be quite closely dated (Petrie *et al.*, 1913: 6, 23–4). Apart from the twined and bound reed mats, two techniques are commonly found among the burials at Tarkhan, which did not occur in the Fayum, Badari and Merimda: bound coffins and woven bed matting. From grave 1004 came a 'basket burial'. It was

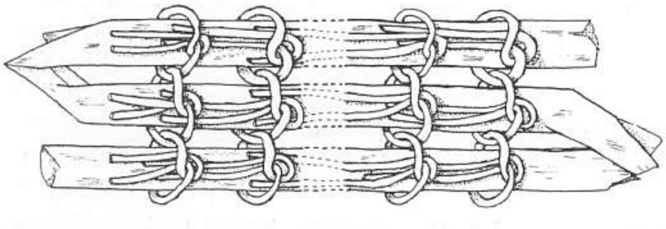


Figure 10.3 Construction drawing of the binding technique of the basketry coffin found at Tarkhan (displayed in room R/U 11 of the Egyptian Museum, Cairo, unnumbered).

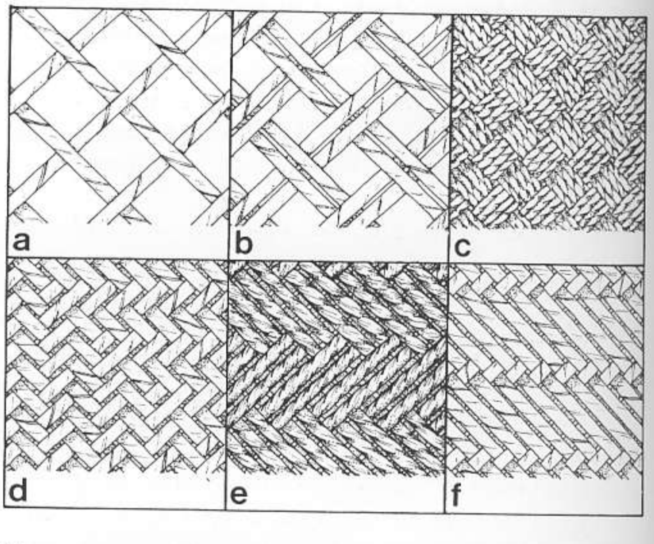


Figure 10.4 Weaving patterns occurring most frequently in ancient Egyptian furniture matting. Tabbies: (a) \1/1\\1 open, S-twisted dom-palm leaf; (b) \2/2\\2 open, S-twisted dom-palm leaf; (c) \4/4\\4 closed, Z-spun flax yarn. Twills: (d) \2/2\\1 closed, S-twisted dom-palm leaf, with pattern shift; (e) \6/6\\2 closed, zS2 grass string, with pattern shift; (f) \1/6\\1 closed, S-twisted dom-palm leaf, with pattern shift.

placed in a recess, bricked across the mouth. (. . .) The basket and body were carried intact to the Cairo Museum' (Petrie *et al.* 1913: 24, pl. xxvi). The oval basketry coffin was made in a binding technique in three parts: base, sides and lid (currently on display in room R/U 11 of the Egyptain Museum, unnumbered). The sides were made by coiling a bundle of papyrus stems (*Cyperus papyrus*) and tying the next row to the lower coil with an irregular, but flexible twig of *Ceruana pratensis*. Each twig was used to tie one half knot of which the ends were held in place by the next knotted twig (Fig. 10.3). The rectangular base and lid of the coffin were made by folding the papyrus bundle sharply at the edge of the rectangle and knotting each bundle to the previous one with the flexible twigs. A First-Dynasty basketry coffin from Helwan was made completely out of bundles of *Ceruana pratensis*, tied with twigs of the same material (Greiss 1957: 108). Coarse First-Dynasty basketry was made by linking loops of, probably, palm leaf around a coiled bundle of grass (Emery 1954: 66, pl. 32).

Wooden bed-frames were woven with matting in a wide variety of weaving patterns. In the First-Dynasty cemetery of Tarkhan, twenty-eight beds were found which were divided into eight different types on the basis of the bed matting and the connection between the matting and the bed (Engelbach in Petrie *et al.* 1913: 23–4). The bed matting was made of twisted rushes, palm leaf or thongs of leather. The weaving patterns of this early bed matting were as varied and intricate as those known from the New Kingdom or later. The photographs in the 1913 publication show two different patterns: a tabby with four parallel strands, made with S-twisted strands ('rushes' according to Engelbach's description but the appearance is more that of palm leaf) and, secondly, a twill pattern woven with two parallel sZ2 strings made of unknown material, probably grass or papyrus rind. The make-up of rope is given in a formula which indicates the direction of spin, ply and cable, as well as the number of strands involved; thus sZ2 string is made of two strands, plied in Z-direction, each of which has been spun in S-direction (see Chapter 11, this volume and Wendrich 1991: 30–2). Figure 10.4 shows a number of tabby- and twill-weaving patterns that occur most frequently in ancient Egypt. Tabbies are patterns in which the shift in the pattern is the same as the number of strands, twills have a shift which is smaller than the number of strands, which gives the pattern an oblique appearance. Both weaving and plaiting patterns can be indicated with a formula: \1/1\\1 is the pattern 'under 1 – over 1 with a shift of one' (a simple tabby). Examples of twill patterns are: \2/2\\1 'under 2 – over 2 with a shift of one', \6/6\\2 'under 6 – over 6 with a shift of two'. An asymmetrical twill pattern is for instance \1/6\\1 'under 1 – over 6 with a shift of one (see Fig. 10.4 and Wendrich 1991: 65–6). Also from a First-Dynasty grave was a mat, probably woven of grass culms and leaves. The excavators published a photograph of the old mat together with 'a modern Egyptian *hasyrah* mat, to show the exact similarity of the work, entirely unchanged in style during 7,000 years' (Petrie *et al.* 1913: 25). The only difference seems to be the material used: rushes rather than grass. Although the appearance of the mats is strikingly similar, a study of technical details, such as the selvedge and finishing off of the bundles could have given valuable information, since it is in such details that the exact production sequence can be inferred and local traditions may become apparent. The photographs and descriptions, unfortunately, do not register such details.

Old Kingdom basketry shows the same general range of techniques as the earlier material: all baskets are made in the coiled technique, mats are woven or twined, furniture matting is woven in the wooden frames of beds, chairs and stools. Twined bags made of string, many examples of which date to the New Kingdom, were also evidently very common during the Old Kingdom, judging from their frequent depiction in tomb paintings (see imitations

p. 263). No actual examples have been published, but just as the coiled baskets were present in large quantities inside every house, these twined bags were used outside and were the Old Kingdom equivalent of our plastic carrier bags. Like these bags, fish traps are depicted in Old Kingdom tomb paintings but these have not been found in any archaeological context.

The binding technique of the Early Dynastic coffins is not found in the Old Kingdom, and nor is the Predynastic pierced matting technique, which seems to be a unique find, not occurring in the Dynastic period or later. Although the sewn plaits technique does not occur until the Greco-Roman period, continous plaiting seems to have developed from weaving during the Old Kingdom, but this technique is not widespread until the Greco-Roman period either. The awnings of Khufu's funerary boat (from his pyramid complex at Giza) are plaited in a twill pattern (\3/3\\1), out of what seem to be four parallel rows of single culms of rushes. Large quantities of this matting were found in the boat pit, and have been stored in a nearby room. The fragment on display in the boat museum at Giza is bordered by two side edges and has a total width of 60 cm. The original length is not known, because the fragment has no top or bottom edges. It is not clear if the width of 60 cm was the standard, so that a number of strips of this width were fastened parallel to each other in order to cover the wooden palisade under which the rowers were seated.

Most surviving Egyptian basketry from archaeological contexts is of New Kingdom date, and especially the late Eighteenth Dynasty onwards, both from tombs and settlements. The coiled technique was used to make all of the household basketry found during excavations in the Workmen's Village at Amarna in 1921–2 and in 1985–6.

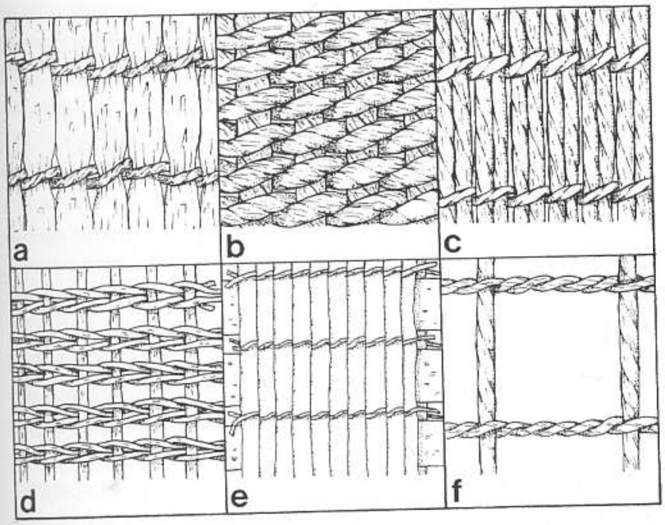


Figure 10.5 Examples of twined basketry: (a) openly twined matting of string around bundles of grass; (b) closely twined matting (made into bags); (c) openly twined seed bag; (d) openly twined sieve grid; (e) twined three-system basket; (f) openly twined carrier net

Peet and Woolley (1923: pl. XXI/4) published one photograph of a basket in sewn plaits technique. This basket was probably a later contamination, its date either contemporary with the late burials, or perhaps even with the excavations, because the workmen used the same type of basketry to move the sand. The fact that the basket seems to have been made of date-palm leaf, while all Eighteenth-Dynasty baskets found at Amarna were made of dom-palm leaf, or in rare cases papyrus, strengthens this suspicion. During the excavations directed by Barry Kemp in the 1980s no plaited basketry was found (*cf.* Wendrich 1989). The mats from Amarna were all made of grass, either woven or twined. These mats were used as floor mats, sleeping mats and awnings, while open twined mats were re-used as roofing material (Fig. 10.5a). Closely twined bags, made of dom palm leaf and grass string possibly served to transport heavy weights on donkey back (Fig. 10.5b), as is still widely done in Egypt at present. These days the closely twined bags are made of the leaf-sheath fibres of the date palm, however. The brushes made of grass or dom-palm leaf were well worn. In general there is a striking absence of date-palm leaf at the Amarna Workmen's Village. Fragments of twined seed bags were found as well as sieves (Figs 10.5c and 10.5d, *cf.* Peet and Woolley 1923: pls. XX/4, XXII/2; note that Fig 10.5d represents a different form of twined grid from that in the sieve depicted in Peet and Woolley 1923).

The basketry of Deir el-Medina has been published by Gourlay (1981); illustrated with clear drawings, a large number of different techniques are presented and classified. Gourlay was handicapped by the low standard of excavation and registration of Bruyère's excavations and has refrained from speculation on the date of the finds. The result is that basketry from the New Kingdom and the Ptolemaic period are presented together and, given the technical innovations in the Greco-Roman period, this limits the usefulness of the publication, as does the fact that no identification of the raw materials is given. Thus it is not known if twined baskets in a three-system technique (Fig. 10.5e) should be dated to the New Kingdom or much later. By far the largest group of baskets used in house-contexts at Deir el-Medina are coiled baskets in a wide range of sizes and shapes. Most frequent are round and oval baskets with conical lids.

There are also many surviving baskets from funerary contexts, for instance from the tombs of Queen Meritamun (DB358), Ramose and Hatnefer, Kha (TT8) and Tutankhamun (KV62). Three very large coiled baskets contained Queen Meritamun's wardrobe. The coiling has a regular appearance because the stitch just picks up the winder covering the previous row, rather than stitching into the previous bundle (*cf.* Fig. 10.6a and b). The baskets are round, about 500 millimetres in diameter and approximately the same in height. Two of them still have their slightly conical lids, which are resting on a supporting ridge formed by an extra coil sewn on the inside of the basket.

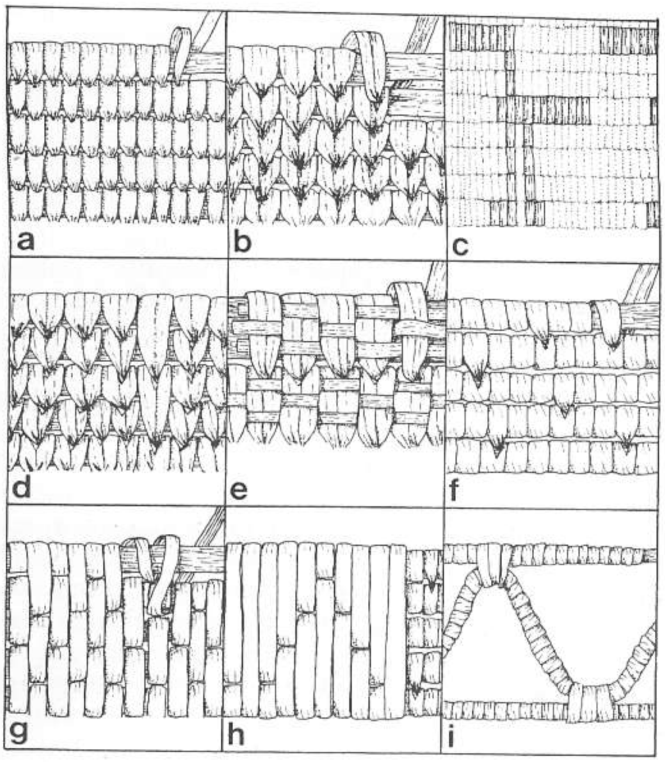


Figure 10.6 Examples of coiled basketry: (a) stitch through the previous winder (smooth appearance); (b) stitch through the previous winder and bundle (stronger than a); (c) coloured winders forming a pattern; (d) vertical rows of stitches over two bundles (for strengthening and decoration); (e) decoration with inlay of horizontal strips; (f) 'lazy basket-maker's stitch' (winding with widely spaced stitches); (g) coiling over alternately one and two bundles; (h) decorative stitches covering the 'lazy basket-maker's stitch'; (i) open coiling, used as decoration of rims and sides.

One basket has two more ridges on the inside, to help maintain the shape and possibly to hold two trays as internal divisions. The bundles, with a diameter of 1.5 cm are made of grass and in one case of the leaves of the ordinary reed. The winders, covering and holding in place the coiled bundles, consist of 1 cm-wide strips of dom-palm leaf. Some of the winding strips are coloured blue and red and thus add a touch of decoration (Cairo JE 55149 A, B and C, presently on display in room R/U 46, case 6186). In a similar fashion, but more lavishly decorated with a pattern of coloured winders which continues on the lid, is a large coiled basket from the early Eighteenth-Dynasty tomb of Ramose and Hatnefer. This basket, 38 centimetres high and about 45 centimetres in diameter, is on display in the Luxor Museum (Journal no. J.18, Cairo JE 66204, for photograph see Anonymous 1978: 80 no. 209 B). The matted furniture and the small basket shown in the same photograph are from Deir el-Medina. The use of coloured winders is sometimes also figurative: three long-necked animal figures, ostriches or giraffes, which stand out in brown winders on a light brown, natural dom-palm leaf coloured background (Fig. 10.6c; currently on display in the Egyptian Museum in Cairo in room R/U 46 in a case with finds from the MMA's excavations from 1929/30 at Deir el-Bahari). Another decorative effect is the regular use of larger stitches, over two bundles rather than one, often arranged in vertical lines over the entire body of the basket (Fig. 10.6d, e.g. Gourlay 1981: pl. XVIII D–F).

Finds from the tomb of Kha, excavated by Schiaparelli in 1906 and now mostly in the Turin Museum, illustrate well the variety of basketry items, the craftmanship of the basketmakers and the importance of this commodity in ancient society. The baskets containing household items, such as food and clothing, were round or oval coiled baskets of several sizes, sometimes decorated with ribs of larger stitches and closed with conical lids (Bonioanni 1987: 115). A large bag of knotless netting filled with dom-nuts was part of his supplies for the after life, as were three small, coiled baskets with condiments. A finely woven sleeping mat decorated with an intricate weaving pattern, chairs and stools with matted seats and a table made of date-palm midribs covered with papyrus culms were among the furniture in the tomb (Bonioanni 1987: 108, 144, 147).

The tomb of Tutankhamun contained 116 baskets, all of them coiled. They range from small containers in which all kinds of foods were stored (see section on function p. 265), to unusual specimens such as decorated bottle-shaped baskets and a round, coiled basket with separate strips interweaving the winders (Fig. 10.6e). In contrast with these finely made objects are the foundation deposits of the Kiosk of Thutmose III in the Asasif. Among these are a number of baskets, crudely made in what could be called the 'lazy basket-maker's stitch': quickly covering the bundle with a wrapping strand, which is stitched into the previous bundle at long intervals (Fig. 10.6f). These items were clearly not made to be used, because this rapid technique results in weak objects and, furthermore, the baskets show no wear marks at all (currently displayed in the Egyptian Museum in Cairo, room R/U 49, unnumbered).

It has been mentioned that in the Greco-Roman period there is a large shift in basketry techniques. Sewn plaits and stake-and-strand baskets were previously unknown, plaiting occurred rarely in Pharaonic Egypt. On the other hand, the traditional Egyptian techniques did not disappear; basketry from Karanis, Qasr Ibrim, Abu Sha'ar and Berenike (Wendrich 1995; Wendrich and Veldmeijer 1996) show a continuity within the long tradition which runs from the Neolithic until at least the New Kingdom. This is reflected in the occurrence of coiled basketry used inside the houses, woven grass mats for sleeping, bound matting for screens, woven bed matting, twined mats as awnings and closely twined bags for outside use. Innovations in coiling techniques are the use of stitches alternating over one and two bundles (10.6g) and the use of decorative wrapped patterns over a roughly coiled foundation made in the 'lazy basket-maker's stitch' (10.6h). The use of widely spaced decorative rims on coiled baskets (10.6i), also a variety of coiling, has not been attested until the third century AD (Qasr Ibrim). Apart from innovations of existing techniques, a number of new techniques were introduced which, by the first century AD had taken over a large part of the 'niche' of the traditional Pharaonic basketry. The most important of these was plaiting. Continuous plaiting, which occurred rarely in the earlier periods, is used widely in the Greco-Roman period, for making small decorative containers, fans and mats (e.g. Petrie 1927: pl. XLI, 162, 163). Coiled sandals were completely replaced by plaited sandals. The sewn-plaits technique, which did not occur at all before the Greco-Roman period, is from then on widely used for making floor mats and flexible baskets (e.g. Petrie 1927: pl. XLI, 167, 168). There are local differences, however. In Middle Egypt the sewn-plaits baskets replaced the twined bags, but the sewn-plaits matting did not replace the woven mats. In Nubia both the baskets and mats are nowadays made in the sewn-plaits technique, the origin of which is at present unknown. Judging from the many texts about Christian monks making this type of basketry (e.g. Wipszycka 1986: 117–44) its spread was fast and wide. Today it is still the most common type of basketry found in the streets of Cairo and rural Egypt alike.

A new type of decorative basket in the Greco-Roman period was the stake-and-strand type. The stake-and-strand baskets, which in ancient Rome were made of quite sturdy and rigid materials, such as willow rods, were in the Egyptian version quite refined because of the thin and relatively flexible rushes used (e.g. Petrie 1927: pl. XLI no. 161, XLII nos. 172–7). Another development of the late Roman period is the occurrence of pierced basketry made of the midribs of the date-palm leaves. This technology gradually replaced the pharaonic production line of furniture and crates made of bound reeds or palm midribs, lined with palm-leaf and flattened papyrus culms (e.g. Petrie 1927: pl. XLI nos. 170–1).

As a general conclusion it can be said that there is a clear continuity between neolithic, Predynastic and Pharaonic cultures, which is in contrast with the basketry revolution taking place in the Greco-Roman period.

Tools

The range of tools necessary to make basketry is limited. Coiled basketry is made with the help of a small needle or awl to make the holes in the bundle through which the wrapping leaf can be pushed. For twined basketry a simple frame is used, the form of which depends on the rigidity of the materials. If reeds are made into a mat, the frame is formed by the reeds themselves and only two fixed points, for instance two pegs in the ground, are needed to fasten the start of the mat. Twining with flexible materials requires a simple loom, consisting of four wooden pegs and two cross-bars holding the warp. The production of twined matting is depicted in tomb reliefs of the Old and Middle Kingdom (DB2; Fig. 10.8e). A slightly less simple loom was used for weaving floor mats with grass or rushes. Although the loom still consists of four pegs in the ground with two cross bars, the warp is run through a heavy beam with holes, which is used to beat the weft. A mat-weaver is depicted in the tomb of Khety in Beni Hasan (BH17; Fig. 10.7). The loom consists of four pegs in the ground to which cross bars have been fastened, holding the tension on the warp, which is running through a heavy beam in front of the mat-maker, who is sitting on top of the finished part of the mat. As Crowfoot (1933) points out, this is a problematic depiction, since the act of sitting on the finished mat would disturb the tension of the warp threads. She is also puzzled by the yellow and green strands in front of the weaver, wondering if an unknown technique of weaving from two sides was depicted. From the study of modern mat-makers it is clear that the weaver is sitting on the finished mat, but supports his weight, by something like a wooden plank on two bricks, running underneath the finished part of the mat in order not to influence the tension of the warp. To have his raw materials close at hand he puts them on the warp threads in front of him, just as is depicted in the tomb of Khety. The yellow and green blocks are the result of weaving with young (green) and slightly older (yellow) rushes in a block pattern. A tool which might be used in weaving mats is a hook with which the rushes are pulled in order to tighten the weft to a greater extent. Weaving on an existing frame (a wooden bed or chair), involves even less tools. The warp is mounted around or through holes in the wooden frame. The weft is beaten with a stick and perhaps some tapering wooden pegs are used for different tasks: as an awl to open up the edges, or to make space for the weaving string in the last phase of the process, when the frame is almost filled.

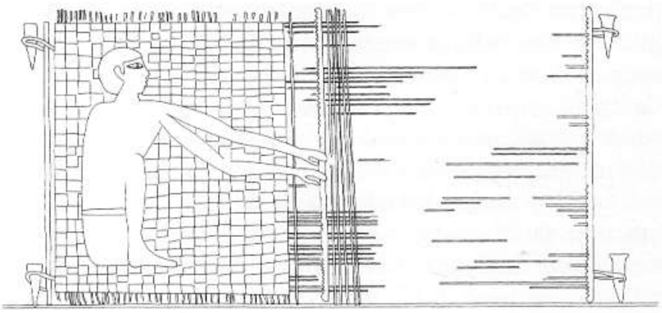


Figure 10.7 Mat-maker from the tomb of Khety in Beni Hasan (BH17).

For binding and plaiting no tools are necessary, other than a pot with water to soak the palm leaf. For the sewn-plaits technique a large needle is used. A 10 cm-long flat model is known in modern Nubia, and a 30 cm-long round model is attested in modern Middle Egypt. The identification of production areas and tools in excavations is often difficult. Thus a large needle found in a Badarian tomb was suggested to be indicative for mat-making (Brunton and Caton-Thompson 1928: 32). Such large needles are nowadays indeed used for making sewn-plaits mats, but since this technique does not occur until the Greco-Roman period, the large needle found at Badari must have had another function. On the other hand, the awls and needles found, which were thought to have been used for leather working, might have been used for making coiled basketry and pierced matting (Fig. 10.1h).

Representations and imitations

Baskets, chair matting and floor mats are depicted in many tomb paintings, with baskets commonly appearing in the lines of offering bearers and scenes of daily life. The depictions, however, are not always clear, due to the sometimes-stylized ways in which scenes are represented, but it is possible to give a number of indications. Apart from the representations of basketry, there are a number of imitations and decorative patterns derived from basketry.

Representations

In reliefs or painted scenes coiled basketry is represented mostly as half-round or straight-lined forms with horizontal stripes indicating the coiled bundle (Fig. 10.8a), or with horizontal stripes and cross lines indicating the bundle and the winding stitches (Fig. 10.8b). Often the coiled baskets are chequered, with colourful decorations, either representing coloured winders, or as an artistic means of bringing more colour to the walls (Fig. 10.8c). In statues, coiled basketry occurs as round, horizontally ribbed shapes. Statues of beer-brewers, for instance, have a coiled jar stand and a sieve with coiled sides. The grid in the sieves is twined, which is indicated often by a simple cross hatch. Twined bags are depicted most often in relation to agricultural scenes. Sowing is done from the same twined bags in which the harvested wheat and barley is brought in. The writers recording the harvest seem to note the number of bags coming in, which suggests that the twined bags were a measure of contents as well. They are often depicted as a tapering rectangle with cross-hatched lines and two loops at the top, but sometimes the slanting twining pattern is clearly indicated (Fig. 10.8d). In statues and tomb models twined bags are depicted as simply cross-hatched, cushion-like shapes. Model baskets of *shabtis* are also depicted as slightly bulging rectangles, often with cross-hatching, representing the twined seed and harvest bags. From the tomb-paintings one is led to believe that the largest variety of shapes and function is found in twined basketrey. The depictions of carrier bags on donkeys are often twined bags, but also large carrier nets, which are depicted as cross-hatched large ovals (Fig. 10.8i). Although these are flexible knotted or twined nets (Fig. 10.5f), they are depicted as being rigid. It is not clear if the fish traps, which are depicted as being made of stakes, fastened by openly spaced rows of twining, were rigid or not, since no archaeological remains have been found (see p. 259).

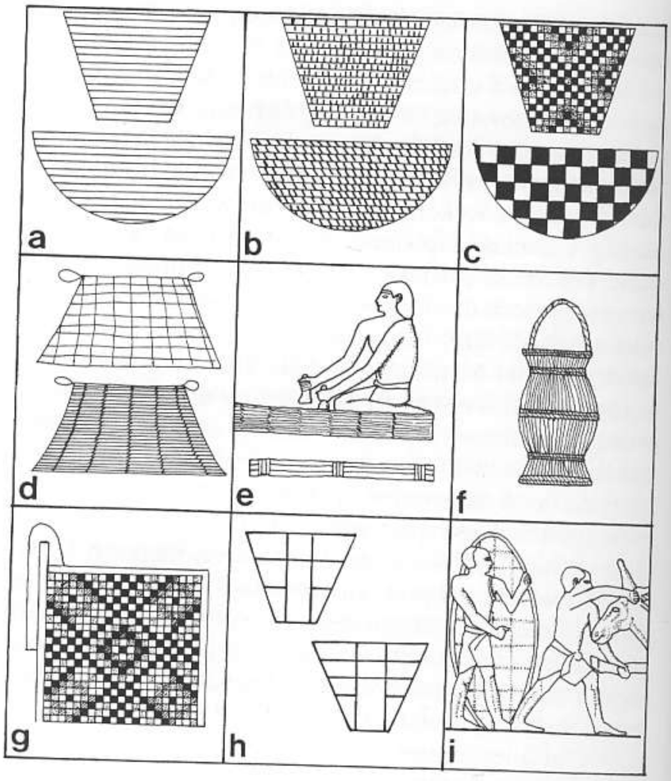


Figure 10.8 Representations of coiled basketry: (a) horizontal stripes representing the coil; (b) horizontal stripes with an indication of the stitches; (c) chequered patterns, in some cases representing coloured stitches, in other cases an artistic liberty. Representations of twined basketry: (d) seed bags are depicted with cross-hatched lines or, more precisely, with rows of oblique stripes; (e) twined mats are stylised as horizontal lines, interrupted by vertical lines. In more precise representations the rows of twining are indicated with oblique stripes; (f) basket with double rows of twining and a rope handle. Representations of other techniques: (g) woven (chair) matting is represented with, sometimes colourful, chequers; (h) rectangular tapering chests, probably made of wood or papyrus; (i) twined or knotted carrier nets are indicated with simple crossing lines.

Quite enigmatic are the square tapering chests often seen with Middle Kingdom offering bearers. They are lidless, usually contain beer jars and seem to have rigid sides. Sometimes a second crate seems to have been put upside down to form a lid. The cross-hatched patterns (mostly black lines on a white background) shows some variation, usually within the same scene (Fig. 10.8h). They might represent boxes, rather than baskets, made of strips of papyrus or palm leaf on a frame of reeds or palm midribs. The square boxes found in archaeological contexts, however, have straight sides rather than the flaring sides of the offering chests. Alternatively they might be plastered wooden boxes.

The chair mat is depicted as a square under the actual line of the seats (Fig. 10.8g), and mostly these matting representations are similar to the chequered coiled baskets. Here we find a clear warning not to try to apply our desire for a consistent iconography to these wall-paintings: the technique indicated is weaving. The weaving patterns on chairs vary from a simple open grid to intricate patterns, but are never coloured. The chequered equivalents on wall-paintings are lavishly coloured and thus do not give a clear image of the actual mats (see Fig. 10.4).

The stylised way of representing mats is as three rectangles with horizontal lines, bordered by three blocks with vertical lines (Fig. 10.8e). This is a depiction of twined matting, the horizontal stripes representing bundles of grass, culms of reeds or sedges and the vertical strokes representing the rows of twining connecting the bundles. Woven mats and (rarely occurring) plaited mats, for instance awnings on ships, are shown as chequered, often colourful rectangles, with the same kind of patterns as the chair matting and some of the coiled baskets (Fig. 10.8g). Terracotta miniature baskets from the Roman period show horizontal lines and sometimes chevron patterns indicating sewn-plaits basketry.

Imitations

Basketry and matting have been used as decorative patterns throughout Egyptian history. The *kheker* motif is thought to represent the top edge of matting, where bundles of reeds are tied together. In the architectural tradition from the Early Dynastic period onwards, mat imitations represent archaic walls. Similarly the zigzag string pattern at the base of walls and along the torus moulding of temple pylons are reminiscent of walls consisting of a frame covered with mats. Although often difficult to discern, because most of the colours on tomb walls have not survived, many walls of niches and false doors in the Old Kingdom *mastabas* are decorated with colourful motifs: chequered and occasionally chevron patterns representing woven matting. Chevron patterns indicate twill-weaving or plait patterns, but their occurrence in decoration is not representative of the number of twill-woven mats occurring. These were very rare, the earliest example being the awnings from the Khufu boat (see p. 259). Sometimes it has proven possible to reconstruct the original patterns from fragments of paint on the wall, for instance in the tomb of Hesyra (Quibell 1913: pl. ix) and tomb S3505 (Emery 1958: pls. 6, 7, 8), both at Saqqara. The drum in the central part of the false door represents a mat, rolled up to give access. The lavishly coloured matting imitations seem to represent an 'ideal' mat, rather than a mat that has been actually present at any time. One of the walls of the funerary chapel of tomb S3505 was, for instance, lined with simple grass matting (see p. 257).

Many of the underground chambers of the Step Pyramid complex of Djoser at Saqqara are lined with matting patterns in faience and plaster. Small faience tiles, measuring about 6 × 4 cm, thick in the middle and sloping down to four sides, are held in on copper wires through a boss on reverse and then plastered. The cushion-like faience tiles represent the bundles of grass or reeds, dented by 'strings' which are twined around the bundles at regular intervals. The strings are imitated in plaster with horizontal lines.

A stone-carved imitation of a twined basket, dated to the Predynastic period, is very detailed and includes the knots which fasten off the twining strands as well as the string tying together the bundles at both ends of the basket (JE 71298, *cf.* Saleh and Sourouzian 1986: no. 13). The importance of placing baskets of stone in a funerary context was probably that these, in contrast with real baskets, represented permanence, and thus outlived eternity for the benefit of the deceased.

From a much later setting, the Nineteenth Dynasty, basket imitations in metal are known. Among the treasures found in 1906 at Tell el-Basta were two jars, one of which had a handle in the form of a gazelle, made of silver. The bodies of both jars are covered with regular rows, of round shapes, and, the second, of heart shapes, imitating the stitches of coiled basketry (Vernier 1927: 415–6, pls. 104 and 105; Saleh and Sourouzian 1986: no. 222).

Classification and terminology

Under 'techniques' (see p. 255) nine basketry techniques were distinguished: coiling, weaving, twining, continuous plaiting, sewn plaits, looping around a core, looping, piercing and binding. It was not specified, however, on what basis this distinction was made, nor was anything said about the terminology.

Classification

The basketry techniques have been classified by discerning the *number of systems* used and the the interaction of these systems. In this context a *system* is a strand, or a number of parallel strands which are made of the same material and have the same orientation and function in building a basketry fabric. An important concept in understanding the interaction of the systems are the terms *active* and *passive*. The active system causes the coherency of the basket, while the passive system forms the base of the structure.

Coiled basketry is made with two systems: a passive bundle, which is fastened in a coil by an active winding strand. Both the active and passive system consist of one *element* (one bundle and one winding strand). The terms active and passive refer not only to the 'task' of the strands in the technique, but also to the production process. The basket-maker concentrates his actions on the active system, while the passive system is usually handled far less. Often the passive system is rigid or completely fixed. An example of the latter is weaving: the passive system, the warp, is fixed in a loom, while the active system, the weft consists of a strand which is woven up and down the warp strands. In the case of weaving, the passive system consists of a number of *elements*, namely the parallel strands making up the warp, while the passive system is one element: the matmaker weaves the strands one by one.

In coiling the active and passive element are oriented parallel to each other (they both follow a coiling movement from the centre of the base to the rim of the basket). In weaving the active and passive systems are oriented at a right angle.

Twining is very similar to weaving: the passive system is formed by a number of elements, for instance a number of parallel culms of reed, a number of parallel strings or a number of parallel bundles of grass. These are fastened by the active element running at a right angle (Figs 10.1c and 10.5). The active element consists of two *members*, two strings which twist around the bundles and around each other.

Plaiting is a technique in which both systems are active. This is true for continuous plaiting, as well as for the first production stage of the sewn-plaits technique: long strips are plaited out of strands of palm leaf or bundles of grass. In the second stage the plaited strip is the passive system, which is sewn with a string (the active system) into an ongoing fabric (Wendrich 1991: 59–64).

Looping around a core is also a two-system technique: a bundle of, for instance, grass is fixed in a coil by a strand which forms a loop around the bundle and links into the loop of the previous coil. It resembles coiling, in that the two systems follow the same direction, from centre to rim. It is distinguished from coiling because the movement of the active strand is different.

Not all techniques are two-system techniques. Looping (without a core), for instance, is done with one strand only. The coherency of the net is caused by the twist in the palm leaf which results in slightly stiff loops which retain their shape. Apart from one- and two-system techniques, there are also techniques with three or more systems. An example of a three-system twining technique is shown in Fig. 10.5e. Two passive systems are layed out cross-wise, the strands of system one being sandwiched between two layers of strands of system two. They are connected by a third, active, system which twines in between the strands of system one and around the double layer of strands of system two.

Binding occurs as a two- or three-system technique. An example of the former is the Predynastic coffin from Tarkhan, which is made by fixing a bundle of papyrus culms in a coil with knotted twigs (Cairo, Egyptian Museum room R/U11) (Fig. 10.3). A three-system binding technique is found in roof-constructions and wind-screens (Fig. 10.1i). In this case there are two passive systems: a screen of reeds is layed out, and a number of cross-bars are layed on top of this. The two passive systems are connected by a third, active, system: with string or twisted palm leaf the reeds are tied to the cross-bars.

Piercing is a two-system technique in which the passive system is pierced by the active system. The active system can be rigid (such is the case in the *gereed* crates, furniture and bird cages) or flexible, as in the Predynastic matting fragment which consists of parallel stems of rushes, sewn with flax yarn.

Further distinctions can be made for the active and the passive system separately, for instance, by specifying the space between the strands and the rigidity of the strands. Thus all techniques can be classified according to the same criteria, which makes it possible to find out which combinations do and which combinations do *not* occur. Finding explanations for the empty classes is what makes such a classification an important heuristic tool, rather than just a set of pigeon holes (see Wendrich 1991 and forthcoming).

Terminology

'Looped basketry' refers to the looped shape of the active system, while 'coiled basketry' refers to the passive system which is fixed in a coil. 'Stake and strand' basketry describes the flexibility of the two systems (rigid stakes, flexible strands), but in fact comprises a number of techniques: twining, weaving and waling (the latter is a form of twining with three or more elements). Wickerwork, a term used often as an alternative for stake-and-strand basketry, refers to the material used (wicker being an old term for willow rods). It may be clear that the terminology used in this, and many other, publications on basketry is all but consistent. A consistent terminology is based on a consistent classification, but it is debatable whether a consistent terminology is necessary or even preferable. A terminology comprising all aspects which are of importance in discerning one technique from another would result in terms which are multicomposite and, therefore, often unreadable. It is acceptable to use and, if necessary, adapt existing terms, as long as these are clearly defined and, preferably, accompanied by drawings.

Although a generally known basketry term, wickerwork has not been used above. The reason for this is that wickerwork is an English term, referring to a material, willow, which has never been used for making baskets in Egypt and using this term evokes a misleading image of Egyptian baskets. Following this line of reasoning brings to light the most important weakness of both terminology and the underlying classification: it is a construction which not necessarily complies with the world of the Egyptian basketmakers. When working with present-day Egyptian basketmakers it becomes painfully clear that neither a Eurocentric, nor a 'neutral systematic' terminology is in accordance with modern Egyptian basketry classification, let alone with the ancient Egyptian terminology and the classification which silently underlies it.

Function

As this chapter has indicated, basket-makers in ancient Egypt had a number of materials and techniques to choose from, resulting in mats and baskets with different properties. The properties of baskets and mats which are of importance for their functions are size, shape, flexibility and the space between the strands.

Despite the fact that most of the raw materials used were flexible, the baskets themselves were not, due to the technique employed. In particular, coiling results in strong baskets with rigid walls. Rigid materals, such as reeds, papyrus culms and midribs of date-palm leaves, were used for the production of twined or bound screens, (trap)doors, roofs and boxes.

Coiling is not only the most frequently occurring technique, but also the most versatile. Coiled baskets have been found in an enormous variety of sizes and shapes. They were mainly, or perhaps even exclusively, used inside the houses. Personal belongings and jewellery were kept in small decorative baskets, large storage baskets were the ancient Egyptian equivalent of our linen-closet. The contents of the coiled baskets in the tomb of Tutankhamun (KV62) give an impression of what type of goods were stored in baskets. They contained spices, dried fruits, seeds, dom-nuts, wheat and bread. A large coiled dish, with internal divisions, contained dom-nuts, a sealed linen bag, a fragment of bread and a few seeds. The baskets ranged in diameter from about 10 to 50 centimetres. There were thirty-two round baskets, eighty-one oval baskets, often with slightly conical lids, which rested on an extra coil on the inside of the rim and three bottle-shaped baskets, two of which contained dried grapes. Pulses (lentils and chickpeas) were not stored in baskets but in pots (Reeves 1990: 204–7). Of course, the large total of baskets in the tomb, of which there were more than any other kind of artefacts, is unlikely to reflect a normal household situation, but it does show the importance of basketry as storage containers. Pot stands and the rims of sieves were also coiled, while the grids of sieves and strainers were always twined.

The variety in spacing of the active and passive elements mainly reflects the function of twined basketry. For the grid of sieves both the active and passive elements of the twined grid were evenly spaced, the size of the strands and the space between them varying with the function of the sieve. The finest grids were twined out of animal hair. Twined bags were usually made of grass or palm leaf and, when loosely twined, quite flexible. Using the same materials and technique, but pulling the twining strands tightly, resulted in closely twined stiff mats, used, for instance, as saddles. Twined basketry was used mainly outside the house for carrying seeds, grain and other commodities or for moving pots, harvested plants, earth or dung on donkey-back. In the Ptolemaic period, most of the functions of twined basketry were taken over by sewn-plaits basketry, with the exception of the large twined donkey-bags which are still used widely today.

The function of mats is often difficult to determine, because they are used and re-used for a large number of purposes. Twined grass mats were found re-used as roofing material, but they did not end up there until after they had been used extensively as floor mats. Thick, woven mats, which could be easily rolled up, were probably used as sleeping mats, but the context in which they were found at Amarna suggests that they were also used as awnings (Wendrich 1989).

The correlation between function and aspects of size, shape, flexibility and spacing is not a simple linear one. Ethnoarchaeological research shows that the function of baskets is often very specific, and that tradition plays an important role. Furthermore, there is a difference between function and use: a basket might be used for something other than its official function and there are many instances of re-use of baskets and mats, for other purposes than their original function.

Producers and users

Who were the people who made and used the baskets? Both in the Amarna Workmen's Village and the tomb of Tutankhamun (KV62) large quantities were found. The question of who used basketry is therefore easily answered: everybody. Although there were differences between the relatively coarsely coiled and well-worn baskets from the workers and the finely decorated baskets from the tomb.

A tentative identification of the producers is also possible. The production of basketry involves a number of stages. Gathering and preparing the raw materials was probably part of the task of the basket-maker. For some materials, such as grass, or palm leaf, this can be done all year round, whenever the need is felt, but other materials, such as rushes and sedges, have to be gathered at a certain time of year and are dried and stored until needed. The time spent on harvesting and storing requires a certain level of professionalism.

Making coiled basketry does not require a special workshop; it can be made anywhere, the only tools necessary being an awl or needle and perhaps a knife. Although it is a time-consuming process, coiling can be interrupted at any time. Since the baskets seem to have been used only inside the houses it seems likely that they were made by women, perhaps mainly for their own use and whenever their other tasks left them time. Twining and weaving, on the other hand, require the use of looms for which a workspace has to be set apart. This suggests that twined matting, twined bags (which are sewn out of mats) and woven matting were made by part- or full-time professionals. It is a moot point as to whether we should conclude from the male matmaker depicted in the tomb of Khety at Beni Hasan (BH17) (Middle Kingdom), that these mats were generally made by male basket-makers. The producers of sewn-plaits basketry probably were part- or full-time professional males. This is at least true for the early-Christian hermits. Bound matting is mostly used in architectural contexts (screens, doors, walls of huts). The bound matting was probably made on the spot, which would lead to the conclusion that the producers were involved in the building activities. In tomb paintings the builders depicted are always male.

Most probably there was some degree of specialisation, simple coiled basketry being produced by women for their own use, while the other techiques were made by part-time or full-time professionals. This can also be inferred from the fact that the few depictions of basketry producers in tomb paintings are only men, making twined or woven mats. There was also a regional specialisation as is clear from the archaeological material, but also from a painting in the tomb of Rekhmira (TT100; see Fig. 10.9 and 10.10) where part of the tribute from Nubia and the Kharga oasis is a large number of baskets, among which are decorated, finely coiled examples.

From the supposition that there were (semi-)professional basket- and mat-makers follows the possibility that basketry was bought and sold. For the New Kingdom this is confirmed by prices quoted in some of the ostraca found at Deir el-Medina. For some of the prices quoted, it seems likely that they were not sold separately, but that prices included the contents (Janssen 1975: 135). These were probably standard-sized twined bags, containing wheat or barley.

Discard and preservation

Although the basket materials were inexpensive, their production is labour-intensive. Basketry from settlements were found to have been used and re-used extensively. At Qasr Ibrim, for instance, many storage pits were lined with cut-up carrying baskets and mats. Even baskets from funerary contexts often have traces of use, although they are generally in good condition. Baskets found in foundation deposits were produced whimsically and especially for the occasion. Beautifully decorated basketry, on the other hand, survived a number of generations as heirlooms. After a long life of service, the basketry was not thrown away, but many items probably found a final use as fuel for ovens, kilns or fires.

Although the preservation of organic materials is exceptionally good in Egyptian desert sites, the baskets found in excavations, represent only a small portion of the amount that must have been in use. Still, this portion is of vital importance to our understanding of one aspect of Egyptian daily life and serves to correct our view of sites in which the conditions are less favourable.

References

Adovasio, J.M. 1977. *Basketry Technology; a Guide to Identification and Analysis.* Chicago: Aldine.

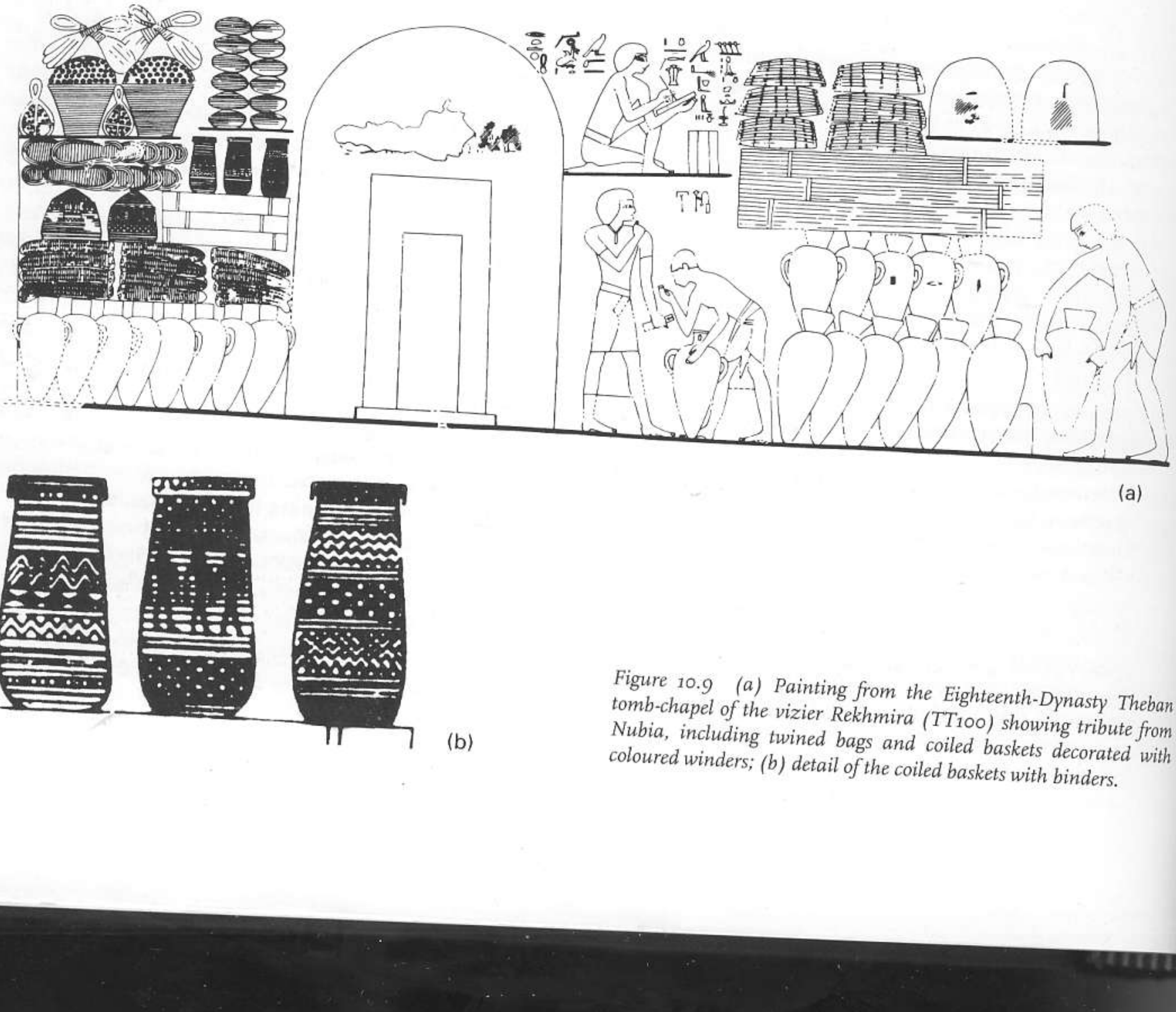


Figure 10.9 (a) Painting from the Eighteenth-Dynasty Theban tomb-chapel of the vizier Rekhmira (TT100) showing tribute from Nubia, including twined bags and coiled baskets decorated with coloured winders; (b) detail of the coiled baskets with binders.

Anonymous 1978. *Guidebook: The Luxor Museum of Ancient Egyptian Art.* Cairo: EAO.

Balfet, H. 1952. La vannerie; essai de classification. *L'Anthropologie*, 56: 259–80.

Bonioanni, A. 1987. Weaving: mats and baskets. In *Egyptian Civilization: Daily Life* (ed. A.M. Donadoni Roveri). Milan: Egyptian Museum of Turin/Electa, pp. 106–19.

Brunton, G. and Caton-Thompson, G. 1928. *The Badarian Civilisation and Prehistoric Remains near Badari.* London: Quaritch.

Caton-Thompson, G. 1926. The Neolithic industry of the Northern Fayum desert. *Journal of the Royal Anthropological Institute of Great Britain and Ireland*, 56: 309–23.

Caton-Thompson, G. and Gardner, E.W. 1934. *The Desert Fayum.* London: Royal Anthropological Institute of Great Britain and Ireland.

Crowfoot, G.M. 1933. The mat weaver from the tomb of Khety. *Ancient Egypt*: 93–9.

1954. Textiles, basketry, and mats. In *A History of Technology* I (eds. C. Singer, E.J. Holmyard and A.R. Hall). Oxford: Clarendon Press, pp. 413–47.

Emery, I. 1980. *The Primary Structures of Fabrics; an Illustrated Classification.* 2nd edn. Washington DC: The Textile Museum (1st edn. 1966).

Emery, W.B. 1954. *Great Tombs of The First Dynasty* II. London: EES.

1958. *Great Tombs of The First Dynasty* III. London: EES.

Forbes, R.J. 1964 . Sewing, basketry and weaving. In *Ancient Technology* IV. Leiden: Brill, pp. 175–95.

Germer, R. 1985. *Flora des pharaonischen Ägypten.* Mainz: von Zabern.

Gourlay, Y. J.-L. 1981. *Les Sparteries de Deir el-Médineh I, Catalogue des Techniques de Sparterie.* Cairo: IFAO.

Greiss, E.A.M. 1957. Anatomical Identification of Some Ancient Egyptian Plant Materials. Cairo: Imprimerie Costa Tsoumas Mémoires de l'Institut d'Egypte T.55.

Janssen, J.J. 1975. *Commodity Prices from the Ramessid Period.* Leiden: Brill.

Junker, H. 1929. Vorlaufiger Bericht über die Grabung der Akademie der Wissenschaften in Wien auf der neolithischen Siedlung von Merimde-Benisalame (West Delta) vom 1 bis 30. Marz 1929. *Anzeiger der Phil.-hist. Klasse der Akademie der Wissenschaften in Wien*, 66: 156ff.

1930. Voraufiger Bericht über die zweite Grabung der Akademie der Wissenschaften in Wien auf der vorgeschichtlichen Siedlung Merimde-Benisalame vom 7. Februar bis 8. April 1930. *Anzeiger der Phil.-hist. Klasse der Akademie der Wissenschaften in Wien*, 67: 21ff.

1932. Vorbericht über die dritte Grabung der Akademie der Wissenschaften in Wien in Verbindung it dem Egyptiska Museet in Stokholm unernemmene auf der neolithischen Siedelung von Merimde-Benisalame vom 6. November 1931 bis 20. Janner 1932. *Anzeiger der Phil.-hist. Klasse der Akademie der Wissenschaften in Wien*, 69: 36–99.

Larsen, J.L. and Freudenheim, B. 1986. *Interlacing; the Elemental Fabric.* Tokyo: Kodansha International.

Lehmann, J. 1907. *Systematik und geographische Verbreitung der Geflechtsarten. Abhandlungen und Berichte des Königlich Zoologischen und Anthropologisch-Ethnographischen Museums zu Dresden* XI nr.3. Dresden.

Leroi-Gourhan, A. 1971. *L'homme et la matière.* Paris: Editions Albin Michel.

Lucas, A. 1962. *Ancient Egyptian Materials and Industries*, 4th edn., rev. J.R. Harris. London: Edward Arnold.

Mason, O. T. 1904. Aboriginal American basketry: studies in a textile art without machinery. In *Annual Report of the Board of Regents of the Smithsonian Institution, Report of the U.S. National Museum for the Year ending 30 June 1902.* Washington: Government Printing Office, , pp. 171–548, pl. 1/248.

Peet, T.E. and Woolley, C.L. 1923. *The City of Akhenaten* I. London: EES.

Petrie, W.M.F. 1927.*Objects of Daily Use.* London: Quaritch.

Petrie, W.M.F. and Quibell, J.E. 1896. *Nagada and Ballas 1895.* London: Quaritch.

Petrie, W.M.F., Wainwright, G.A. and Gardiner, A.H. 1913. *Tarkhan I and Memphis V.* London: Quaritch.

Quibell, J.E. 1913. *Excavations at Saqqara: the Tomb of Hesy.* Cairo: SAE.

Reeves, N. 1990. *The Complete Tutankhamun.* Cairo: The American University in Cairo Press.

Rizkana, I. and Seeher, J. 1989. *Maadi III. The Non-Lithic Small Finds and The Structural Remains of The Predynastic Settlement.* Deutsches Archäologisches Institut, Abteilung Kairo, Archäologische Veröffentlichungen 80. Mainz am Rhein: von Zabern.

Saleh, M. and Sourouzian, H. 1986. *Die Hauptwerke im Ägyptischen Museum Kairo, offizieler Katalog.* Mainz: von Zabern.

Seiler-Baldinger, A. 1979. *Classification of Textile Techniques.* Ahmedabad, India: Calico Museum of Textiles.

Täckholm, V., Täckholm, A. and Drar, M. 1941–69. *Flora of Egypt*, 4 vols. Cairo: Cairo University Bulletin of the Faculty of Science, 17 (1941), 28 (1950), 30 (1954), 36 (1969).

Vernier, E. 1927. *Bijoux et Orèvreries Catalogue Général des Antiquités Egyptiennes du Musée du Caire no's 52001–53855*, Cairo:IFAO.

Vogt, E. 1937. *Geflechte und Gwerbe der Steinzeit.* Basel: Schweizerische Gesellschaft für Urgeschichte.

Wendrich, W.Z. 1989. Preliminary report on the Amarna basketry and cordage. In *Amarna Reports* V (ed. B.J. Kemp). London: EES, pp. 169–201.

1991. *Who is Afraid of Basketry? A Guide to Recording, Basketry and Cordage for Archaeologists and Ethnographers.* Leiden: CNWS.

1995. Basketry and cordage. In *Berenike 1994, Preliminary Report* (eds S.E. Sidebotham and W.Z. Wendrich). Leiden: CNWS, pp. 69–84.

1996. Ancient Egyptian rope and knots. In *History and Science of Knots* (eds. J.C. Turner and P. van de Griend). Singapore: World Scientific, pp. 43–68.

forthcoming *The World according to Basketry.* Leiden: CNWS.

Wendrich, W.Z. and Veldmeijer, A.J. 1996. Basketry and cordage. In *Berenike 1995, Preliminary Report* (eds. S.E. Sidebotham, W.Z. Wendrich). Leiden: CNWS, pp. 269–96.

Wipszycka, E. 1986. Les aspects economiques de la vie de la communauté des Kellia. In *Le Site Monastique Copte des Kellia; Sources Historiques et Explorations Archáologiques.* Geneva: Mission Suisse d'Archéologie Copte.

11. Textiles

GILLIAN VOGELSANG-EASTWOOD

Introduction

Textiles figured prominently in all aspects of ancient Egyptian life; they were needed from the cradle to the grave. Although many examples derive from Egyptian tombs and represent cloth for the dead, recent excavations of settlement sites have produced a more representative selection of 'daily-life' textiles and these are now available for study. They include the textiles from Kahun and the Workmen's Village at Amarna (Allgrove 1986: 226–52; Eastwood 1985: 191–204), forming an important source of information about the way in which Egyptian textiles were made and used.

It is clear from textiles excavated from both tombs and settlement sites that, as early as the Predynastic period, the Egyptians were proficient spinners and weavers (Caton-Thompson and Gardner 1934: 46, 49, 88, 90). Information about the textile technology of Pharaonic Egypt derives both from the textiles themselves and from representations of the various stages of textile production, from the sowing of the flax-seed in the ground to the weaving of material.

Tomb-paintings and models are a particularly valuable source of information about the production of cloth, in particular spinning techniques and loom forms. The most important paintings are in the Eleventh- and Twelfth-Dynasty tombs at Beni Hasan (BH2, 3, 15 and 17; Newberry 1893: pls. XI, XXIX, 1894: pls. IV, XIII), the Eleventh-Dynasty tomb of Dagi at Thebes (TT 103; Davies 1913: pl. XXXVII), the Twelfth-Dynasty tomb of Thuthotep at Deir el-Bersha (DB2; Newberry n.d.: pl. XXVI.), the Nineteenth-Dynasty tomb of Neferronpet at Thebes (TT 133, reign of Rameses II; Davies 1948: pl. 35) and the Eighteenth-Dynasty tomb of Thutnefer at Thebes (TT 104; Davies 1927b: 233–55). One of the most useful models of a spinning and weaving workshop is from the early Middle Kingdom tomb of Meketra (Cairo JE 46723; Winlock 1955: 29–33; see Fig.11.1). Other models of this type are in the Metropolitan Museum, New York (MMA 32.1.125 and 30.7.3) and the Ny Carlsberg Glyptothek, Copenhagen (A 516).

Figure 11.1 Model of a spinning and weaving workshop from the early Middle Kingdom tomb of Meketra (Cairo, JE 46723).

Fibres

Although ancient Egypt is known for the production of linen cloth, the flax from which it was made was not the only textile fibre in use. Excavated textiles made from sheep's wool, goat hair and palm fibre are also known. Cotton was not in general use in Egypt until the first century AD; the identification of cotton on a mummy has been discounted, as the mummy in question (Philadelphia University Musuem: PUM II) was shipped to America in raw cotton. For the original report about the presence of cotton see Cockburn *et al.* (1983: 52–70). Silk became widely available only after the seventh century AD.

Sheep's wool

The earliest known depictions of sheep in Egypt are the rock drawings of wild barbary sheep in southern Egypt and Lower Nubia, which appear to date from the Neolithic or early Predynastic period. In addition, two species of domestic sheep are depicted in Pharaonic tomb paintings and reliefs. The oldest type of sheep (*Ovis longipes palaeoaegyptiacus*) has long, loosely spiralling horns which come out the side of the skull. It is likely that its wool was coarse. The other form (*Ovis platyura aegyptiaca*) has horns which develop downwards and curl forwards, while keeping close to the head. The wool is shorter than that of *Ovis longipes palaeoaegyptiacus*, with distinct and regular locks and it is likely that it provided reasonably good wool, suitable for weaving.

It has become an established 'fact' that the ancient Egyptians did not use wool. This, however, is a misconception based on several comments by classical authors, notably Herodotus in the fifth century BC and Plutarch in the first century AD (*De Iside et Osiride*: 4). Herodotus states: 'It is, however, contrary to religious usage to be buried in a woollen garment, or to wear wool in a temple' (*Histories* II: 82). The prohibition on wool, if it existed, appears to have applied only to priests since Herodotus also comments that lay-people, especially young men, wore 'linen tunics with a fringe hanging around the legs and called *calasiris*, and a white woollen garment on top of it'.

Wool and woollen textiles were known from the Predynastic onwards, and various excavators record wool from such early contexts. Thus Petrie and Quibell (1895: 44) refer to Predynastic 'brown and white woollen knitted stuff' at Naqada, while Zaki Saad (1951: 44) mentions a woollen cloth wrapped round the skeleton of a man in a First-Dynasty burial at Helwan. A find of wool from Kahun which was originally dated to the Middle Kingdom has recently been radiocarbon-dated to the Roman period (Cooke pers. comm.). From the New Kingdom come several examples of woollen textiles excavated both from the Main City and the Workmen's Village at Amarna. Finally, the unmummified body of an unknown man, was found wrapped in sheepskins in an unmarked coffin within the royal cache of mummies at Deir el-Bahari, Thebes (Andrews 1985: 67, pl. 86).

Goat hair

A small number of goat hair textiles have been found at ancient Egyptian sites. Several of them come from the Workmen's Village, Amarna (Eastwood 1985: 192); one of these was made from dark brown hair, while the others were of cream-coloured fibres. The range of colour suggests that either the goats may have been piebald or perhaps several different coloured goats were being reared. In fact, a wall-painting in the Middle Kingdom tomb of Khnumhotep at Beni Hasan (BH3) depicts goats with fleeces ranging from black to cream (Griffith 1896: pl. III). Piebald goats are also portrayed alongside black- or white-haired goats on a painted papyrus dating to the mid-twelfth century BC (BM EA10016).

Palm fibre

Palm fibre comes from the bast or bark of certain trees, notably the palm tree. It is usually brown in colour, hard to the touch and brittle. It is not commonly found in connection with textiles from the ancient world, but some pieces of cloth from the Workmen's Village at Amarna had a series of possible palm-fibre loops woven into them (Eastwood 1985: 192). It should be noted that some authorities use the term 'coir' to refer to palm fibre, although it strictly refers only to the husk of the coconut, which is not native to Egypt; this term is therefore avoided here.

Grass and reeds

The use of grass and reeds for matting is described in Chapter 10, this volume; it is possible that these fibres were also used for textiles, although this is not certain. Midgley states that some Predynastic fabrics were probably of grass or reed: 'The microscopic structure of the fibre is similar to that used in some Badarian cloths . . . It is apparently some fibrovascular tissue not in any way related to flax' (Mond and Myers 1937: 139–41). He also described some textiles as 'spun from reed fibres', and others as 'made from yarns of grass or reed fibre'. As Lucas (1962: 149) himself noted, much more work is still required on this subject.

Hemp and ramie

True bast fibres identified with ancient Egyptian textiles include hemp (Brunton 1937: 145; Lucas 1962: 149) and ramie (Midgley 1912: 6), but these identifications are not certain and more work needs to be carried out on the textiles in question.

Flax

The majority of ancient Egyptian textiles are of linen which is made from the bast fibre, flax. Flax is a member of the *Linaceae* family, of which there are twelve genera (Catling and Grayson 1982: 13). Although the genus *Linum* has 230 species, only a few are of use for the production of textiles. *Linum* is an annual herb with alternating, lanceolate leaves along the entire length of the stem. The flowers have five petals which can be white, blue or purple. The fruit is a capsule form enclosing ten seeds.

Flax is not a native of Egypt, although its use dates back to the prehistoric period and it is possible that it was imported into Egypt from the Levant (Germer 1985: 101). Two types of flax are believed to have been grown in

Predynastic Egypt: the oldest is *Linum bienne* Mill. (ex *Linum angustifolium*) which grows to one metre high and has small, white flowers. Evidence for the early use of this type of flax has been found in the form of a flax capsule (tomb 3000/object 3) at the Predynastic site of Badari in Middle Egypt (Brunton and Caton-Thompson 1928: 63). The second type of *Linum* known from Predynastic Egypt is *Linum usitatissimum*, which again grows to about one metre high, but it has small, light blue flowers. It is this form of *Linum* which became the main source of flax in ancient times. In some tomb-paintings, the flax flowers are represented by a line of blue paint, which probably indicates that *Linum usitatissimum*, rather than *Linum bienne*, was being depicted.

Turning the flax plant into a piece of cloth is an elaborate process, which took a long time to develop, but it can be shown from excavated textiles from the Fayum region that a variety of types of linen cloth were being produced by the Neolithic period (*c* .5000 BC; see Caton-Thompson and Gardner 1934: 40, 43, 46, 49, 51 and 90).

Sowing and harvesting

The task of sowing flax seeds was carried out in the middle of November following the annual inundation of the Nile Valley. There are numerous representations of sowing scenes in Old and Middle Kingdom tombs, thus allowing the process to be followed and reconstructed. Often the sowing of cereal grain and flax is shown combined, as in the Middle Kingdom tomb of a man called Urarna at Sheikh Saïd in Middle Egypt (tomb 25; see Davies 1901: pl. XVI), where a man is depicted collecting seeds from the storerooms watched over by two officials who note the amount on a writing board (see Fig. 11.2). The seeds are then taken to the fields. In both cases the ground has been prepared by a team of oxen pulling a plough. However, the man sowing cereal grain uses an overarm action, while the man scattering the flax seeds uses an underarm movement which is typical for the sowing of this crop. Finally, flocks of animals, usually sheep, are sent into the fields in order to trample the seeds into the ground.

Flax plants take about three months to mature; once the flowers have died away and the seed heads appear, the plants are almost ready to be harvested. The timing of the harvesting is important, because the age of the plant affects the uses to which the fibres can be put. Thus, if the flax plants are harvested while still young and green then a fine textile can be produced, and if it is harvested when slightly older then the fibres are suitable for a general, good quality cloth. However, if the harvesting takes place when the plants are old, then the resulting flax is usable only for coarse cloth and ropes.

According to various representations of flax harvesting, such as the New Kingdom tomb of Paheri at Elkab (EK3; Tylor and Griffith 1894: pl. III), both men and women were involved in the process. In each case, a bundle of flax stems were grabbed in both hands and then pulled out of the ground. The flax was pulled rather than cut, in order to obtain as long and straight a length of fibre as possible, then the plants were tied into bundles and allowed to dry in the sun. This stage was also portrayed in the tomb of Urarna.

After the flax plants had been thoroughly dried, the seed heads were removed, using several different methods of stripping or 'rippling' the heads. They were often simply removed by hand, but the paintings in the tomb of Paheri show flax stems being pulled between the 'teeth' of a long

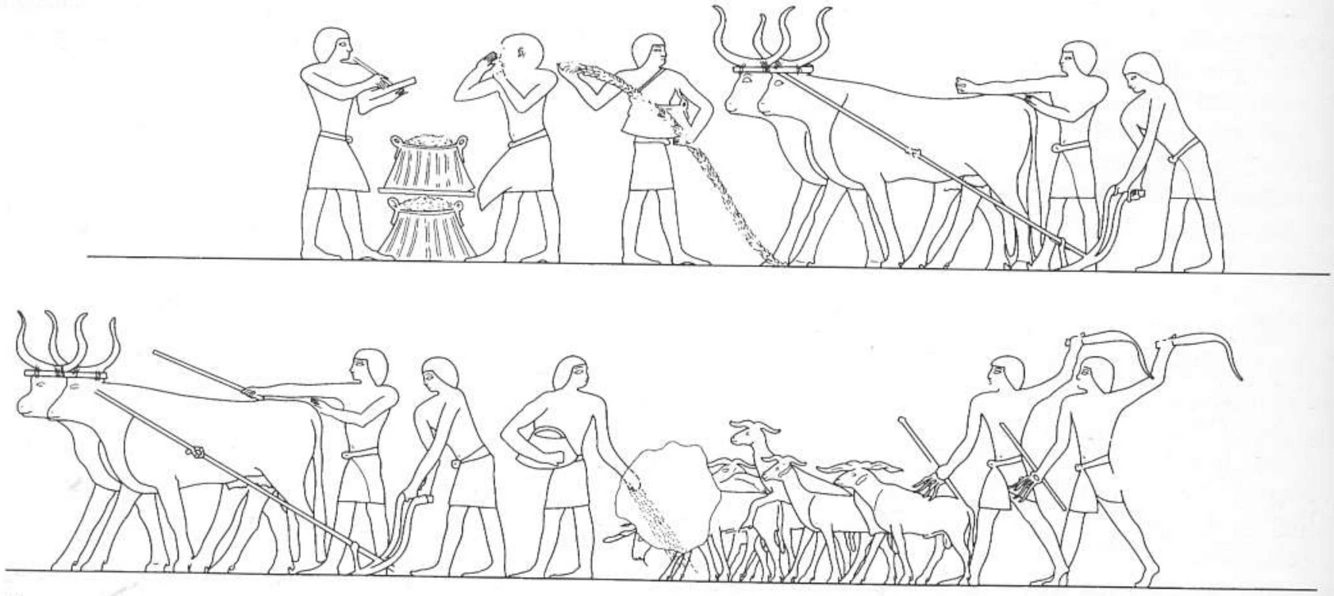


Figure 11.2 Scene showing the sowing of flax from the painted decoration of the Middle Kingdom tomb of Urarna at Sheikh Saïd (tomb 25).

board or rippling comb, an example of which was excavated from the Middle Kingdom town-site of Kahun (Manchester Museum Acc. No. 6859). A similar board (this time equipped with a stand) is depicted in the New Kingdom tomb of Menna at Thebes (TT 69; Petrie 1914: 95–6). The seeds of the flax (linseeds) were saved for several reasons: in order to sow the following year, to produce linseed oil, and possibly also as a form of animal-food.

Preparing the flax for spinning

In order to follow the various processes involved in preparing flax for spinning it is first necessary to understand something about the nature of the flax plant and, in particular, of its stem, which is made up of several layers (Catling and Grayson 1982: 13–5, figs. 3–4). Of importance to the production of flax are the fibre bundles (pericyclic fibres), which lie between the phloem and the epidermis and cortex. The bundles contain between twenty and eighty fibre cells (or ultimates) separated by narrow girders of parenchyma cells, and it is these fibres that are used to make the cloth. In order to release the fibre it is necessary to break down and remove the other layers of cells. The preparation of flax for spinning can be divided into two processes: (1) the retting, cleaning or scutching (i.e. the removal of the hard, outer cell layers of the flax stems); and (2) the twisting of the bundles of flax filaments into a rough, preliminary sliver or rove.

With regard to the first stage: once the seed heads have been removed it is necessary to rot or 'ret' the flax stems in order to remove the hard outer bark or cortical tissue of the plant. This is usually achieved by placing the stems in slowly running water; the length of time for which the stems stay in the water depends on the type of flax and the temperature of the water, but ten to fourteen days is normal. After the outer bark of the flax plants has deteriorated, the stems are removed from the water and allowed to dry in the sun.

The second stage in the process of preparing the flax stems for spinning is the beating or bruising of the plants to separate the fibres from the wooden parts of the stem. In the Dynastic period the flax was probably laid on a large stone and beaten with the mallets, but this stage is unfortunately not shown in any of the ancient representations. The excavations of several sites have yielded wooden mallets which may have been used for this task, and such implements were still being used for the same purpose in the Upper Egyptian village of Nahya during the 1930s (Crowfoot 1931: 34).

In order to remove any resistant fibres left over after retting and beating, the lengths of flax were either beaten with a large wooden fan (or 'bat'), to shake out all the loose pieces, or passed between two sticks held in the hand ('scutching'; see Fig. 11.3). The latter technique can be seen in the Middle Kingdom tomb of Dagi (TT 103) and the New Kingdom tomb of Thutnefer (TT 104; Davies 1913: pl. XXXVII; Davies 1927b: fig. 1).

Spinning: producing a linen thread

The ancient Egyptians had two techniques for making a thread: spinning and splicing. Spinning is the twisting together of a fibre or fibres in order to produce a long, cohesive length which is slightly elastic. As the length of individual fibres can vary from about 1 cm (e.g. in cotton), to more than two metres (in jute), different techniques of preparating and spinning have been developed to cope with these variations. It would appear both from actual finds and from representations that the technique of spinning in ancient Egypt was divided into two distinct, but related, processes: firstly the flax fibres were given a loose twist, and secondly they were actually twiste spun in order to produce the thread.

Once the flax fibres had been scutched they were passed on to another inidvidual who transformed them into rough but orderly lengths by rolling the threads either on the

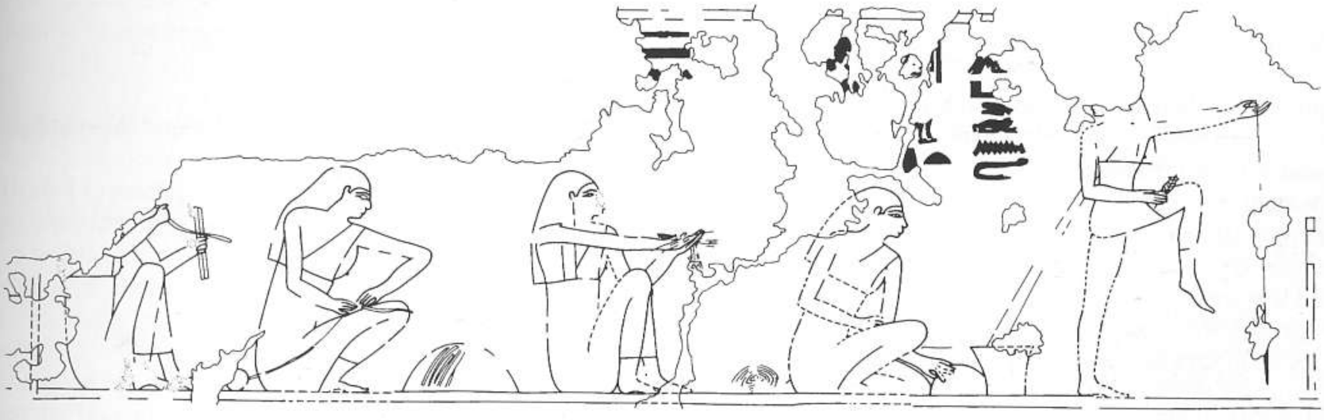


Figure 11.3 Detail of a wall-painting in the tomb-chapel of Dagi at Thebes (TT103), showing the preliminary preparation of flax ; the second woman from the left is probably splicing flax together rather than preparing it for the more conventional spinning of the fibres.

thigh or on a semicircular form placed directly in front of the person. These forms can be seen in various tombs, including that of Thuthotep at Deir el-Bersha (DB2) and those of Dagi and Thutnefer at Thebes (see Fig. 11.3).

The next stage of the process is the winding of roughly spun lengths of flax either into balls, as in the Eleventh-Dynasty tomb of Khety at Beni Hasan (BH 17; Newberry 1894: pl. XIII), or into coils, as in the tomb of Thuthotep at Deir el-Bersha, which seems to show semi-spun lengths being coiled and then passed through an internal loop in a bowl (Newberry n.d.: pl. XXVI). The woman's hands in this scene are held to her mouth, suggesting that she was moistening the fibres. This is of interest because it is normal for flax fibres to be moistened before being spun, in order to produce a coherent thread, usually by wetting the fingers prior to spinning or by moistening the balls or coils of flax with saliva from the mouth. The same method process was still being used by women in certain areas of Upper Egypt and the Sudan until comparatively recently, and two villages – Nahya and Kurdasseh – were famous for the 'women who spin through the mouth' (Crowfoot 1931: 33–5).

Spinning – the technique of twisting together a number of fibres into a strong, continuous thread – is made up of three distinct stages: (a) the drawing-out of the fibres; (b) the twisting of the fibres; and (c) the winding of the thread. Once the spindle is set in motion the spinner pulls or draws out (attenuation, drafting) a few fibres at a time from the mass held in the hand or on a separate holder or distaff. As the spindle turns the fibres, twist or spin is added. When there is sufficient twisted thread, the spindle is stopped and the thread is wound onto the spindle shaft or into a ball. Spun threads may be described as being S-spun (anticlockwise), Z-spun (clockwise), or I-spun (no spin), with the lie of the central bar of each letter indicating the direction of spin. In general, when two or more spun threads are re-spun (plyed) together, it is in the opposite direction to the original spin; thus, for example, an S-plyed yarn may be made up of two or more Z-spun threads.

Numerous forms of hand spinning have been developed throughout the world, employing a range of aids from a stick or stone to more complex forms using bowls, hand-spindles or distaffs. The most common form of spinning equipment used in ancient Egypt is the hand-spindle. A hand-spindle is made up of a stick (the shaft or spindle) and a weight (the whorl), with the latter acting like a fly wheel, keeping up the momentum of the spin. When a sufficient length of thread has been produced, the spindle is stopped and the thread is wrapped around the shaft (Crowfoot 1931; Vogelsang-Eastwood 1992a: 3–17).

A wide variety of materials were used for making whorls in ancient Egypt, including limestone, travertine, clay and wood (examples include Amarna 21/59 in limestone, 21/117 in travertine, 21/447 in clay and TA85.WV. no. 1784 in wood). Most ancient Egyptian whorls are either discoid or dome-shaped. The disc form would appear to be the oldest of the two and has been found at prehistoric sites such as Kom W in the Fayum (Caton-Thompson and Gardner 1934: 33). The dome-shaped whorl appeared at the end of the Middle Kingdom and was in widespread use by the New Kingdom. The shape of the whorl and its precise location on the shaft can vary depending upon local custom: in Egypt, the whorl was usually placed at the top of the shaft. The thread was often secured to the top of the shaft by means of a groove cut into its side around which the thread was secured, probably with a half-hitch knot.

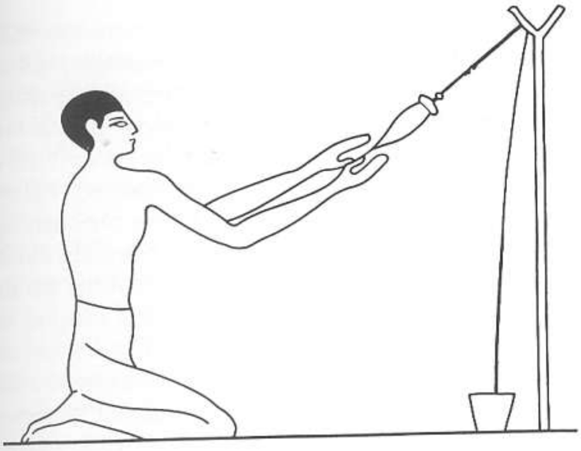
Some whorls have been found to have marks cut into their sides, including three wooden examples from Amarna, one having an elongated V on its side; another with an X and a third bearing a rectangle with two horizontal lines (Vogelsang-Eastwood 1994: 22, fig. 26). A likely explanation for these marks is that they were used to identify the tools as the property of a particular spinner.

Although depictions of men spinning yarn for making nets are known from tombs of the Old Kingdom, it is not until the Middle Kingdom that representations of spinning thread for cloth can be found. There are three basic methods of spinning known from these depictions which and were apparently in use during the Middle and New Kingdom – grasped spindle spinning, support spindle spinning and drop spindle spinning.

Grasped spindle spinning In this method, a prepared rove is passed through a ring or over a support such as a forked stick and then spun on a large spindle grasped in both hands. This technique is shown in the tombs of Bakt III and Khety at Beni Hasan (tombs BH15 and 17) where a forked stick is used (Fig. 11.4a) and in the tomb of Thutnefer at Thebes (TT 104) where a ring is visible (Fig. 11.4b).

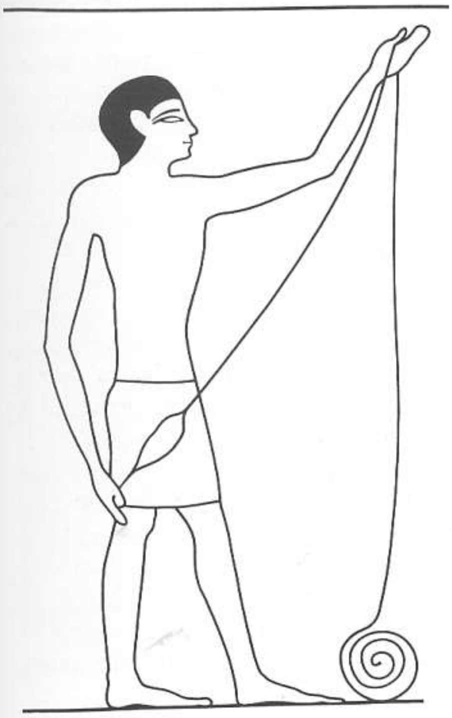
Support spindle spinning This technique involves supporting the spindle while it moves. In the tomb of Khety (BH 17) a man is shown sitting back on one heel while drawing a rove from a pot through his left hand and spinning with a spindle held in his right hand (Fig. 11.4c). It is possible that the slightly thicker yarn he was producing was to be used either by a net or mat-maker.

Drop spindle spinning In the third technique, the spindle is rolled on the thigh and is then allowed to drop. This scene is depicted in a number of tombs, notably those of Bakt III and Khety at Beni Hasan. Normally the spinners stand on the ground, but sometimes they are shown standing on blocks in order to achieve a greater height (see Fig. 11.4d). Often the spinners are shown with one or two so-called 'spinning bowls' by their feet (Fig. 11.4b). Spinning bowls have from one to six loops or handles set in the bottom of the vessel (Peet and Woolley 1923: 21, 61, no. 22/591; see also Dothan 1963: 97–112; Vogelsang-Eastwood 1987–88: 78–88). Semi-spun and fully spun threads are passed

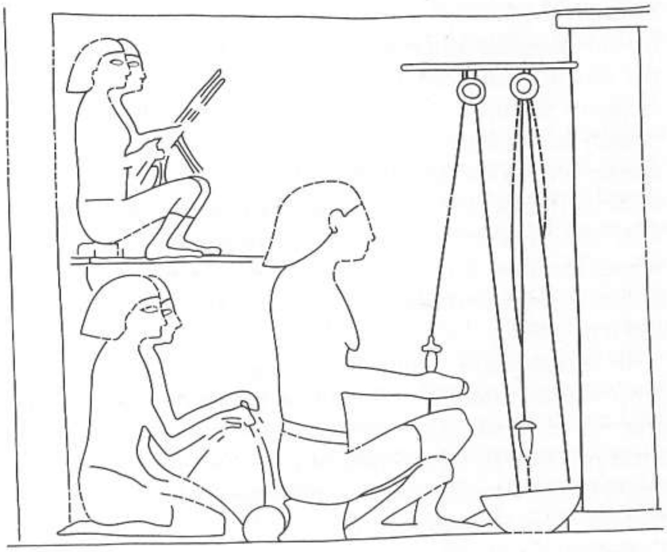


11.4a

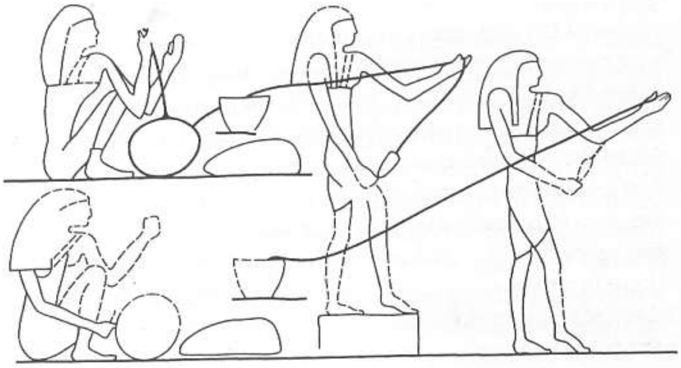
11.4c



11.4e



11.4b



11.4d

Figure 11.4 Different methods of spinning, as represented in the wall-painting of various Middle Kingdom and New Kingdom tombs. (a) The Middle Kingdom tomb of Khety at Beni Hasan (BH17); (b) The New Kingdom tomb of Thutnefer at Thebes (TT104); (c) The Middle Kingdom tomb of Khety at Beni Hasan (BH17); (d) the Middle Kingdom tomb of Thuthotep at Deir el-Bersha (DB2); (e) the Middle Kingdom tomb of Bakt III at Beni Hasan (BH15).

through these loops during spinning in order to keep the threads separate and to place a small amount of tension on the thread. The sides of the bowl can vary from a shallow slope to an upright, bucket-like, form. Such bowls are usually made from pottery, but occasional stone examples are known. In the Middle Kingdom tomb of Khnumhotep at Beni Hasan (BH 3), the spinner has two bowls by her feet, one of which is painted red to represent a ceramic vessel, the other is painted red and white, which is probably meant to represent a bowl made from alabaster (Newberry 1893: pl. XXIX).

In recent years, attention has been paid to the ancient processes by which the length of the flax thread was increased. In most cases this was done as part of the attenuation process. In Egypt, however, a second method, splicing, was also developed which gives the effect of two S-spun threads being S-plyed together.

In the case of extremely fine cloth, one to three bundles of between three and twenty ultimates are spun together (Cooke and Brennan 1990: 9). In coarser cloth, however, it would appear that two threads, rather than bundles, were spun together. In both cases it is likely that the fibres were moist when spun and as they dried they set into position, so preventing the threads from unravelling. The length of the splice varies from about 5–20 cm. Splicing seems to have been used occasionally in the Old Kingdom, but by the New Kingdom it was quite common. The use of spliced threads occurs both in extremely fine as well as very coarse cloth. It may be that the technique had to be used to achieve the desired fineness, while in the coarser examples it was a method of using up lengths of thread in the most economical manner possible.

While spinning, it is always a problem to hold enough raw fibres in the hand to continue for as long as possible, before having to stop and collect more fibres in order to continue the process. In the Classical world, the problem was partly solved by using sticks (distaffs), usually of wood, around which the fibres were wrapped, but a slightly different solution was adopted by the ancient Egyptians. They made a small 'yarn carrier' from lengths of wood or palm bound together to form a cage-like structure (Crowfoot 1931: pls. 39–40); the raw flax fibres were then either inserted into the cage or wrapped around it.

Preparing the warp threads

After the flax fibres have been spun into a thread or yarn they are then ready to be woven into cloth. The first task in this process is to remove the thread from the spindle and to warp (warping) the loom. This involves placing the warp threads in position on the loom. Subsequently the threads have to be tensioned. Once this has been done the actual weaving can commence (see below).

Warping involves laying threads of equal length in parallel lines. Three different methods of winding are represented in tomb models and paintings. The first and simplest method, which uses three pegs driven into a wall, is shown in the Eleventh-Dynasty model from the tomb of Meketra at Deir el-Bahari (Cairo JE 46723). The warp thread is either wound off the spindle directly around the pegs or from a previously wound ball; in either case a figure-of-eight shape is created. A second method is illustrated in the tomb of Dagi (TT103), where a woman is shown winding thread around two pairs of uprights which have a cross-beam set about halfway up each of the stands (Davis 1913: pl. XXXVII). The third method of warping is depicted in the Eleventh-Dynasty tomb of Thuthotep I at Deir el-Bersha (Newberry n.d.: pl. XXVI); it involved balls of thread being placed in bowls or containers of some kind, and then groups of perhaps as many as twelve threads either being wound onto a series of pegs driven into a wall (in the manner described above) or being directly wrapped around the warp and cloth-beams of a ground loom.

Weaving

Weaving is the process of interlacing two or more sets of threads according to a pre-defined system to produce all or part of a textile (see Fig. 11.5). The simplest form of weaving is the 'tabby weave' where one weft thread (pick) passes over and under the warp threads (ends). In the next row (throw) the pick passes under one end and over the next, so forming an interlocking structure. All other weaves (e.g. basket weave and tapestry weave) are variations on this idea, although some of the possible variations can be extremely complex.

In tabby weave, the basic binding system or weave is based on a unit of two ends and two picks, in which each end passes over one and under one pick. The binding points are set over one end on successive picks. Various forms of tabby weave have been found in Egyptian contexts. The most common are the simple or balanced tabby weaves whereby there is an equal number of warp to weft threads, and the warp and weft-faced tabby weaves. A faced tabby weave has more threads in one system than the other. Thus a warp-faced tabby has more warp than weft threads per centimetre. Conversely a weft-faced tabby weave has more weft than warp threads.

Basket weave, or extended weave, is a tabby weave in which the warp ends or weft picks move in groups of two or more. Several different forms of basket weaves have been recorded, but most of these are New Kingdom in date. The following forms of basket weave were recorded from the Workmen's Village at Amarna (Eastwood 1985: 195–6): half basket (paired warp threads, single weft-threads); full basket (paired warp and weft threads); warp-faced basket (single warp and paired weft threads); weft-faced half-basket (paired warp threads, single weft threads) and warp-faced half-basket (paired weft threads and single warp threads.

Tapestry weave comprises one warp and a weft. The latter is composed of threads of different colours which do not pass from selvedge to selvedge but are carried back and forth, interweaving only with the part of the warp that is required for a particular pattern area. Only a few examples of textiles woven in a tapestry weave have so far been found in Egypt and most are associated with royal tombs. Several pieces were recovered by Carter and Newberry from the tomb of Thutmose IV (KV43; Thompson 1904: 143–4). One of the textiles bears the cartouche of Amenhotep II (Cairo JE 46526; dovetail tapestry), while another has a ground decorated with lotus buds and flowers (Cairo JE 46526; Thompson 1904: pl. 1). A further example, worked in slit tapestry weave, derives from an unknown tomb in the Valley of the Kings (Cairo JE 24987; Daressy 1902: 302–3, pl. LVII); it includes a block pattern and a line of hieroglyphs set within a vertical column.

A number of examples of tapestry weave have been identified among the textiles from the tomb of Tutankhamun (KV62). These include several instances of slit tapestry (Carter nos: 367j (JE 62626), 46cc (JE 62674), 367f (JE 62775), 50u (JE 62669), 92g (JE 30/3/34/10) 50t (JE 6270821ff.) and JE 62645), one of dovetailed tapestry (54f (JE 29/3/34/05)), a horse blanket of 'Coptic' or 'bent-weft' tapestry (333 (JE 61992e)) and a form of open-work tapestry (21e (JE 30/3/34/51)).

In addition to the tapestry textiles found in royal tombs, several examples were found in the Eighteenth-Dynasty tomb of the architect Kha (TT8; Schiaparelli 1927), including a piece of material of unknown use which has two large squares of looping set in a tapestry-woven ground (Turin, Mus. Egizio inv. suppl. 8528; Donadoni Roveri 1988: 213, fig. 301). The ground is decorated with a pattern of lotus flowers and buds, and, as in the case of the horse blanket from the tomb of Tutankhamun, the design is worked in a 'bent-weft' system which later became a characteristic feature of Coptic tapestries. These New Kingdom finds indicate that this type of weave has a much longer history than hitherto supposed.

Finally, there is one piece of cloth (Carter no. 21e, JE 30/3/34/51) which has been woven in an unusual variation of tapestry weave. According to Emery's weave classification system it is a form of open-weave tapestry (Emery 1966: 84). So far, however, no near or exact parallels to this type of cloth have been found.

A small number of textiles with warp-patterned type designs have been recorded from various New Kingdom sources. This type of cloth has been variously described as a double weave; compound weave; tablet weave or a warp-pattern weave and it is one of the most complex of the weaves used in the Dynastic period. The weave is a warp-faced form in which the close-pressed warps make the pattern while the weft thread is concealed. Relatively few details are known about the history of this type of weave. In general it is believed to be an imported form because so far it has mainly been found in the tombs of members of the royal family dating to the New Kingdom. There are several surviving textiles in this type of weave. One example, now in the Victoria and Albert Museum, London (VA T251.1921) was found by Carter in an Eighteenth-Dynasty tomb at Thebes (Vogelsang-Eastwood 1994: pl. 38). It is made from coarse flax and has a simple geometric pattern in blue, brown, red and natural, repeating over four throws of the weft. Since there are several, repeating weaving faults, it may be suggested that the cloth was woven using two heddle rods and a shed rod, or possibly three heddle rods (see section on Looms p. 276).

The so-called 'Hood Textile' (VA T21.1940; Crowfoot 1933: 43–5) is possibly from Thebes and probably dates to the New Kingdom; it has a triangular pattern in blue and natural flax. The textile is woven in a warp-faced weave, but

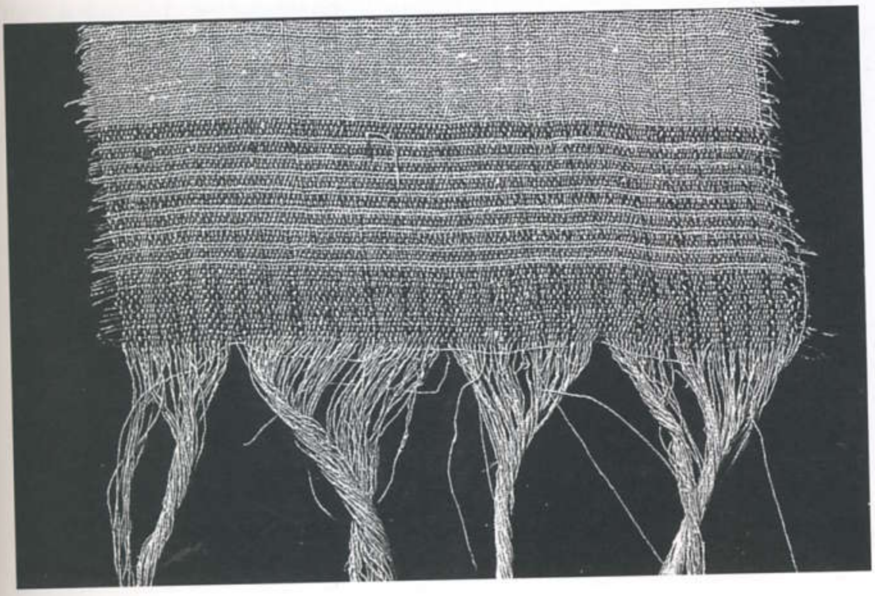


Figure 11.5 Close-up of some fine, warp-faced cloth decorated with a band in red (madder) and blue (indigotin) (Leiden, RMO, no. unknown).

the main pattern is produced by substituting weft for warp threads, which are then used to form a long fringe.

A warp-faced braid, sewn onto a saddlecloth, was found on a mummified horse excavated in front of the Theban tomb of the Eighteenth-Dynasty official Senenmut (TT71; Lansing and Hayes 1937: 10–11, 14, figs. 14–15). Among the textiles in the tomb of Tutankhamun (KV62), such braids were used to decorate the side of one of the king's elaborate bag tunics (Carter no. 367j, JE 62626) as well as a number of the decorated collar-form tunics (Carter nos. 210, JE 62644; 21aa, JE 62643) (Fig. 11.6). One of the largest and most elaborate examples of this type of work is the so-called 'girdle' of Rameses III, which is now in the Liverpool Museum (M 11158; Peet 1933), measures 5.2 metres in length and tapers from 12.7 to 4.8 cm in width, it is decorated with zig-zags, dots and rows of *ankh* signs in blue, red, yellow, green and undyed flax.

Sometimes the ancient weavers also used a combination of various weaving techniques, as in the case of one of the sashes in the tomb of Tutankhamun, the back panel of which was woven in a slit-tapestry technique while the rest was executed in a warp-faced tabby weave (Carter no. 100f; JE no. 62647).

At the beginning of the Middle Kingdom a form of weaving now called weft-looping appeared. This technique involves lifting or looping the weft thread up above the surface of the cloth at regular intervals, producing an effect similar to modern towelling; the Egyptians also created intricate patterns using loops, including chevrons, diamonds and bands. One of the earliest examples of this type of cloth, woven with short loops, comes from the collective burial of sixty soldiers at Deir el-Bahari in western Thebes, dating to the reign of the Eleventh-Dynasty ruler Mentuhotep II (Winlock 1945: 31–2, fig. 3, pl. 30B); similar textiles were found in other Middle Kingdom tombs in the immediate vicinity (Winlock 1945: 32). The use of weft-looping continues well into the New Kingdom and is often found in association with bedding, where looped cloth was used as a mattress (as in the tomb of Kha at Deir el-Medina, see Schiaparelli 1927: pl. 105), although in this later instance the loops are usually long. Cloth with long loops (similar to the symmetrical or ghiorde knot in construction) was also used for matting, such as that found on chariot 120 in the tomb of Tutankhamun. The springiness of the looping would have been used to cushion the movement of the vehicle.

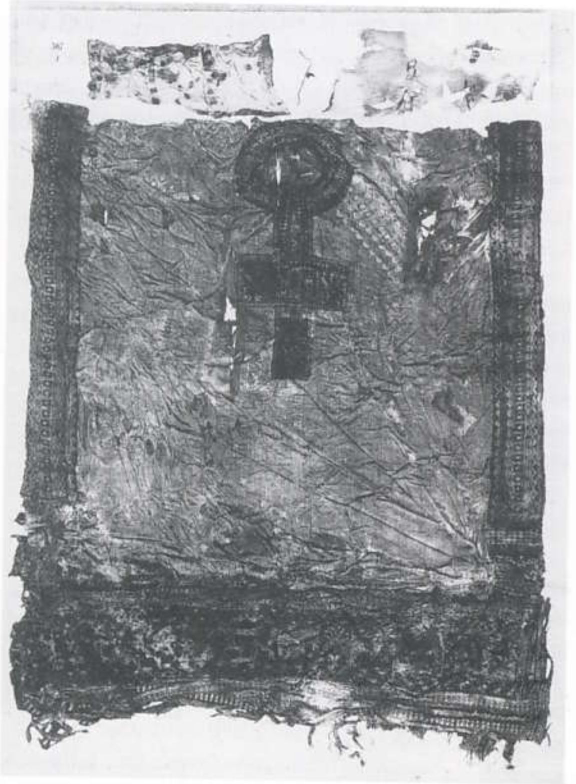


Figure 11.6 Warp-faced braids used on the side edges and lower edge of a tunic from the tomb of Tutankhamun (KV62) (Cairo, JE 62626).

Looms

A variety of written and representational sources suggest that two basic types of looms were in use in Egypt by the Eighteenth Dynasty: the ground (or horizontal) loom and the vertical (or fixed-beam) loom.

The ground (or horizontal) loom

The ground loom has a simple construction, consisting of a horizontal warp stretched in its length between two beams (Roth 1951; Barber 1991: 83–91), the latter being generally kept in place by a pair of pegs driven into the ground (Fig. 11.7). The warp threads are divided into two sets: 1 3 5 7 9 etc, and 2 4 6 8 etc. By lifting up one set of threads using a heddle rod (a stick with a row of long loops attached to it), a shed is created, the first of which is called the natural shed. The countershed is obtained by pulling up a second heddle rod or by individually lifting the warp ends, thus lifting the second set of threads. The weaver starts at one end of the warp and works until the other end is reached, moving the position of the heddle as needed. In order to keep the warps in place, the ground-loom weaver used a 'warp-spacer', consisting of a long rounded bar with slots cut into it at regular intervals (see Petrie 1917: pl. LXVI, nos. 133–6). The length of cloth woven on a ground loom was limited only by the amount of thread spun, as the web or warp thread was simply wrapped around the warp beam and unwound as needed. Thus it was not necessary to have the two sets of pegs set far apart in order to weave long lengths of cloth.

A painting executed on an early Predynastic pottery bowl from a woman's tomb at Badari (Tomb no. 3802; Petrie Museum, UC 9547; see Brunton and Caton-Thompson

Figure 11.7 Bird's eye view of a ground loom from the Middle Kingdom tomb of Khnumhotep III, Beni Hasan (BH3).

1928: 54, pl. XLVII6, no. 70k) is one of the oldest Near Eastern representations of the ground loom. The painting shows four corner pegs holding two beams, one at either end, with the warp running between them. A small amount of woven cloth can be seen at one end and three bars are shown across the middle, possibly the laze rod, heddle rod and a beater of some kind. The laze rod was used to keep the order of the warp threads. It is possible that a long, straight lath found in the Middle Kingdom town of Kahun was such a rod (Roth 1951: 22, fig. 20); measuring 124 cm in length, 5.2 cm in width, and 2.2 cm in thickness, it has notches at both ends.

To support the heddle rod, two 'jacks' were used, one on either side of the loom. It is likely that large stones were sometimes used for this purpose, but a number of wooden jacks have been found, including several excavated at Kahun (Manchester Museum, Acc. no. 50), which vary in size from about 20–40 cm in height, each with a large notch cut out of the side on which the heddle rod rested.

A number of shaped sticks, commonly called 'sword-beaters', have also been found (e.g. Leiden, RMO AJ147a); these were used to beat in the weft thread after it had been passed through one of the sheds. In most cases, one side of the long edge has become worn and shiny due to constant contact with the warp. Judging from the representations of swords in various tombs at Beni Hasan and Thebes, the shape and size of such sticks could vary considerably (Newberry 1893: pl. XXIX; Davies 1948: pl. 35).

Large wooden combs, found at a number of Egyptian sites, were probably used to beat in the weft threads (e.g. Leiden, RMO AH147a; see Vogelsang-Eastwood 1994: fig. 43; Petrie 1917: 54, pl. LXVI, nos. 148–54). There is, however, some doubt about their exact age and it is possible that they are Roman in date. Weaver's combs are usually about twenty centimetres long, ten centimetres wide and about four centimetres thick, with teeth cut into one end, and a handle placed at the other. It is not clear whether the use of such combs with one or both types of loom, although the latter would seem the more likely.

One of the characteristic features of cloth woven on the ancient Egyptian ground loom is a selvedge or weft-fringe which always appears on the left-hand side of the cloth. Depictions of clothes including such fringing are common in the Middle Kingdom but less so in the New Kingdom (see the Eighteenth-Dynasty paintings in tomb TT21 at Thebes, showing User and his wife; Davies 1913, pls. XXVI and XXVIII).

The ground loom has continued in use until the present day in certain more remote regions of the Near East, although in recent years its use has declined. A virtually identical loom was used in Sudan in the late twentieth century for the production of long lengths of coarse cloth (Picton and Mack 1979: 59–62). One reason for the survival of this type of loom is that it is suitable for the life of nomadic people, because it can be easily packed and then later reassembled.

Vertical (or fixed two-beam) loom

The second form of loom depicted in ancient Egyptian tombs is the vertical loom or fixed two-beam loom (Roth 1951; Barber 1991: 113–16). As the name suggests, the threads were stretched vertically, instead of the horizontal tension employed in the ground loom (Fig. 11.8). The warp ends were wrapped around two beams (the top or warp beam, and the lower, breast or cloth beam). The loom was either placed vertically or leant against a firm object such as a wall, and weavers stood or sat at the base of the loom, working upwards. The warp was released during the weaving process, by either turning or lowering the warp beam.

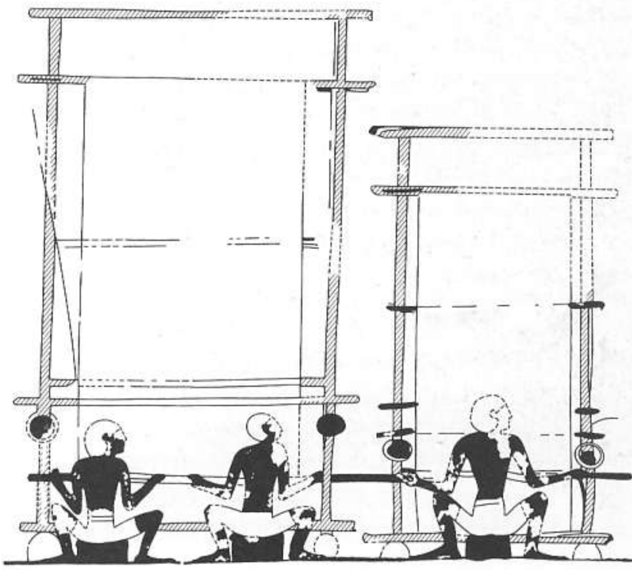


Figure 11.8 Detail of a painting depicting a vertical loom in the New Kingdom tomb-chapel of Thutnefer at Thebes (TT 104).

The lower (or cloth) beam was fixed into position by one of a variety of methods, perhaps being placed in a slight hollow in the ground, resting in grooves cut out of heavy blocks, or fixed to the floor of a room. Most depictions of ancient Egyptian vertical looms show the upright beams resting on blocks of some kind. Suitable stone blocks have been found both inside and outside houses in the Workmen's Village at Amarna (Vogelsang-Eastwood 1994: fig. 46), notably three opening from the Main Steet (Peet and Woolley 1923, pl. XVI). They are all very heavy limestone blocks, each with a large groove carved into the upper surface. Such stones are usually found in pairs, which would agree with their use as supports for a large loom, as represented in the depictions discussed above.

The size of the vertical looms seems to have varied; the two depicted in the Eighteenth-Dynasty tomb of Thutnefer at Thebes are of different heights (TT104; see Davies 1929: fig. 1). Judging from the size of the weavers, it is possible that the upright beams were three to five metres in height, but this should be regarded as speculation until actual examples are found.

Since the vertical loom is first attested in Egyptian representations at the beginning of the New Kingdom, it has been suggested that it may have been introduced into Egypt by the Hyksos (the Canaanites who came to power in the Second Intermediate Period). This atttribution, however, should be treated with caution, given our lack of knowledge of the range of looms used by the Hyksos themselves.

Balls and spools of thread

The numerous balls of thread known from Egyptian sites may possibly have been intended for weaving; in most cases the threads are fine and likely to have been used for the weft. The balls are sometimes wound around a thread core, and sometimes wound around pieces of pottery which act as a foundation for the thread (Cartland 1918: 139). Various types of short sticks wrapped with thread have also been recorded, and it is likely that these were shuttles or spools (e.g. Leiden, RMO AH152 and 176; Vogelsang-Eastwood 1994: fig. 47; Petrie 1917: pl. LXVI, nos. 111–16, 126–7); they are sometimes described as 'embroidery sticks', but there is no real evidence to suggest that they were actually used for embroidery.

Dyes and dyeing

Although the Egyptians are known for their love of colour and for paintings on the walls and floors of the houses, temples and tombs, it seems strange at first sight that so many of the surviving textiles were undyed. This may be because dyed textiles were considered more precious and therefore were not normally placed within a tomb, but this seems unlikely. It is much more probable that the dearth of coloured linen (the most common Egyptian textile) simply results from the fact that flax, being a cellulose substance, is difficult to dye.

The use of dyed threads or cloth can be tentatively traced back to the First Dynasty via a brownish piece of linen found at Tarkhan, and with greater confidence to the late Third or early Fourth Dynasty based on a red-dyed fragment from the site of Meidum (Midgley 1911: 38, 1915: 50; Germer 1993: 7–8). The Tarkhan linen should be treated with some caution as it is not certain whether the colour is natural or whether it is some form of staining which occurred later. In general, it was not until the New Kingdom that cloth was frequently woven with coloured threads.

Dyestuffs

Ancient Egyptian dyestuffs can be divided into two basic types: ochreous earths and plant dyes (see Chapter 4, this volume, for a detailed discussion of pigments). Ochre is an earth consisting of a hydrated oxide of iron mixed with clay. This substance can vary in colour from light yellow to deep orange or brown. Most natural ochres are coloured yellow because of the hydrated oxide, but yellow iron oxide can be transformed into red iron oxide by heating. Red ochres are coloured from the anhydrous ferric oxide.

The dyeing of linen with iron oxide has a long tradition in Egypt, which may date back to the Early Dynastic (depending on the interpretation of the Tarkhan textile mentioned above). Textiles coloured with iron oxide were also identified among the finds from the Workmen's Village at Amarna (Germer 1992: 66–7). The long history of this form of dye can also be confirmed by several examples of cloth coloured with iron oxide in the collection of the Rijksmuseum van Oudheden, Leiden (RMO A142 and 268; see van 't Hooft *et al.* 1994: 34, table 5). One of these pieces is possibly Twenty-first-Dynasty in date, while the other is from the Ptolemaic period.

A wide range of plants produce a colour of some kind, but only a limited number can create a durable dye capable of being reproduced; some of these have been analysed by Germer (1992). Such research has shown that one of the most common sources of the blue colour of Egyptian textiles is indigotin, a substance found in plants of both the *Indigofera* species, such as indigo, and the *Isatis* species, such as woad (*Isatis tinctorum* or *Isatis argentea*; see Germer 1992: 65–6). At present it is impossible to determine exactly the origin of the dyestuff, but written sources suggest that it may well be woad rather than indigo. The more often that fibres or cloth are dipped into a woad or indigo dye-vat, the deeper their colour becomes, and it is clear from New Kingdom finds, especially those from the tomb of Tutankhamun and the roughly contemporary Workmen's Village at Amarna, that both dark and light blue yarns were available (Eastwood 1985: 194–5). The relative social position of these finds would suggest economic reasons behind the difference in colour. Another possible source of blue was the seeds and pods of sunt (*Acacia nilotica*). Winlock (1941: 6) suggests that a late Eighteenth-Dynasty blue textile was probably dyed with 'the juice of the sunt berry', but no further evidence was given to support this suggestion.

Reds were not only produced by ochre, but also by plant dyes, one of the most important of which was madder (*Rubia tinctorum*; see Loret 1930–35: 23–32; Germer 1992: 8–9, 68–70). The main colouring ingredients in madder are chemicals known as anthraquinones, most notably alizarin. This dye plant was introduced into Egypt during the Eighteenth Dynasty, probably from the Levant (Germer 1985: 48). Examples of madder-dyed cloth have been found at numerous sites Egyptian sites, summarised by Germer (1992). Other known sources of red dyes during the Dynastic period are safflower (*Carthamus tinctorius* L), henna (*Lawsonia alba* or *L. inermis*) and alkanet (*Anchusa tinctoria*; see Loret 1930–5: 23–32; Germer 1992). In addition, it is possible that the lichen archil or orseille (*Roccella tinctoria*) and the insect kermes (*Kermoccoccu vermilio*) may have been used as red dyes, but this is not certain.

A small number of textiles have a yellowish colour and it is possible that they may have been dyed. So far, however, the actual dyestuffs have not been identified, although the potential sources are again safflower (*Carthamus tinctorius* L) and possibly pomegranate (*Punica granatum* L).

As noted above, the two most common dyestuffs associated with Egyptian textiles are indigotin and alizarin. Both of these substances are obtained from plants which are not native to Egypt. They were probably first imported from the Levant at some point during the Eighteenth Dynasty. So far no dye plants have been found in any Dynastic-period tombs, despite the fact that many contain a wide array of food plants, spices and flowers.

Dyeing methods

Although Flinders Petrie (1908: II, pls. XIV, XXXVa) excavated a dye-works at Roman Athribis, so far nothing has been found which can satisfactorily be described as a dyeing workshop from an ancient Egyptian context. However, it can be deduced from surviving textiles that four different methods of colouring cloth were used in the Dynastic period. The oldest method is 'smearing', where the colour is literally spread, possibly with the aid of a medium such a clay, mud or honey, onto the cloth.

The more complex technique of 'vat dyeing' is necessary in order to extract indigotin, because it must first be oxidised in order to produce a colour. The solution in the dye bath is called the vat and is colourless. After the fibres are dipped into the vat they are hung up in the open where they come into contact with air and this causes the necessary oxidisation. Within a few seconds of being in the open air the fibres turn blue. In order to create a dark blue the fibres must be re-dipped into the dye bath and it can sometimes take up to ten dips before the required colour is achieved. Most blues used in ancient Egypt would have been produced in this manner.

Alizarin, on the other hand, has to be dyed in another manner. It is an adjective dye which means that a mordant or metallic salt needs to be added to the dye-bath in order to fix the dyestuff to the fibre, thread or cloth. This type of dyeing is called 'acid' or 'non-vat' dyeing. Either the mordant is applied directly to the fibres, threads or cloth themselves or it can be added to the dye-bath. By fixing the dye to the fibres, the colour is made fast and more light-resistant. Mordants are nowadays used with many dye plants, including most of those producing a red or yellow colour. The exact period when Egyptians started to use mordants is open to doubt because the contaminants occurring naturally in the Egyptian sand can make it difficult to detect such substances. Nevertheless, it is likely that the Egyptians used alum, which is a naturally occurring salt (Germer 1992: 10–11).

In addition to dyeing blues and reds, the Egyptians also carried out a process called double dyeing (two-layer dyeing or topping), whereby fibres, threads or cloth were first dyed one colour and then dyed again with a different dyestuff in order to obtain another colour. Purple, for example is made from red and blue, while green is made using yellow and blue. It is not clear whether the first dye-bath would have been a 'vat form' and the second an 'adjective dye' or the reverse; either is feasible. Rare examples of double dyeing have been found at various sites in Egypt, including the Workmen's Village at Amarna. One purple thread (no. 1115 in the catalogue of textiles from the Workmen's Village), for example, had been dyed with indigotin and alizarin (Textile no. 1507 N 17 7; Germer 1992: 70). It is unusual to find linen which has been dyed while at the fibre stage. The Egyptians usually dyed either spun threads (in which case, white patches can sometimes be seen in the thread core if it is slightly unspun) or woven cloth. In the latter case, white areas can sometimes be seen beneath the place where a warp thread passes over a weft, so protecting the lower thread.

Other techniques for decorating cloth

A misconception still prevails that the ancient Egyptians wore plain garments and that their houses contained only undecorated cloth. It is true that garments were often used as a backdrop to elaborate jewellery, but they played a complementary, rather than secondary role. As can be seen from the previous sections on weave types and dyeing, Egyptian textiles and garments were by no means always plain. The Egyptians also had a number of other methods for decorating and embellishing cloth, some of which rendered it more brilliantly white, while others added to its colour.

Although it may seem strange to include bleaching among such decorative techniques, it should be noted that the wearing of white garments appears to have been regarded by Egyptians as an indication of social stature and, perhaps, as a sign of cleanliness. The value accorded to bleached cloth is indicated in an Eighteenth-Dynasty 'linen list' from the tomb of Rekhmira at Thebes (TT100): 'Menkheperra, blessings on him – for the manufacture of king's linen, bleached linen, fine linen, . . . linen, close-woven linen' (Davies 1943: 47). How exactly the Egyptians bleached cloth is not certain. It is likely that it was simply washed and then left to dry in the sun, the action of the sun's rays being sufficient to bleach the cloth. Another possibility is that cloth was bleached with a substance such natron which has a natural bleaching effect. However, too much natron can also cause serious damage to the fibres, so it is unlikely that this would have been used repeatedly.

Beads, rosettes and sequins were also employed to enhance the appearance of a garment. The use of beads, particularly in the form of jewellery, was ubiquitous throughout Egyptian culture from prehistoric times onwards, but occasionally they have also been found either sewn onto cloth or, more rarely, actually woven into the material. The latter can be seen on one textile now in the Victoria and Albert Museum, London (VA T. 729–1907), where blue faience beads have been both woven into the ground of the material and threaded onto the fringe, while glass beads have also been used on the fringe (Vogelsang-Eastwood 1994: 31, fig. 48). Since the origin of this particular textile is unknown, it is uncertain when the technique of threading beads into cloth became popular. There are also several examples of beaded garments from the tomb of Tutankhamun (e.g. Carter no. 21d, Cairo JE62634 and 44w, JE 62653; see Fig. 11.9). These objects indicate that at least six types of beading were carried out on garments at this time.

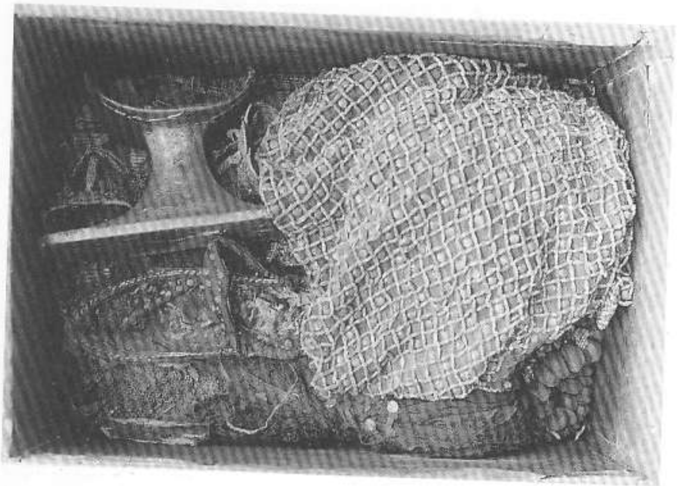


Figure 11.9 Remains of a beaded tunic (Carter no. 21d; Cairo JE 62634) found in the tomb of Tutankhamun (KV62).

Another form of decorating cloth was the addition of rosettes and sequins. Many of the garments in the tomb of Tutankhamun incorporated gold bracteates of various sizes and shapes, as well as faience rosettes and cartouches. Gold discs were frequently used on the textiles and these ranged in size from one to five centimetres. The pall which was placed over the king's sarcophagus was patterned with a 'night-sky of stars', made out of hundreds of gold rosettes sewn on to the cloth in staggered lines (Carter no. 209, Cairo JE 62745a).

Surprisingly it was only in the early medieval period that embroidery became a popular and widespread technique for decorating cloth in Egypt. Only a few fragments of embroidery dating to the Dynastic period have been found, and most were connected with royal establishments, usually tombs. The tomb of Tutankhamun contained several examples, including two tunics. The most famous example is a tunic apparently worn by the king when he was about 12 years old (Carter 367j; Cairo JE 62626; Crowfoot and Davies 1941: 126), to which several embroidered panels have been applied, including hunting scenes, griffins and a sphinx (Crowfoot and Davies 1941: fig. XX). The stitches identified with certainty are the outline stitch, chain stitch, split chain stitch, button-hole stitch, and a form of isolated knot. The second embroidered tunic from Tutankhamun's tomb (Carter 44t; JE 29/3/34/01) was made for a child; it is decorated with small gold rosettes enclosed by embroidered rosettes consisting of chain stitches.

In addition to the embroidered pieces from the tomb of Tutankhamun, fourteen embroidered tunics were found wrapped around the mummy of a priestess which was once assumed to date to the Roman period, but has now been assigned to the Twenty-third Dynasty (National Museum, Copenhagen, Acc. no. 1038; Hald 1946: 49–67). The embroidery is a form of blanket stitch and has been worked around the neck-opening and armholes of each tunic. The embroidery is worked in blocks of red, purple (blue?) and undyed linen.

Another technique which appears in the New Kingdom, and is normally associated with royal clothing, is appliqué. There are various garments from the tomb of Tutankhamun which have been decorated with panels of applied cloth (see Fig. 11.10). In one case a vulture has been created out of strips of red and blue cloth on a natural ground (Carter 101p; Cairo JE 62639). The sizes of the strips have been carefully fitted together to give the appearance of the bird's wings. An example of appliqué found at Amarna shows that the technique may not have been confined to royal clothing (Eastwood 1985: 198–9), although the small size of the Amarna example means that it is not clear whether the textile in question was being decorated or simply repaired with a dyed piece of material.

Another form of appliqué was the use of different widths of braids in order to decorate objects, usually garments.

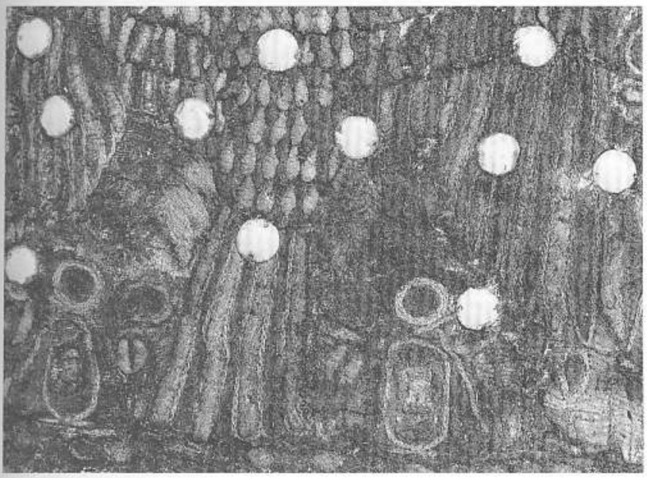


Figure 11.10 Close-up of appliqué and embroidery from a tunic panel (Carter no. 101p; Cairo, JE 62639), tomb of Tutankhamun (KV62).

Various types of braids were in use in ancient Egypt. Sometimes they have small fringes along their longitudinal edges, in which case the braids were placed along the outer edge of a textile. On other occasions, however, there are no fringes and then they are usually found either sewn across the cloth or again down the edges. The size of the braids can vary from about 0.5 to 3 cm. Bands were used in a similar manner to the braids, but they are much wider; one of the best examples of the use of bands can be seen on the embroidered bag-tunic of Tutankhamun mentioned above (Carter no. 367j; Cairo JE 62626). A further example is found on the horse blanket from the tomb of Senenmut (TT71; Lansing and Hayes 1937: 10–11, figs. 14–15). Elaborately decorated bands in red, blue and natural have been sewn down the sides of the garment, both at the front and the back.

Pleating was also used to decorate garments, and the oldest examples seem to be horizontally pleated dresses dating to the Old Kingdom (Riefstahl 1970: 244–9; Hall 1985: 235–45). One of the most elaborate examples (Cairo JE 51513), probably dating to the Middle Kingdom, has three different types of pleating: the first is a simple set of pleats a few centimetres apart; the second is a series of closely set pleats which actually touch each other; and the third is a section of herringbone pleating in which firstly vertical lines were pleated and then secondly, at regular intervals, horizontal lines were pleated to create wide bands with a chevron pattern. Although this example indicates that the Egyptians were capable of complex and decorative forms of pleating, it is still not clear exactly how they achieved this. In some cases, it is likely that the linen was wetted and then pleated by hand so that the pleats set into position as they dried. It is certain, however, that every time a pleated cloth was washed it would have had to be re-pleated, which would have been very time-consuming. Another possibility is that pairs of boards with a series of raised areas, similar to those now used on cigar-making boards, were employed, although it has been suggested that such boards were in fact used for crushing spices (R. Janssen pers. comm.). A third suggestion is that either differences in the spin directions of the weft threads or changes in the weave density have been used to produce the effect of permanent pleating. All of these ideas need to be further explored before any definite answer can be given concerning methods of pleating.

Several surviving linen textiles, dating from the New Kingdom onwards, were painted with designs of varying degrees of complexity. Sometimes these textiles had secular uses, but on other occasions they seem to have been intended for funerary purposes. With regard to secular use, a length of painted cloth was found with a chariot in the tomb of Tutankhamun (Carter 120 [1]; Cairo JE 62746 and 121 [1]; see Littauer and Crouwel 1985: pls. XVIII, XX, XXI); the material has two simple, blue lines painted on it and was placed between the floor of the chariot and the side wall of the frame. In this position the textile would have been subject to hard wear and it is likely that it was necessary to replace it frequently, hence, presumably, the simple method of decoration.

There are numerous examples of textiles which have been elaborately painted in order to represent jewellery (Leiden, RMO AL 48; Raven 1993: 64–5), and such fake jewels were often placed around the wrists of mummies in imitation of bracelets. There are also less elaborately painted examples of cloth bearing the outline of a god, commonly Osiris, which were usually used as shrouds (e.g. the Osiris shroud of Nesitiset, dating to the New Kingdom, see Winlock 1926: 28, fig. 33; Raven 1993: 61). By the Greco-Roman period, more elaborate painted shrouds were in use (Leiden, RMO inv. AMM 8; Vogelsang-Eastwood 1994: 63, fig. 104).

The care of cloth

In ancient times it is likely that textiles and clothes were maintained more carefully than today, holes tended to be mended rather than discarding the garment. Some textiles appear to have been mended three or four times before they were rejected or made into something else. Although there is no direct evidence, it is likely that the care of textiles and clothing was in the hands of women rather than men. It was, for instance, a suitable job for women to carry out while looking after children, as it could be easily interrupted. Sewing, like spinning, is normally a group activity and thus has a social function in bringing people together to make a repetitive task less boring.

One of the few written references to sewing appears in a Nineteenth-Dynasty letter written to Pennesettowy, which was found at the village of Deir el-Medina (O.DM 131; Wente 1990, no. 249). This letter describes the sewing of various garments, including tunics and possibly sleeves, which were then intended to be used to acquire other objects, including some baskets: 'I shall weave two kilts; I shall stitch one tunic; and I shall stitch the pair of sleeves [in exchange for] two baskets and two sieves'.

Sewing equipment

A study of ancient Egyptian sewing shows that a relatively small range of techniques and structural details, such as seams and hems, were used. This situation not only reflects the relatively narrow range of materials then available (a coarse woollen textile requires a different range of seams from a fine silk), but also the ways in which textiles were used in the ancient world. In particular, it illustrates the fact that garments were made in as simple a manner as possible, with drape, rather than tailoring, being emphasised. Before discussing the various types of sewing details it is necessary to look at the range of sewing equipment used in ancient Egypt.

An important point to remember when looking at ancient Egyptian garments is that all sewing tasks were carried out by hand. There were no mechanical devices to help speed up the process or to produce elaborate decorative effects. The basic equipment consisted of a needle, thread and a cutting implement of some kind, although inevitably other items were developed to help with the task at hand.

In addition to fine needles made from pierced fish bones, many bronze, copper and silver needles have been found at sites throughout Egypt; these range in diameter from a few millimetres to a centimetre (e.g. the needles discussed in Petrie 1917: pl. LXV, nos. 65–109; Vogelsang-Eastwood 1994: 35–6). Three different types of metal needles were used in ancient Egypt, each reflecting a different function and quality of stitching when used on cloth. Small, fine, needles pointed at both ends and with one end pierced (New York, MMA 233); needles that were flattened and pierced at one end and sharp at the other end (Leiden, RMO F 1937/1.89) and finally needles that were folded over at one end and sharp at the other (Leiden, RMO F 1937/1.80). In addition to the small needles used for sewing cloth, larger ones were available which were probably used for sewing up the incisions on bodies during the mummification process (e.g. Leiden, RMO AB 145).

Nowadays most people use little finger caps or thimbles while sewing, but the ancient Egyptians used finger guards made out of stone, which were held in place with the other fingers; a Twentieth-Dynasty example is known from Lisht (New York, MMA 11.151.634; Vogelsang-Eastwood 1994: fig. 57).

In order to keep the needles safe, they were often stored in small cases, which have been found at many sites, often still containing needles. They are made from a variety of substances including the hollow leg-bone of a bird, a hollowed-out piece of animal bone or a length of wood. Two such cases – made out of lengths of papyrus rolled up and fastened around the middle with a piece of string – were found in the New Kingdom tomb of the architect Kha and his wife Merit (TT8; Schiaparelli 1927: fig. 62; Donadoni Roveri 1988: fig. 285, Turin inv.suppl. 8379); they contained several copper needles.

Sewing pins were not commonly used, if indeed at all (although cloth is occasionally found with thorns stuck into it). Instead, the cloth was simply held in the hand in order to keep the various elements of a garment together while they were being stitched.

Scissors did not develop until about the first century AD, and there is no evidence to suggest that the ancient Egyptians used them. Similarly, shears did not appear in Egypt until the Ptolemaic period, or possibly even the Roman period (Petrie 1917: 48). Before this date, it is likely that the Egyptians simply tore cloth or used a sharp flint to cut it. Straight cuts were made by simply tearing the cloth, as can be seen in a painting from the Eighteenth-Dynasty tomb of the vizier Rekhmira (TT 100; Davies 1943: pl. LVI). On the other hand, shaped areas, such as neck-lines, were probably cut with a sharp flint, which allows a considerable degree of control to be exerted.

In general, sewing thread was commonly made from two S-spun linen threads which were Z-plyed, although variations such as a three-ply yarn are occasionally found (see van 't Hooft *et al.* 1994: 22–3). The yarn varied in size from fine (0.02–0.3 mm) to coarse (0.6–0.8 mm). Usually the fineness of the sewing thread either matched, or was slightly thicker than, the material being sewed. Although the thread was generally undyed, occasionally a coloured yarn, usually red or blue, can be seen on textiles, especially those dating from the New Kingdom. The blue kerchief found among the textiles in the funerary cache outside the tomb of Tutankhamun was mended with a white thread (New York, Metropolitan 09.184.217–19; Winlock 1916: 238–42 and Winlock 1941).

Sewing techniques

The ancient Egyptians used a narrow range of stitches for functional work such as sewing seams and mending garments. These are the running stitch, overcast stitch, twisted chain stitch and a form of darning similar to that formerly known as 'Swiss darning'. Only a limited range of structural details, such as seams and hems, were used in ancient Egypt. The most common of these were: simple hems, rolled and whipped hems, simple (open) seams, and lap-over seams. Other seams known from the Dynastic period include a form of run-and-fell seam and overcast seams (see Fig. 11.11), but these were rarely used on items of clothing.

When a braid was added to a garment, one of several techniques was used, depending on the nature of the braid and the place where it was to be attached. If it was a fringed braid placed at the lower edge of a garment, it would normally be secured with one line of overcast stitching (e.g. Carter no. 367i; Cairo JE 62625). On the other hand, two lines of overcast stitching were used to sew on fringeless braids, whether along an edge of a garment or down the middle (e.g. Carter no. 101p; JE 62639).

As today, the quality of sewing in ancient Egypt seems to have depended on the ability of the person actually doing the work. Sometimes, for example, fine cloth was worked with coarse stitching, while a relatively coarse cloth might be neatly sewn. In general, however, the stitching on ancient Egyptian cloth is fine and regular in appearance.

Repairing cloth

There are numerous examples of textiles and garments mended in antiquity. Material has been found which has been stitched on several occasions and it would seem likely that most people took care to keep their clothing in a good state of repair. If, however, an item of clothing became too worn, then it was sometimes made into another, presumably smaller, garment. This process can be seen in a letter written during the reign of Rameses II from the draftsman Pay to his son, Preemheb, who was also a draftsman: 'And you shall be attentive to take this rag of a kilt and this rag of a loincloth in order to re-work the kilt into a red sash and the loincloth into an apron. Don't ignore anything I have told you!' (Černy 1930–5: Nineteenth Dynasty; Wente 1990, no. 218).

As with modern sewing techniques, the repair of ancient textiles can be divided into three basic types, namely, darning, mending and patching. Darning is the method whereby a worn area of cloth is strengthened with lines of stitching before a hole emerges (van 't Hooft *et al.* 1994: 24). The basic darning technique in ancient Egypt consisted of lines of stitching, usually elongated twisted chain stitching being worked over the area. Each line of stitching was isolated, began with a small back stitch and ended with a knot. In most cases it would seem that the area of darning was worked away from the body of the seamstress.

Should a piece of material be torn or a wear hole form, then it is necessary to mend the cloth. Most mending involves holding the two edges of cloth together using one or more lines of stitching. The most common form of ancient mending is that whereby the edges are rolled and then overcast using a whipping stitch. Occasionally more elaborate forms can be found with a double line of stitching, using both a running stitch and a whipped stitch. Another form of 'mending' sometimes encountered amongst ancient cloth is the knotting together of the two edges of the cloth.

Although there are numerous examples of textiles and clothing being either darned or mended, or in some cases both, it is rare to find patched examples. Patching is a method whereby a hole is covered by a second piece of cloth which is then stitched down to the ground material. In most cases, although not all, patched textiles seem to be

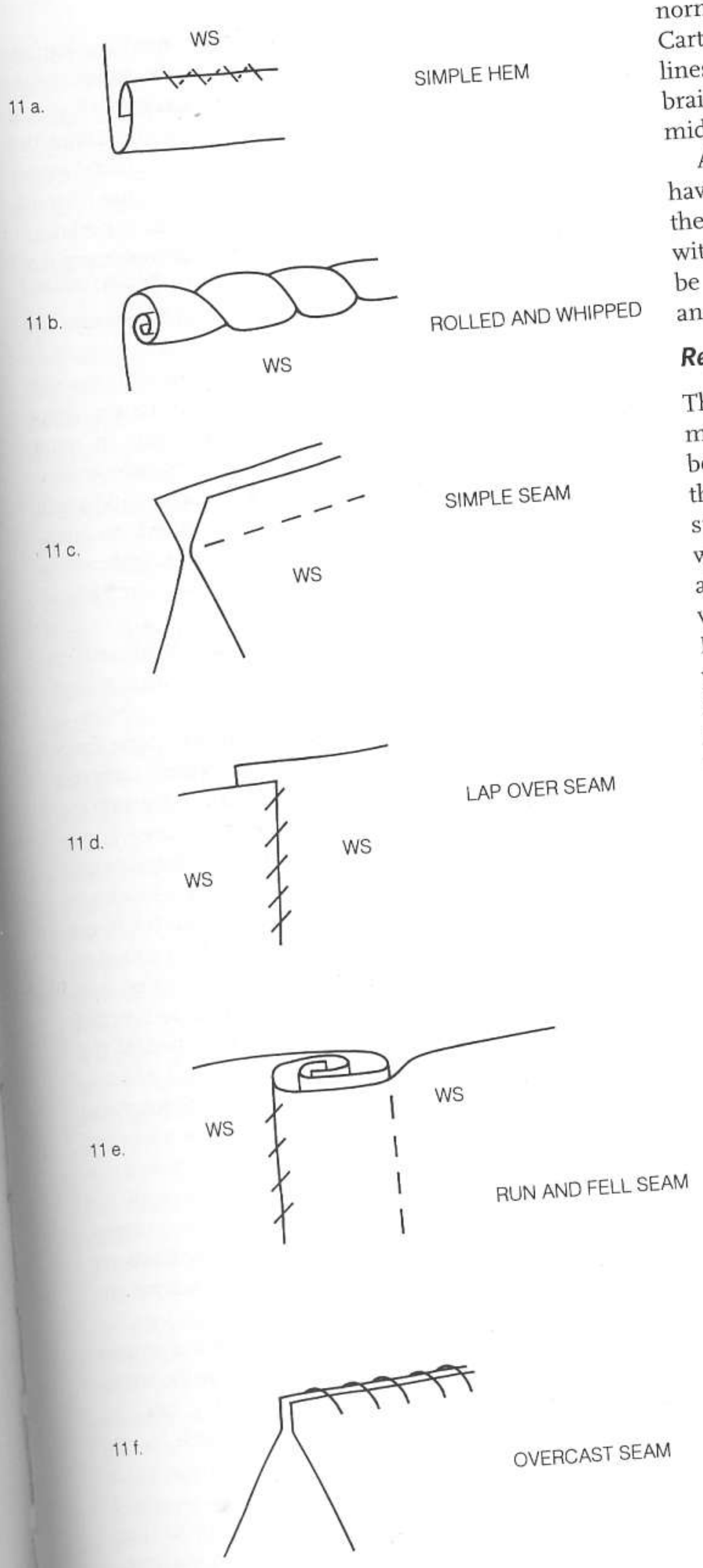


Figure 11.11 *Various seams and hems used in Pharaonic Egypt: (a) simple hem; (b) rolled and whipped hem; (c) simple (open) seam; (d) lap-over seam; (e) run and fell seam; (f) over cast seam (WS = wrong side).*

Ptolemaic or later in date and this may reflect a Greek or Roman influence.

Many Egyptians were well aware of their appearance and especially the state of their clothes. It is not surprising therefore to find descriptions such as 'this rag of a kilt' or 'shabby loincloth' on Nineteenth-Dynasty ostraca (Černy 1930–35: 19; Wente 1990, no. 218; O.DM 554; Wente 1990, no. 245), or indeed to see the care accorded to many textiles and garments.

The laundry

As an extension to the care taken of textiles and clothing, the laundry played an important role in the life of most Egyptians. Nevertheless, this does not mean that the washerman was held in equal esteem. In the Middle Kingdom text, *The Teaching of Duaf's Son, Khety*, the man who washes the laundry is described as someone to be pitied (although it should be noted that texts of this genre routinely pour scorn on all professions other than that of the scribe):

> And the washerman washes on the shore
> and nearby is the crocodile.
> 'Father, I shall leave the flowing (?) water'
> Says his son and daughter,
> 'for a trade that one can be content in,
> more so than any other trade'
> while his food is mixed with shit.
> There is no part of him clean,
> while he puts himself amongst the skirts of
> a woman who is in her period (?)
> He weeps, spending the day at the washboard
> He is told: 'Dirty Clothes!
> Bring yourself over here', and the (river) edge.
> (Parkinson 1991: 75)

The washerman described in this passage was probably a worker attached to a large estate of some kind. His work was similar to that of the men depicted in several Middle Kingdom reliefs at Beni Hasan (tombs BH2 and 3) and the New Kingdom tomb of Ipuy at Deir el-Medina (TT217; Newberry 1893: pls. XI, XXIX; Davies 1927b: pl. XXVIII; see Fig. 11.12 in this volume). It is likely, however, that the women from smaller establishments also washed the linen of their household.

It is known from a letter dating to the reign of Rameses II that washermen were also assigned to particular households in the Workmen's Village at Deir el-Medina. Various questions are raised in the letter to the scribe Amenemope about the work of one of the village washermen. It would seem that several complaints had been made about the man's inattention to his duties: 'Has the laundryman washed or not? It was only six (?) households that Pharaoh assigned to him. Now see, he has been assigned six households as two days' work, making three households per day' (O.DM 314; Wente 1990: no. 191).

A valuable source of information about the range and amount of work carried out by washermen comes from laundry lists inscribed on ostraca (potsherds or limestone chips). In some cases the lists provide information about the number of garments sent to be washed. In other examples, schematic, but still recognisable garments have been painted onto the sherds (Vogelsang-Eastwood 1992b: 105–11). Various garments can be identified on such sherds, including a loincloth, a tunic and a sash; other items of clothing recorded on the ostraca probably include skirts and kilts.

Judging from the depictions of the washing of cloth on the walls of several tomb-chapels of different dates at Beni Hasan and Deir el-Medina, the basic process appears to have been the same throughout the Middle and New Kingdoms. The first task was to dampen the cloth and then rub it, possibly with a detergent of some kind. During the Dynastic period, the Egyptians were able to use various natural detergents, such as natron (a natural soda), potash and the plant soapwort (*Saponaria officinalis*). The use of natron for washing clothes is incidentally indicated in the letter already quoted above: 'As for Nakhtsobek, I found no natron in his possession although you had given him [some] . . . As soon as you ascertain the [reason for the] delay, they shall procure natron for the (?) cloth' (O.DM 314; Wente 1990: no. 191).

Once the cloth had been rubbed with a detergent it was beaten with sticks or wooden clubs on a stone or a wooden base of some kind. It was then washed in water, rinsed and wrangled. The last task is depicted at Beni Hasan (BH3), where one end of the cloth is shown to have been wrapped around a post while the other was firmly twisted (Newberry 1893, pl. XXIX). The damp cloth was then left to dry in the sun.

The various lengths of cloth were laid flat on the ground and then held in place around the outer edges with stones.

Figure 11.12 A laundry scene depicted in the Middle Kingdom tomb of Khnumhotep at Beni Hasan (BH3).

The drying of cloth is portrayed in a scene in the Twelfth-Dynasty tomb of Sarenput I at Aswan (Müller 1940: Abb.14; Vogelsang-Eastwood 1994: 39, fig. 63). Drying items in this way would also have had the effect of sun-bleaching the various lengths of material. Once the cloth was dry, it could be folded and then stored until needed.

Textile marks

Most Egyptian textiles bear no markings, although a significant number of marked examples have been discovered. The function of such marks is not always clear, and we must look to the size, appearance and positioning of such marks to gain an understanding of their purpose.

Some marks are hieroglyphic or hieratic inscriptions, while others are more abstract in form; almost all were placed in a corner of the material where they would have been unobtrusive but easy to check (e.g. Eastwood 1985: 199, fig. 10.11). It would have been hard to remove such marks without leaving some traces of their original presence. The function of the various marks can be divided into three groups: weaver's/maker's marks; owner's marks and quality marks.

The idea of a maker's mark is quite common and can be found on many ancient objects. In the case of textiles, the mark is woven with an extra, thicker yarn, and is usually made up of a series of lines which travel no more than a few centimetres into the cloth before returning. From a distance of a metre or so the marks cannot normally be seen. The idea that such marks may come from a weaving atelier is perhaps supported by the fact that several pieces of cloth bearing the same mark, but of different qualities, were found at the Workmen's Village at Amarna (Eastwood 1985: 199).

Large quantities of Dynastic-period cloth have been found bearing the mark/name of the owner. Some royal cloth even has the regnal year in which the material was produced. It is likely that this was done not only to keep a check on the amount and quality of cloth within an establishment, but also in order to identify the owner when the cloth was sent to be laundered. Sometimes names were painted in black ink, which did not easily wash out, as in the case of the marks on textiles found in the burial of the so-called slain soldiers of Mentuhotep II at Deir el-Bahari (Winlock 1945: 25–32, pls. XVI–XX). In other cases, the mark was either embroidered or woven into the cloth. For example, a tunic wrapped around the body of Seti II bore the name of Merenptah, a son of Rameses II, embroidered in red and blue thread (Smith 1912: 74–5, diag. 16). Similarly, several of the loincloths from the Eighteenth-Dynasty tomb of Kha at Deir el-Medina (TT8) were embroidered with his name, while other items were inscribed with his name in ink (Schiaparelli 1927: fig. 62). Weavers' marks, inscribed in black ink, were also found on thirty of the seventy-six lengths of cloth recorded from the Eighteenth-Dynasty tomb of Ramose and Hatnefer (the parents of Senenmut) in the Sheikh Abd el-Gurna region of western Thebes (Lansing and Hayes 1937: 26; Porter and Moss 1964: 669); one of these marks was a private name (Boki), while the rest referred to the state or temple stores.

A number of textiles have distinctive patterns woven or embroidered into cloth with a blue or red thread (Leiden, RMO AU 38e; Vogelsang-Eastwood 1994: 41, fig. 66). Although located unobtrusively near the corner of the cloth, the colours of these marks make them considerably more striking than the weavers' marks described above. It is possible that such marks were used on large areas of cloth such as bedding or curtains, rather than on clothing where they would have been more apparent.

The last group of marks to be mentioned are the so-called 'quality marks' which are usually added to the corner of a piece of cloth with black ink (Vogelsang-Eastwood 1994: 41, fig. 67; and see Fig. 11.13). Normally there are two marks, one set above the other. It is likely that the uppermost symbol represents the institute which owned the cloth, perhaps a temple, while the lower mark may indicate the quality of the cloth.

Folding and storage of cloth

The study of how cloth was folded in ancient Egypt is of interest because virtually every country has developed its own method of folding material and clothing. The different styles of folding are related to the range of material used, the types of garments worn, and the methods of textile storage. In countries where large linen cupboards are the main form of storage, cloth is often folded so that there is a neat fold line with all the ends and sides of the material hidden. On the other hand, in places where cloth is stored

Figure 11.13 Various 'quality marks' inscribed on Egyptian textiles of the Dynastic period, all five of which are in the Egyptian Museum, Cairo.

in baskets, it is more appropriate to have a small, flat surface area, in order to store greater quantities.

Several different methods of storing cloth are known to have been used in Pharaonic Egypt. The method used depended not only on the available facilities but also on the size and type of cloth in question. In the wall-paintings of the Eighteenth-Dynasty tomb of Rekhmira (TT100), cloth is depicted in the form of flat lengths of material, long lengths and bundles, as well as having been packed in large sacks and boxes (Davies 1943: pls. XXX, XXXII, LVI, LVII).

Folded cloth was also placed in lidded baskets, as was the case with some of the textiles found in the New Kingdom tomb of Kha and his wife Merit (TT8; Schiaparelli 1927: fig. 80). In more elaborate circumstances, cloth was sometimes stored in boxes. In the Old Kingdom *mastaba* of Mereruka at Saqqara, there are several painted relief scenes showing servants carrying lengths of cloth and chests containing cloth (Duell 1938: pl. 72). Sometimes special linen chests were made, usually having a gabled form with a pair of knobs at one end (Lansing and Hayes 1937: 24, fig. 37). A rope or string could be looped around the knobs in order to fasten the chest securely. Several such linen chests were found in the tomb of Tutankhamun, some of them including lists on the lids which described the contents. According to the inscription on the lid, one chest (Cairo JE61500B) originally contained:

The box of *kdt*-wood . . .
What is in it belonging to the House-of-Repelling-the-Bowman:

Royal linen prepared as *mk*, various *swḥ*-garments	2
Royal linen prepared as *mk*, *ʾıdg3*-garments	10
Royal linen prepared as *mk*, long *sd*-garments	20
Royal linen prepared as *mk*, long shirts	7?
Total of various choice linen	39?

It should also be noted that fold marks in a garment could indicate status; thus, the Thirteenth-Dynasty group statue of Satsobek and her two sons (Leiden, RMO AST 47) includes the depiction of deep fold lines on the kilt of one the sons, while his immaculately pressed attire is used to indicate wealth and status.

The uses of textiles

The uses of cloth in ancient Egypt may be divided as follows: 'clothing'; 'household'; 'outside'; 'economic'; 'ritual' and 'funerary'.

Clothing

The basic form of Egyptian clothing can be divided into two types: wrap-arounds and cut-to-shapes. Wrap-around garments consist of a length of cloth wrapped around the body in various ways; this group includes kilts, skirts, cloaks, shawls and most dresses. Cut-to-shape garments tend to be simple triangles or rectangles, sewn down some or all of the edges and fastened with ties; these garments include loincloths, tunics, and one particular type of dress. There is no evidence to suggest that the garments were normally closely tailored to fit individual figures. Similarly, no garments from the Dynastic period have been recorded with pads, darts or complex shaping, elements which are common to modern clothing.

In ancient Egypt – as in many other cultures – the types of clothes worn by individuals reflect their social status. In general, the more clothes a person wears, the higher is his or her social position. Differences in rank were also indicated more by the quality of the cloth worn than by other factors, such as the way in which a garment was constructed. Loincloths and tunics worn by workmen tended to be made of a strong and solid cloth (Vogelsang-Eastwood 1993: 10–12), while those belonging to a pharaoh such as Tutankhamun were made from a fine, almost silk-like, linen (Carter no. 43g; JE 29/3/34/10a–b; thread count of 112 warps and 32 wefts per centimetre). The basic construction of all of these garments, however, was similar regardless of status. Unlike modern garments, ancient Egyptian clothes were characterised by few variations in the way that they were made, and forms tended to remain the same over long periods. Changes more commonly occurred firstly in the way that garments were draped around the body and secondly in terms of combinations of different garment types.

Loincloths, kilts, skirts, aprons, sashes and 'Archaic wrap-arounds'

Loincloths were worn by most of the population (male and female) for virtually the entire Dynastic period. The loincloth is a simple garment, part of which is wrapped around the waist while the rest is drawn between the legs (Vogelsang-Eastwood 1993: 10–31; see Fig. 11.14); it is, however, a versatile garment which could be worn by itself, either open or closed at the front; tied at the top with a sash or worn under other garments. One of the more unusual garments in the ancient Egyptian's wardrobe was the leather loincloth, which seems be one of the few types of garments which were introduced into Egypt from Nubia, rather than *vice versa*. It was most popular during the New Kingdom and was only worn by men, particularly soldiers, sailors and servants. One surviving example was found in a painted box bearing the name of Maiherpri (Boston, MFA 03.1035; Carter 1903: 46–7; see Fig. 11.15). There were also depictions in the tombs of pharaohs and high court officials, showing loincloths being worn by servants and officials (e.g. Davies 1930: pl. XVI).

One separate item worn by men, either by itself or under another garment such as a kilt (Vogelsang-Eastwood 1993: 32–52), was the apron. It was worn from at least the Old Kingdom onwards, and it consisted of one or more pieces of

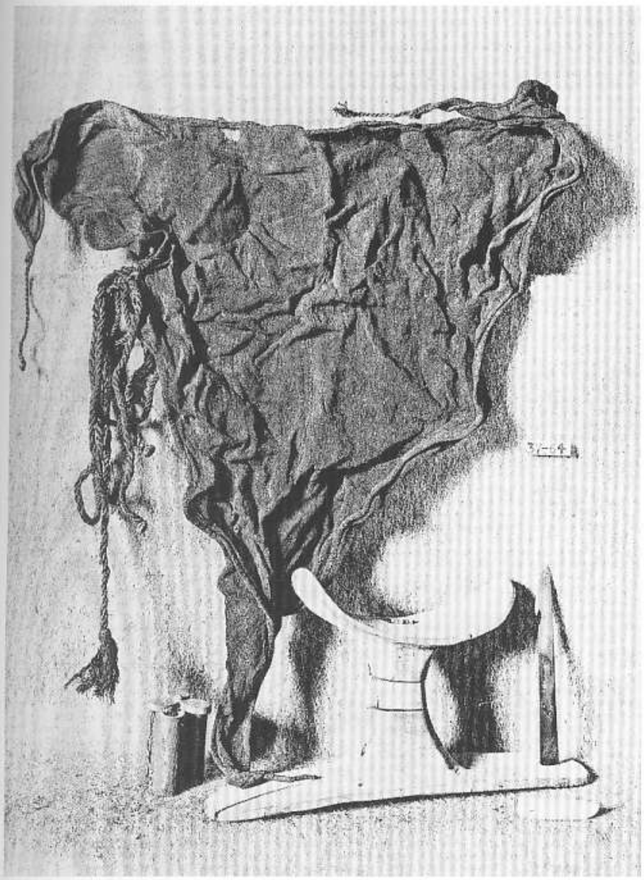


Figure 11.14 A linen loincloth from a 'rectangular gable-topped coffin' at Deir el-Medina.

cloth attached to a belt, sash or band which is fastened around the waist. In general, the apron panel only covers the genital region. Aprons can be simple triangular shapes or elaborately ornate pleated items which extend from the waist to the ankles. Two such are known from the tomb of Tutankhamun, one being made of beadwork (Carter no. 269c (3) [i]) and the other of metal inlaid with glass or gemstones (Carter no. 256j, JE 60685).

Representations of kilts and skirts can be found dating back to prehistoric times. A kilt is a wrap-around garment worn by men, which covers part or all of the lower half of the body (Vogelsang-Eastwood 1993: 53–71). A skirt is a similar garment, but is worn by women. These garments can vary considerably in both size and form. In some cases they are simple items which only covered the hips, but more extreme forms of kilts and skirts could cover all the way from the chest to the ankles. Although the basic construction of kilts and skirts was similar, in general kilts were more elaborate than skirts. Sometimes the men's short kilt was pleated, as portrayed in the painted reliefs of the Fifth-Dynasty *mastaba* of Khafkhufu at Giza (Simpson 1978: fig. 29), and sometimes the pleating extended from half-way around the front to the middle of the back, as depicted in the Sixth-Dynasty *mastaba* of Idut at Saqqara (Macramallah 1935: pl. XX).

In addition to the simple kilts described above there is a second form of kilt known as a sash-kilt, which became fashionable in the New Kingdom. It was worn over other garments, notably the tunic (Vogelsang-Eastwood 1993: 65–71). There were two basic methods of wrapping the sash-kilt: the first method involves a length of cloth which is wrapped around the hips once and then tied with a simple half-knot at the front, as illustrated in the Eighteenth-Dynasty tomb-chapel of Ramose at Thebes (TT55; Davies 1941:

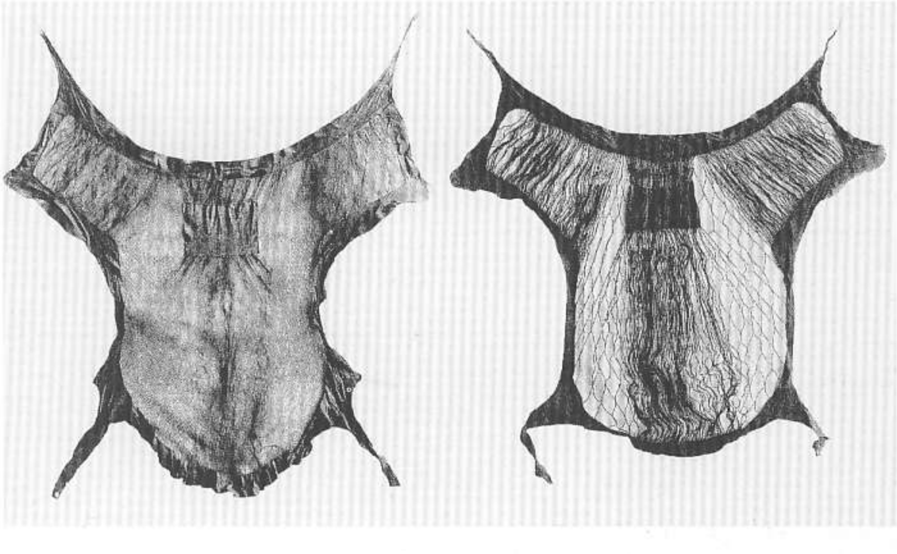


Figure 11.15 Leather loincloths from a New Kingdom box bearing the name of Maiherpri. The cloth on the left is now in the collection of the Museum of Fine Arts, Boston (acc. no. 03.1035), but the present location of the other is unknown.

pl. XXXII); the ends are then allowed to hang decoratively down the front. In the second method, one end of the sash is allowed to hang down from the waist to just above the knees, as in the statuette of Nebnefer (temp. Ramesses II, current location unknown; Wild 1979: pl. 33), while the rest of the cloth is wrapped around the hips (from left to right) and then tucked in at the top.

Sashes are long, narrow lengths of cloth which were worn around the waist. They were often used to secure another garment, such as a kilt or skirt (Vogelsang-Eastwood 1993: 72–87). They can be made of rope (Carnarvon and Carter 1912: pl. LXIX/1), a plain length of cloth (Leiden, RMO Cat. no. 260) or with a fringe for decoration (Carter no. 101m). Sashes decorated with tapestry-weave designs were found in the tomb of Tutankhamun (Carter nos. 21ff, Cairo JE 62645; 21gg, JE 62646). A more elaborately made sash is the so-called 'girdle' of Rameses III (see p. 276). Another form of sash, comprising a back panel with four red streamers, was found in the tomb of Tutankhamun (KV62) (Carter no. 100f, JE 62647).

The 'Archaic wrap-around' is one of the oldest Egyptian clothing types of the Dynastic period. It was worn in a similar manner by both men and women, although in general the female version was much longer than that of men (Vogelsang-Eastwood 1993: 88–94). The effect of an Archaic wrap-around can be recreated using a single rectangle of cloth. The top corner of the material is draped over the left shoulder. The cloth is then passed one or more times around the body and under the arms ending near the left arm-pit. The two top corners are tied together on the left shoulder, giving the impression of a shoulder strap. The garment was then sometimes kept in place with a sash.

Dresses

The dress is a garment specifically worn by women; it generally fits closely to the upper part of the body and has either a flowing or a tightly fitting skirt (Vogelsang-Eastwood 1993: 95–129). It was the most common form of female clothing throughout the Dynastic period and was worn by all women regardless of their social position. There were three basic dress types: wrap-around dresses, V-necked dresses and beaded dresses.

Wrap-around dresses were made out of long lengths of cloth and were wrapped around the body in various ways to produce different effects. They can be divided into two types: simple and complex. The simple wrap-around dress – depicted in Egyptian art from the Old Kingdom onwards – was made out of a length of cloth wrapped between one and three times around the body, depending upon the amount of cloth available. The end of the cloth was tucked in at the top (see depictions in the Eighteenth-Dynasty tomb of Rekhmira at Thebes; Davies 1943: pl. LXIV) and it could be worn either with or without shoulder straps.

Complex wrap-around dresses appeared during the New Kingdom; they could be made out of one or two lengths of cloth, and their principal forms are portrayed on a New Kingdom stele in the British Musem (EA36; Davies 1926: pl. XII, 1941: pl. XI). They were knotted, tucked in or secured in place with a sash, or a with a combination of these fastening methods. On the basis of surviving examples and the study of representations, it would appear that there are two forms of V-necked dress: sleeveless and sleeved.

The sleeveless form has a deep V-neckline and two examples are known. One was found spread over the mummy of a woman (Reisner 1942: 451–2, pl. 42; Roth 1988: 76–7; see Fig. 11.16) and was described by the excavator, George Reisner (1942: 452), as 'a large sheet of linen . . . laid over the body, looking like a tunic with a V-shaped neck, leaving arms and the lower part of the legs exposed'. Unfortunately this example was destroyed during the examination of the mummy, therefore it is not certain how the garment was made. A second example was found more recently at Saqqara (Munro 1983: 102–3) but it was in an extremely poor condition, thus again preventing any analysis of construction methods.

The V-necked dress with sleeves was a cut-to-shape,

Figure 11.16 Mummy wearing a V-necked dress of the sleeveless type (now destroyed).

usually pleated garment (Riefstahl 1970; Landi and Hall 1979; Hall 1982; Vogelsang-Eastwood 1993: 115–25; see Fig. 11.17). At least fifteen ancient Egyptian examples have been excavated, ranging in date from the Fifth to the Eleventh Dynasty and dying out by *c.* 2000 BC.

Beaded net-dresses were made out of beads strung together in geometric patterns, usually diamonds. So far only two have been identified. The first was found in Mastaba G7440Z at Giza and probably dates to the Fourth Dynasty (Boston MFA 27.1548; Jick 1988) and the second was found in a Fifth-Dynasty tomb at Qau (tomb 978; Petrie Museum UC 17743; Hall 1986: 64–5). The Qau example was made up of a series of beads and the breasts were covered and accentuated by two small caps made out of blue faience with nipples in black (see also Kamal 1901: 34, 38; Brunton 1927: I, 64).

Figure 11.17 Old Kingdom V-necked dress with sleeves, from Asyut (Louvre E 12026).

Tunics, shawls and cloaks

The tunic or bag-tunic (*mss*) was made up of a long rectangle of cloth folded in half and sewn up the sides (Janssen 1975: 260; Hall 1981; Vogelsang-Eastwood 1993: 130–54; see Fig. 11.18). There are two forms. The full-length tunic, covering the body from the shoulders to the calves or ankles, was worn by both men and women. The half tunic, stretching from the shoulders to the buttocks (or, less frequently, the knees) was only worn by men. Both the half and full-length tunics were worn by themselves or with other garments.

Occasionally tunics are found with sleeves, which were constructed by two basic methods. In the first method, the sleeve is made out of a single length of cloth which narrows towards the wrist, as in the case of two examples from the Eighteenth-Dynasty Workmen's Village at Amarna (nos. 2674 and 1560 in the unpublished catalogue of textiles from the village; see also Hall 1980: 29). The second form of sleeve is again shaped, but this time there is a flat seam placed at the centre of the back of the sleeve (Vogelsang-Eastwood 1993: 137, fig. 8/4).

Most surviving tunics are plain, but various decorative elements are known to have been used. The basic forms of

Figure 11.18 Long tunic from the New Kingdom tomb of Kha at Deir el-Medina (TT8; Turin, Museo Egizio, Inv. suppl. 8530).

decoration are: fringing along the bottom edge (Petrie Museum UC 28616Ci and Brussels E.6205), the use of coloured bands woven into the cloth along the selvedges and transverse edges (Leiden, RMO E1), vertical or horizontal bands woven into the garment (Carter no. 261a, Cairo JE 62706; Carter no. 50j, JE 62757), and the use of coloured bands sewn onto the garment along all of the edges of the garment and around the neckline (Carter no. 367i, JE 62626; see also Schiaparelli 1927, fig. 69). In addition, beadwork, sequins of gold and faience, applied pattern bands, and embroidery were sometimes used to decorate tunics (see p. 279ff., decorative techniques).

Shawls and cloaks are outer garments worn by both men and women (Vogelsang-Eastwood 1993: 155–68); they normally consisted of a square or rectangular piece of cloth. Shawls only covered the upper part of the body, while cloaks were much larger and covered most if not all of the body. Shawls were worn over the shoulders and allowed to hang down the back. Two basic types of cloaks are known to have been worn in ancient Egypt. The first was a simple length of cloth wrapped around the body, one example being a protodynastic figurine of a woman (Ashmolean E.326; Quibell 1900: I, pl. IX). The second form was made from a length of cloth with two ties knotted on one shoulder (Davies 1900: I, pl. XVII; Davies 1948: pl. XXVI; see Fig. 11.19).

Leggings

There are three pairs of leggings in the Egyptian Museum, Cairo (nos. 13/1/26/19 and 13/1/26/18). They are made from a long rectangle of cloth folded in half and sewn (overlap seam) down the back, each having a single, very long tie knotted to the front top; this tie was probably wrapped several times around the leg. At the bottom, and set off-centre, there is a V-shaped notch cut out of the material. To date no representations of Egyptians wearing these garments are known. In the late Eighteenth-Dynasty tomb of Ay (KV23), however, there is a depiction of a table bearing various items, including gold collars, gloves and what have been described as 'collars?' (Davies 1908: pls. XXX–XXXI) although they may actually have been leggings.

Figure 11.19 Detail from a painted wall-relief in the Old Kingdom mastaba *of Ptahhotep and Akhethotep at Saqqara, showing a hunter wearing a knotted cloak.*

Kerchiefs

A kerchief is a piece of cloth which covers part or all of the head (Vogelsang-Eastwood 1993: 169–78). In general it is made out of a single piece of cloth, usually rectangular, kept in place with a headband of some kind or tied with a piece of string at the back of the nape (e.g. Copenhagen, Ny Carlsberg Glyptotek AE IN 670; Davies 1936: II, pl. XCVII). More elaborate versions, worn by kings and princes (the *khat* headdress), were made out of two semicircular pieces of cloth sewn together (e.g. Winlock 1916; New York, MMA 09–184.217–219; Carter no. 46i, 29/3/34/30a-d). A separate tie or tape was sewn to the centre-top of the semicircle of cloth which was used to fasten the garment to the head. Several examples of these kerchiefs were recorded from the tomb of Tutankhamun (KV62).

Combinations of different garments

The ancient Egyptians used various combinations of the garments described above. The attire of both sexes varies chronologically. Men in the Old Kingdom might wear some combination of loincloths, short wrap-around kilts, long narrow aprons, sashes and long cloaks. In the Middle Kingdom they often wore loincloths, wrap-around kilts of various lengths, long, narrow aprons and triangular aprons, sashes, short shawls and long cloaks might be worn. New Kingdom male attire included loincloths, wrap-around kilts of various lengths (sometimes two worn together), sash-kilts, triangular aprons, tunics, sashes, knotted and wrap-around cloaks of various kinds.

Women in the Old Kingdom wore loincloths, skirts of various lengths, wrap-around dresses (usually simple forms), V-necked dresses, sashes and long cloaks. In the Middle Kingdom they often wore loincloths, skirts of various lengths, wrap-around dresses (usually simple forms), V-necked dresses, sashes and long cloaks. Their New Kingdom wardrobe comprised loincloths, skirts of various lengths, wrap-around dresses (both simple and complex forms), sashes, tunics and long cloaks.

Household uses

Textiles were very widely used in ancient Egypt, and constituted an important part of Egyptian daily life. Perhaps the most obvious and familiar use of cloth was within the household. Although it may be presumed that material was used for curtaining and wall-hangings, it is difficult to find actual evidence. Other household uses ranged from cushions, curtains and bedding to more prosaic items such as spice bags and lamp wicks. Although it is likely that the ancient Egyptians used curtains and wall-coverings, especially on the inside of the buildings, no examples or depictions of such items have yet been found.

Towels

One of the more familiar, modern uses of textiles is that of towels made in order to dry either an object or a person. There are numerous examples of ancient textiles with all-over patterns of looping, similar to modern terry-towelling. Several such cloths were found in the mass-burial of sixty soldiers at Deir el-Bahari (Winlock 1945: 32), and two other textiles of this type were found in an Eleventh-Dynasty tomb at the same site (tomb no. DB813; Winlock 1945: 32; Riefstahl 1944: 16–17, fig. 19). The textiles have a pattern of chevrons, zig-zags and bands of different widths.

Cushions

Ancient Egyptian representations include depictions of a variety of cushions. There were at least four different ways of using them: long, lounging cushions for which a textile now in the Victoria and Albert Museum may have been a cover (VA T251.1921; Davies 1903: I, pl. VII), chair cushions (e.g. the tomb of Huya at Amarna, EA1; Davies 1905: pl. IV), stool/chair cushions (as depicted in the Theban tomb of User, TT260; Greenlees 1923: 131, pl. XXI) and footstool cushions (e.g. the tomb of Huya; Davies 1905: pl. IV). A footstool was found in the Eighteenth-Dynasty tomb of Yuya and Tuyu (KV46; Cairo CG3675); it is made from two roughly rectangular pieces of linen tightly packed with feathers. The size and solidity of this cushion suggests that it was used as a footstool of some kind. A possible long cushion or pillow, made out of red leather and stuffed with bulrush down, was found in the Eighteenth-Dynasty tomb of Ramose and Hatnefer at Thebes (Lansing and Hayes 1937: 16; Porter and Moss 1964: 669).

Beds

Ancient Egyptian beds were made up of rectangular frames mounted on four legs. The base was made from an interlacing structure of rope, sometimes woven into intricate patterns. On top of this matting there was a length of cloth serving as a mattress which had a deep pile made from numerous closely-set loops as in the bed from the tomb of Kha (TT8; Schiaparelli 1927: II, fig. 105; see Fig. 11.20). Over the piled cloth were placed more lengths of material to act as covers or sheets. It is likely that in winter-time additional layers were used, and possibly a woollen blanket. Instead of a pillow a headrest, usually made from wood, was placed at the head of the bed.

More elaborate beds might be surrounded by canopies. A bed canopy was placed inside the tomb of Hetepheres, mother of the Fourth-Dynasty ruler Khufu (Reisner and Smith 1955: 23–7). It measures about 3.20 metres in length, 2.50 metres in width and 2.20 metres in height. It was decorated with gold, and around the inside of the top beams there are small copper hooks which may well have held the drapes covering the top of the canopy and hanging down its sides. Unfortunately, they have not survived, although they may originally have been placed in a long box which was found in the queen's tomb.

Figure 11.20 Bedding from the tomb of Kha (TT8) at Deir el-Medina (Turin, Museo Egizio, Inv. Suppl. 8629–36).

Bags

As with modern bags, the size, range and functions of ancient Egyptian bags were extensive. They were used for carrying spices, as well as small amounts of grain, and were made from lengths of cloth folded in half and sewn down the sides (Leiden, RMO AU 41). Cloth sacks for carrying cumbersome or numerous objects were also in use, judging from depictions in a number of tomb-paintings, such as those in the Eighteenth-Dynasty tomb of Neferhotep (TT 49; Davies 1933: pl. XVIII).

Lamp wicks

The Egyptian hieroglyph for a lamp wick, (Gardiner 1957, sign type V2) clearly shows the basic form of the ancient wick, which was made by twisting a length of cloth or fibres, and then allowing the length to twist back on itself (Eastwood 1985: 202, fig. 10/15). The wick was then allowed to float in the lamp oil.

Seals

The use of cloth as part of a seal has a long tradition in Egypt. Seals were not only used within tombs to fasten and secure doors, but they were also used inside houses, palaces and temples to secure workshops and more particularly storerooms. In addition, they were used on commodities such as jars, with the material placed over the opening of the jar before dropping a plug of clay in place (e.g. Leiden RMO. F.1957/11.4). A second length of cloth was sometimes placed over the clay plug. Occasionally a blob of clay was placed at the ends and then an impression of the owner's mark was made by pressing a seal into the damp clay.

Uses outside the home

The uses of textiles outside the home ranged from items such as the cloths used to cover an object to sacks for the transportation of grain. One of the most widely used methods of extracting oils and juices was to strain the liquid through a piece of cloth. Such strainers would have been strong but flexible, and depictions of the production of wine indicate that two forms of cloth wine strainers were used (see Chapter 23, this volume). One end of the bag could be tied to a fixed support, while the other was fastened to a pole, which was then twisted by several men as depicted in the tomb-chapel of Bakt III at Beni Hasan (BH15; Newberry 1893: pl. VI). In the second method, both ends of the bag were tied to poles and two groups of workmen wrung the bag by turning the poles in opposite directions as in the scene portrayed in the tomb-chapel of Amenemhat at Beni Hasan (BH2; Newberry 1893: pl. XII; see Fig. 11.21).

Another use for cloth strainers was in the production of oils (see Chapter 17, this volume). There are several New Kingdom and later tomb-reliefs which show the production of perfume oils. In most cases the seeds or flowers are placed in a cloth bag. These bags are not as large as those used for wine-making, but they were wrung in the same way as wine bags. A fragment of relief dating to the Ptolemaic period (Turin 1673) depicts the extraction of lily essence by this means.

Textiles were also used in the equipping of animals and the vehicles drawn by them. Donkeys were one of the main pack animals of the ancient world and to protect their backs the animals were covered in a cloth. Back cloths of this type have been depicted in numerous tomb-chapels of the New Kingdom, although no actual examples of this date have been found. A saddle cloth of the first century BC was found at the Red Sea coastal site of Quseir el-Qadim (Vogelsang-Eastwood 1990: 197). It was made from numerous layers of small fragments of cloth sandwiched between two layers of coarse material. Cloths made in an identical manner are in use for donkeys in rural Egypt today and it is probable that the back cloths of the Dynastic period were made in the same way. Occasionally more valuable animals, such as cows and bulls, are shown wearing a cloth covering on their backs as in the Sixth-Dynasty tomb of Isi at Deir el-Gabrawi (Davies 1902: pl. XIX). In such cases it would seem that these blankets were designed to stress the animals' importance, rather than having a more practical function as in the case of the cloths described above. Another form of animal trapping are the blankets worn by horses during the New Kingdom. The remains of such a horse blanket (housing) dating from the New Kingdom were found in association with the mummified horse buried in front of the tomb of Senenmut at Thebes (TT71; Lansing and Hayes 1937: figs. 14–15). A large piece of cloth, with wide bands sewn onto it, was used. Elaborate versions of this type of cloth can be seen in representations of Tutankhamun and Rameses II, riding their chariots into war. Such textiles are also depicted on the hunting chest of Tutankhamun (Carter no. 21; Cairo JE 61467). It is also probable that another textile from the tomb of Tutankhamun (Carter no. 333; JE 61992e) was also part of a horse blanket. There is also a depiction of a horse blanket in the Eighteenth-Dynasty tomb-chapel of Kenamun at Thebes (TT93; Davies 1930: pl. XXII).

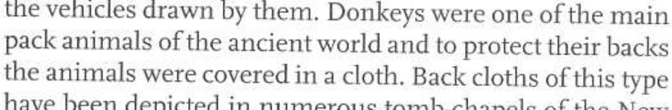


Figure 11.21 Detail from a wall-painting in the Middle Kingdom tomb of Amenemhat at Beni Hasan (BH2), showing the use of a cloth grape-juice strainer.

Another use for textiles in relation to chariots is that of coverings for the floor of the vehicle itself, upon which the occupants could stand. Several textiles have been found in the tomb of Tutankhamun (associated with chariots nos. 120 and 122). One cloth is covered with a dense layer of loops, and it is likely that they were used as a springy layer, cushioning some of the bouncing movement of the chariots.

Cloth was also used on ancient Egyptian boats, primarily for sails and awnings but probably also for such purposes as coverings over merchandise, although at present there is little information about the latter more minor uses. Most information about Egyptian sails derives from funerary models and various representations of boats in tomb-paintings. In most cases the sails are shown as large sheets of cloth, one of which was recently found re-used as a set of mummy-wrappings when a mummy was unwrapped in the Musée des Beaux Arts, Lyon (Goyon and Josset 1988: 129–32). The bandages were removed and laid out, and by matching various structural details (seams and hems) it was discovered that the cloth originally came from a shaped sail. The great wooden boat found in a pit near the pyramid of Khufu (see section on boat-building in Chapter 15, this volume) included fourteen poles which were fitted into holes along the sides of the boat forward of the cabin (Landström 1974: 34, Abb.90). These poles were originally used to hold up a large awning, presumably made of cloth, under which the king and his entourage could have sat.

Although there are several references in Egyptian texts and representations to the use of cloth or matting tents, no tents appear to have survived or have been recognised as such. Tents were mainly used by the court or by soldiers while on the move. Military tents (including a possible rolled-up example) are depicted on fragments of relief from the late Eighteenth-Dynasty tomb of Horemheb at Saqqara (Martin 1989: 37–8, 44 and pls. 28, 29 and 35), and they also feature in the depictions of the Battle of Qadesh in several of the temples of Rameses II (Wreszinski 1923–42: II, no. 92a). The use of tents by the New Kingdom court is indicated on one of the boundary stelae (stele F) at Amarna, where there is a reference to a tent made of matting (Davies 1908: 32). In addition, there is a brief literary reference to couriers on the move who used tents: 'be his home of cloth or brick', in the Middle Kingdom work *Satire of the Trades* (see Lichtheim 1973: 188).

Flags played an important part in the decoration of temples and palaces in ancient Egypt. They were used both on the outside of the building and around internal courtyards. For example, in a depiction of one of the palaces at Amarna, flags are shown in such a courtyard (Davies 1903: I, pl. XXXI). Similarly, there are numerous depictions of New Kingdom temples which have two sets of flags set against the outer pylons (Davies 1903: I, pl. XXVII). Rameses II describes the erection of similar flagpoles during the redesigning and extension of the eastern part of the Temple of Amun at Karnak: 'very great flagstaffs, I erected them in the noble courtyard in front of his temple' (Spencer 1984: 10).

The use of decorated cloth for identification purposes by military forces is well-known from various historical sources and is still practised. Each section of the ancient Egyptian army used standards as a means of identification, and they are usually portrayed as plaques with pairs of streamers placed beneath (Davies 1903: I, pl. XV).

'Economic' functions

The ancient Egyptians did not have coinage until the end of the Dynastic period, therefore most transactions were based on a bartering system in which the rough value of most objects was known to both seller and purchaser. Surpluses of any goods were usually bartered in order to make up any deficiencies, and cloth and made-up garments played an important role within this bartering system. All wages in ancient Egypt were paid in kind, frequently in foodstuffs, but also in metalwares, basketry or textiles (although it is not clear whether these goods should be regarded as wages or as rations, see Janssen 1975: 455ff; Kemp 1989: 237). There are various direct references to garments being given as wages. Papyrus Turin 1881 records seventy-eight items of cloth or clothing as the wages of a group of men (see also O.Cairo 25504; Janssen 1975: 492). Cloth and clothing were also among the items sent by Rameses IX to the 'feather-wearing Nubians', according to Papyrus Cairo C-D (Wente 1990: no. 38) in which two garment types are referred to specifically: twenty-five *dw*-clothing (probably kilts) of *sm*-cloth, and twenty-five tunics of 'smooth cloth'.

In addition to being used as wages or rations, textiles were also used in a direct manner to acquire other objects. A Nineteenth-Dynasty letter from the village at Deir el-Medina (O.DM 125; Wente 1990: no. 229) was sent to a woman called Henutudjebu, asking her to acquire a tunic on behalf of the sender 'in exchange for the bracelet and have it furnished to me [in] ten days' (see also O. DM 185; Janssen 1975: 279, 281). Another way in which large households and temples might have acquired textiles was by using the so-called 'traders' (*šwtyw*). These were men who travelled up and down the Nile with surplus goods produced on the estates, trading them for objects that were in short supply within the households or temples.

Income had to be found from various sources in order to support royal expenditure such as the court, temples, building programmes and the army. Part of the income was raised through country-wide tax levies, paid in the form of animals and goods up to a certain value (Kemp 1991: 237). An example of this form of taxation can be seen in the wall-paintings of the Eighteenth-Dynasty tomb of Rekhmira at Thebes (TT100; Davies 1943: pl. XXXI), where the 'recorder' and 'scribe of the recorder' of the town of Wah-set (south of Abydos) are shown delivering linen garments as well as lengths of linen cloth, some carried in a chest.

In addition to using cloth already available in a household, the weaving of lengths of material was sometimes commissioned for specific purposes, including the renting of land. In one of the early Middle Kingdom 'Hekanakhte letters', a farmer writes to his sons telling them to have some cloth woven and to use it, if necessary, to rent some land: 'I said "Weave it", and they shall take it [the cloth] when it has been valued in Nebeseyet and rent land against its value' (P. Hekanakhte no. 1; James 1962: 13).

As well as new cloth, it would appear that there was a thriving trade in second-hand textiles, some of which came from private households, where the selling of excess material in order to purchase other items was not unusual. A New Kingdom story recounts the tale of a woman who sent her servant out to the market in order to sell a length of cloth, perhaps a cloak, but was unable to make the sale because of its poor condition (Janssen 1980). It is also likely that some of the cloth presented for sale at the markets had been robbed from various tombs. This point is reflected in some Twentieth-Dynasty trial records of tomb-robbers. Among the numerous items stolen from various tombs was 'royal linen, *mk* linen, good Upper Egyptian linen, rolled and bound, various garments [total] 63; skeins of thread [total]1' (Peet 1930: 89).

Large quantities of cloth were given by various ancient rulers to each other in order to cement their relationships. When the Mitannian king Tushratta sent his daughter to marry the pharaoh Akhenaten, the dowry included numerous garments and other textiles (Amarna Letters EA14 and 25; see Moran 1992: 32, 80). Similarly, surviving records state that Akhenaten sent the Babylonian king, Burnaburiash II, a total of 1,092 items of 'linen cloth' (textiles and clothes). In addition to cloth being given as part of a dowry or official gift, it is likely that linen was also used to pay obligation gifts. These are gifts which would have arisen out of a duty or obligation to someone else, symbolising the debt owed by one person to another.

Textiles were probably often obtained as booty from various foreign conquests. In 1457 BC Thutmose III is said to have sacked the city of Megiddo in Palestine, bringing back with him, according to various accounts, quantities of cloth and clothes (Breasted 1906: no. 436), and it is likely that cloth was also brought back to Egypt among the loot and booty of other expeditions. It may even be that in this way both new production techniques and foreign weavers were brought into Egypt during the New Kingdom.

Medical uses

Because of the Egyptians' interest in mummification, the art of bandaging was highly developed at a very early date. Indeed the term *wt* is sometimes used in Egyptian documents to refer to a medical bandager and a bandager of bodies in the course of mummification (Ghalioungui 1983: 6–8). There are various references in the Edwin Smith Surgical Papyrus, to the use of bandages and raw flax for medical and surgical uses (Breasted 1930). There are also references to the use of raw flax being placed on wounds in order to absorb pus or blood and thus serving as a swab (Ghalioungui 1973: 43).

Bandages are described in the surgical thesis of Papyrus Edwin Smith as 'coverings for physician's use' and various different ways of using them are recorded in the case studies, including their employment as covers or splints. Bandages were used both for covering a wound and for keeping medicaments in place. One of the ways in which a flesh wound was treated was by placing a piece of raw meat over it, and keeping it in place with a bandage (P. Edwin Smith, case 32). If the sides of a wound needed to be brought together then paired strips of cloth were used to close the gap (P. Edwin Smith, case 10). It is likely that these banadages were impregnated with wax in order to keep the cloth in place. In addition, various medicaments, such as grease and honey, were soaked into the bandages in order to have healing agents locally applied (P. Edwin Smith, case 14).

The Edwin Smith Papyrus describes three different forms of splint. The first is the mouth splint, whereby pieces of wood bound with cloth were placed in the mouths of patients whose jaws had locked, perhaps because of tetanus, and who could only be fed with liquid food (P. Edwin Smith, case 7). The second form of splint was the so-called soft splint made up of rolled linen used as a plug for a broken nose (P. Edwin Smith, cases 11 and 12); this type of splint was also known as 'posts of linen'. Another form of soft splint was a roll of linen placed behind a wounded ear in order to support it (P. Edwin Smith, case 23). The third type of splint discussed in the papyrus was used for mechanically retaining a major break in position. In such cases wooden splints were padded with linen and then bound around a fracture in the leg or arm. Splints of this type were found around the broken forearm of a Fifth-Dynasty mummy (Smith and Dawson 1924: 161, fig. 69). In the Hearst Papyrus there is a reference to bandages being soaked in some form of starch (Worth Estes 1989: 63); once the starch had dried it took on a hard, stiff form, similar to modern plaster casts.

Religious uses

Mention has been made above of various secular uses of textiles, but cloth also had an important ritual function in temples. One of the rituals which occurred throughout the country on a daily basis was the washing, feeding and clothing of the statues of deities within the various temple sanctuaries. A text in the temple of Seti I at Abydos contains a reference to 'adorning Amun-Ra with red, green and white garments' (Calverley and Broome 1935: pl.12). The exact nature of the 'clothing for the gods' is not clear, but there are two main possibilities: firstly that actual garments were made and either presented to the gods by laying them in front of the image or actually fitted onto the statues; secondly that a length of cloth was wrapped around the statues, perhaps like a cloak, in a manner similar to the ritual figures found in the tomb of Tutankhamun (KV62; Reeves 1990: 130). Of the two possibilities, the second would seem the more likely.

Although the material for clothing the gods was often woven in the temples, textiles were sometimes donated by outsiders. An inventory was made of all the property and goods given by Rameses III to various temples, and among the numerous items are garments and linen which he gave to the gods, including 'wrappings of Horus [total] 2' and 'garments for the august statue of Amon [total] 4' (Breasted 1906: 232). Special garments were made for particular events, such as the Festival of the New Year. As part of the endowment of the temple of Amun at Thebes, Thutmose III ordered that the god should be given new clothing: 'the donning of linen garments and offering of anointing oil in the entire house as is done at the New Year's Day festival . . .' (Cumming 1982: 1255).

In the temple at Medinet Habu, there was a room which is now known as the 'clothing room' (*Medinet Habu* VI/2: pl. 444). One of the wall-reliefs shows the king about to clothe the statue of a god with garments which are depicted as lengths of cloth (rather like an upside-down Y) instead of conventional items of clothing. When it was time to dress the statue again, the old and now 'sanctified' garments were put on one side for other uses, notably as bandages for mummies (Andrews 1984: 25). This detail would suggest that lengths of cloth, rather than actual garments were meant when reference was made to the 'clothing of the gods'.

Funerary uses

One of the most important uses of cloth was related to funerary rites. Tait (Tayt, Tayet), the goddess of weaving, is occasionally associated with funerary practises. Mummy bandages were sometimes known as being or belonging to the 'land of Tait', and one of the earliest references to this goddess appears in Utterance 417 of the Fifth- and Sixth-Dynasty Pyramid Texts, where she is described as clothing (i.e. wrapping with bandages) a dead king: 'While (?) the Great One sleeps upon his mother Nut, your mother Tait clothes you, she lifts you up to the sky in this her name of Kite' (Faulkner 1969: 137).

Most ancient Egyptian burials contained items which were regarded as essential in this life and thus equally important in the next. These objects included pottery, food, jars, cosmetic items, tools and weapons, as well as textiles and clothing. In addition, cloth was placed in the tomb in the form of covers for amulets and statues, and incidentally as cloth being wrapped around cuts of meat and other foodstuffs. The quantity of cloth found in a tomb can be considerable. It has been estimated that Wah, estate manager to the early Middle Kingdom vizier Meketra, had a total of 845 square metres of cloth in his tomb (Winlock 1940: 257), including 375 square metres of linen around the body, the rest being made up of pads and lengths of cloth which ranged in length from 2.56 to 25.6 metres. The tomb of Tutankhamun (KV62) contained at least 400 items of cloth, including clothing, covers for ritual figures, linen arrow quivers, lamp wicks and the trappings for a chariot (Vogelsang-Eastwood and Kemp 1999).

The main element in the furnishing of the tomb was the coffin. This was usually covered with a large length of cloth or pall, the length of which could vary from two or three metres to about twenty, depending on how it was used. In representations of funerals the pall is usually shown as a small piece of cloth, so that the coffin underneath is still visible. The pall was also frequently painted red as this colour was associated with death and regeneration. Tutankhamun was buried inside three coffins, a sarcophagus and four shrines. The second shrine was enclosed by a frame covered with a large sheet of cloth made out of several lengths of material sewn together and decorated with gold rosettes to represent stars (Carter no. 209; Cairo JE 62745a).

A shroud, or cloth cover, was also placed over, and sometimes around, the body. Sometimes only one cloth was placed on the mummy, and in other instances several were used. Most shrouds consisted of a single length of cloth wrapped around the body, sometimes being inscribed in ink with spells, or chapters, from the Book of the Dead, as well as the name of the deceased (see Quirke *et al.* 1995). Occasionally actual garments were used as shrouding; the Eighteenth-Dynasty burial of Ramose and Hatnefer at Thebes, for instance, included at least two tunics covering the outer layer of bandages around the body of Hatnefer (Lansing and Hayes 1937: 19–20; Porter and Moss 1964: 669). A more ornate form of shroud is the so-called Osiris shroud, comprising a linen sheet spread over the bandages and then fastened in place by ties woven for the purpose, an example of which was also found over the mummy of Hatnefer (Cairo JE 66218). This type of shroud is often decorated with a painted life-size figure of Osiris, which may be either a simple outline executed in black ink or a more elaborate painting. Occasionally other gods or human forms are depicted (e.g. Leiden, RMO AMM 8). A more unusual form of shroud, taking the shape of a human being, covered the body of the New Kingdom queen Ahmose Meritamun, who was probably the Great Royal Wife of the early Eighteenth-Dynasty ruler Amenhotep I (Hayes 1990: 54; see Fig. 11.22).

There were various sources of cloth to be used for mummy bandaging, depending on the financial resources to be spent on the funeral (see Benson *et al.* 1979; Wild 1979, and see also Chapter 16, this volume). In most cases the mummifiers used old cloth and clothing which were torn up and wrapped around the body. The Twenty-third-Dynasty mummy of a priestess called Ankhefenkhonsu was wrapped in at least twelve tunics and one or two cloaks (National Museum of Denmark, Copenhagen, Acc. no. 1038). Old cloth and clothes for bandages also formed part of the list of acquisitions prior to military activities, in anticipation of losses. In a Twentieth-Dynasty letter, 'the general of Pharaoh' wrote to the scribe Tjaroy: 'As soon as my letter reaches you, you shall send some old cloths in the form of many strips . . . And don't let them go to waste (?), for they shall be made into bandages with which to wrap up men' (No. 300 Wente 1990: 182).

In more influential households it was possible to obtain what was called 'sanctified mummy wrappings'. These were the old 'clothing of the gods', described above in the section on religious uses (Andrews 1984: 25). In Spell 61 of the Coffin Texts, there is a reference to such garments, which have been used to make bandages for the dead: 'You are dressed in the pure garments of Ptah, in the cast-off garments of Hathor' (De Buck 1935: I, 258).

The amount of cloth used during the mummification process was considerable. It was required to pack the body in order to speed up the dehydration process and to prevent the body from being accidentally crushed (Andrews 1984: 20–6). Linen bags filled with natron were also placed inside the body. After the corpse had been in natron for forty days it was emptied, washed, rinsed and then allowed to dry. Any cavities were again filled with linen and all the facial orifices plugged with cloth. The actual wrapping of the body began about fifteen days later. At this point all the cloth needed was placed into various piles around the room. The piles were for bandages; folded sheets for layering; shaped bundles for wadding; padding, and finally the shrouds. The wrapping of the body began with the fingers and toes and then the arms and legs (Andrews 1984: 26–7; Raven 1993: 21, pl. 21). Gradually the whole body was wrapped in bandages, and pads of cloth were used to fill in certain areas (e.g. under the neck). In addition, if a limb was missing, a substitute was made out of a roll of cloth. Often worn and damaged cloth was used for bandaging the body itself, while the outer bandages were made of material in a better condition.

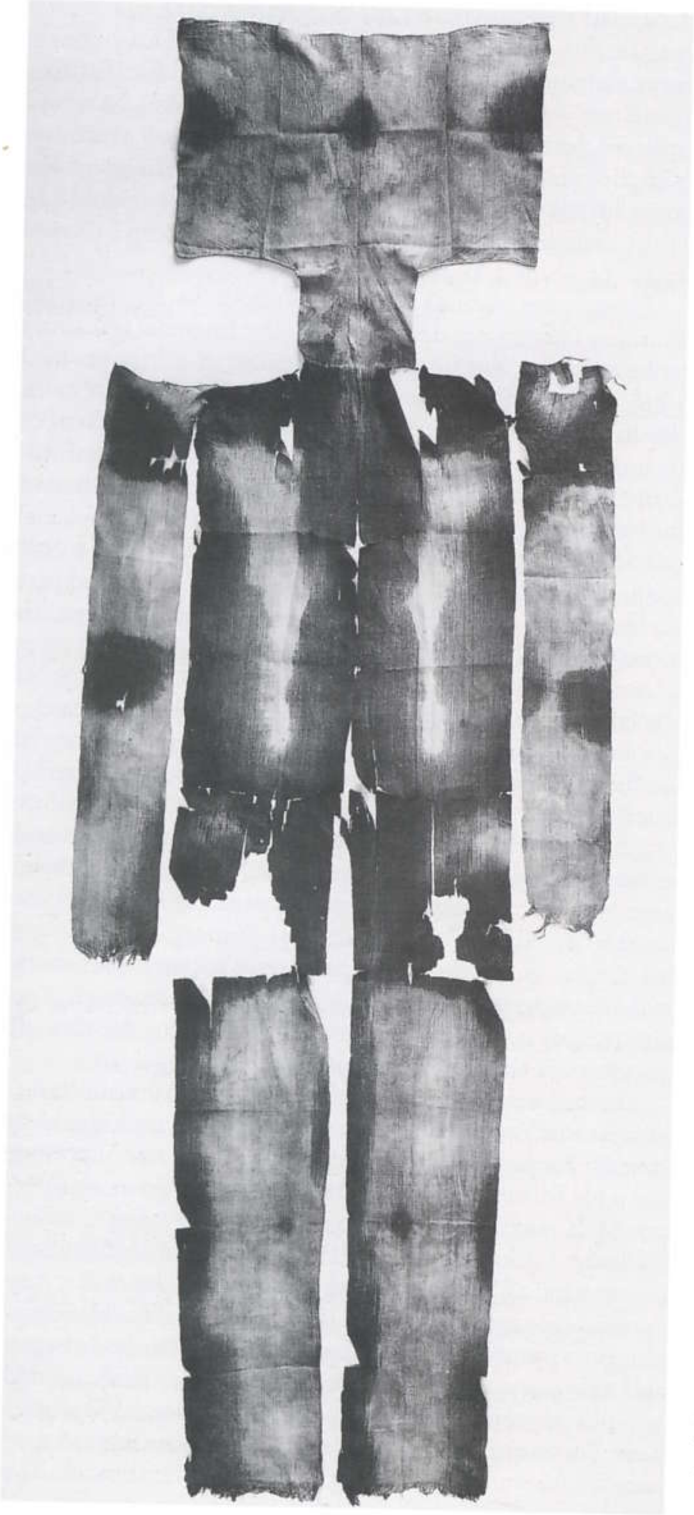


Figure 11.22 *Shroud of Ahmose Meritamun, who was probably the wife of the early Eighteenth-Dynasty ruler Amenhotep I (Cairo, Egyptian Museum).*

A wide range of animals, reptiles and birds were als mummified (Andrews 1985: 64–5). In the beginning onl certain animals were mummified, notably rams and gees bulls, cows, crocodiles and falcons, but by the later periods wide range of animals were mummified including snakes fish, mice, gazelle, baboons, dogs and cats. The role of clot during the mummification of animals has yet not bee studied in detail.

Conclusions

Until comparatively recently, the study of textiles ha lagged behind that of other Egyptian material remains. Th study of Egyptian pottery, for example, was initiated ove 100 years ago. In contrast, the early reports rarely deal with textiles, providing only occasional references to 'mummy cloth' or simply 'linen'. The situation changed somewhat in the early twentieth century, when various scholars, such as Walter Midgely, Ling Roth, Grace Crowfoot and later Elizabeth Riefstahl each took a specific interest in textiles. After the Second World War, however, there was for some time a general dearth of interest in the subject.

During the last few decades of the twentieth century, there has been a notable change in the attitude of Egyptologists towards the study of ancient textiles. One of the major factors in this change is that the Egyptologists themselves, who once focused primarily on the philological and religious aspects of Egyptian culture, have begun to accept the fact that the material culture of the Pharaonic period is worthy of equal attention.

Changes in the available technology for the analysis of textiles have also played an important role in the study of these objects. Until the development of minimum or non-destructive scientific tests, many museums were reluctant to allow textiles to be used for the analysis of fibres or dyes. The situation is changing, but the growing complexity of analytical techniques has meant that there is an ever-widening gap between the specialist in the field and the person who is analysing the objects; unfortunately it is likely that this gap will widen further in the future.

Despite such problems, the future of the study of ancient Egyptian textiles looks far from gloomy. There is an ever-growing awareness of their intrinsic interest and their value both to scholars and to the general public. More importantly, information about textiles is now more widely available, which means that future generations of students will realise that pieces of linen are much more than simply tatty old rags.

References

Allgrove-McDowell, J. 1986. Kahun: the textile evidence. In *The Pyramid Builders of Ancient Egypt* (ed. A.R. David). London: Routledge and Kegan Paul, pp. 226–52.

Andrews, C. 1984. *Egyptian Mummies.* London: BMP.

Barber, E.J.W. 1991. *Prehistoric Textiles.* Princeton: Princeton University Press.

Benson, G.G., Hemingway, S.R. and Leach, F.N. 1979. The analysis of the wrappings of Mummy 1770. In *The Manchester Museum Mummy Project* (ed. A.R. David) Manchester: Manchester Museum. Manchester: Manchester Museum, pp. 119–32.

Breasted, J.H. 1906. *Ancient Records of Egypt* (5 vols). Chicago: University of Chicago Press.

1930. *The Edwin Smith Surgical Papyrus.* Chicago: University of Chicago Press.

Brunton, G. 1927. *Qau and Badari.* London: BSAE.

1937. *Mostagedda and the Tasian Culture.* London: BMP.

Brunton, G. and Caton-Thompson, C. 1928. *The Badarian Civilization and Predynastic Remains near Badari.* London: BSAE.

Calverley, A.M. and Broome, M.F. 1935. *The Temple of King Sethos I at Abydos* II. London: EES.

Carnarvon, Earl of, and Carter, H. 1912. *Five Years Exploration at Thebes.* Oxford: OUP.

Carter, H. 1903. Report on the general work done on the South Inspectorate. *ASAE,* 4: 43–50.

Cartland, B.M. 1918. Balls of thread wound on pieces of pottery. *JEA,* 5: 139.

Catling, D. and Grayson, J. 1982. *Identification of Vegetable Fibres.* London: Chapman and Hall.

Caton-Thompson, G. and Gardner, E.W. 1934. *The Desert Fayum.* London: Royal Anthropological Institute.

Černý, J. 1930–35. *Ostraca hiératiques* Cairo: Egyptian Museum.

Chassinat, E.G. and Palanque, C. 1911. *Une campagne de fouilles dans la nécropole d'Assiout.* Cairo: IFAO.

Cockburn, A., Barraco, R.A., Peck, W.H. and Reyman, T.A. 1983. A classic mummy; PUM II. In *Mummies, Disease and Ancient Cultures* (eds. A. Cockburn and E. Cockburn). Cambridge: CUP, pp. 52–70.

Cooke, W.D. and Brennan, A. 1990. The spinning of fine royal or byssos linen. *Archaeological Textiles Newsletter,* 10: 9.

Crowfoot, G.M. 1931. *Methods of Hand Spinning in Egypt and the Sudan.* Halifax: Bankfield Museum Notes.

1933. A textile from the Hood Collection of Egyptian antiquities. *Ancient Egypt*: 43–5.

Crowfoot, G.M. and Davies, N. de G. 1941. The tunic of Tut'ankh'amun. *JEA* 27: 113–30.

Cumming, B. 1982. *Egyptian Historical Records of the Later Eighteeth Dynasty.* Warminster: Aris and Phillips

Daressy, G. 1902. *Fouilles de la Vallée des Rois1898–9.* Cairo: Catalogue Géneral des Antiquités du Musée du Caire.

Davies, N. de G. 1900. *The Mastaba of Ptahhotep and Akhhotep at Saqqara.* London: EES.

1901. *The Rock Tombs of Sheikh Saïd.* London: EEF.

1902. *The Rock Tombs of Deir El-Gebrawi* II. London: EEF.

1903. *The Rock Tombs of El-Amarna* I. London: EEF.

1905. *The Rock Tombs of El-Amarna* III. London: EEF.

1908. *The Rock Tombs of El-Amarna* VI. London: EEF.

1913. *Five Theban Tombs.* London: EES.

1926. *The Tomb of Huy.* New York: MMA.

1927a. The town house in ancient Egypt. *Metropolitan Museum Studies,* 1–2: 233–55.

1927b. *Two Ramesside Tombs at Thebes.* New York: MMA.

1930, *Tomb of Ken-Amun at Thebes,* 2 vols. New York: MMA.

1933. *The Tomb of Nefer-Hotep at Thebes.* 2 vols. New York: MMA.

1936. *Ancient Egyptian Paintings* (2 vols). Chicago: University of Chicago Press.

1941. *The Tomb of the Vizier Ramose.* New York: MMA.

1943. *The Tomb of Rekh-mi-re at Thebes.* New York: MMA.

1948. *Seven Private Tombs at Kurnah.* New York: MMA.

De Buck, A. 1935. *The Egyptian Coffin Texts.* Chicago: University of Chicago Press.

Donadoni Roveri, A.M. 1988. *Egyptian Civilization: Daily Life.* Turin: Museo Egizio di Torino.

Dothan, T. 1963. Spinning bowls. *Israel Exploration Journal,* 13: 97–112.

Duell, P. 1938. *The Mastaba of Mereruka.* Chicago: University of Chicago Press.

Eastwood, G.M. 1985. Preliminary report on the textiles. In *Amarna Reports* II (ed. B.J. Kemp). London: EES, pp. 191–204.

Emery, I. 1966. *The Primary Structures of Fabrics.* Washington: The Textile Museum.

Faulkner, R.O. 1969. The Bremner-Rhind Papyrus I. *JEA,* 22: 121–40.

Gardiner, A.H. 1957. *Egyptian Grammar.* 3rd edn. Oxford: OUP.

Germer, R. 1985. *Flora des pharaonischen Ägypten.* Mainz: von Zabern.

1992. *Die Textilfärberei und die Verwendung gefärbter Textilien im Alten Ägypten.* Wiesbaden: Otto Harrassowitz.

Ghalioungui, P. 1973. *The Physicians of Pharaonic Egypt.* Mainz: von Zabern.

1983. *The House of Life: Magic and Medical Science in Ancient Egypt.* Amsterdam: Hodder and Stoughton.

Goyon, J.C. and Josset, P. 1988. *Un Corps pour l'Eternité, Autopsie d'une Momie.* Paris: Le Léopard d'Or.

Griffith, F.L. 1896. *Beni Hasan* III. London: EEF.

Hald, M. 1946. Ancient textile techniques in Egypt and Scandinavia. *Acta Archaeologica* 17: 49–67.

Hall, R. 1980. A pair of linen sleeves from Gurob. *GM,* 40: 29–40.

1981. The Pharaonic *mss* tunics as a smock?. *GM,* 43: 29–37.

1982. Garments in the Petrie Museum of Egyptian Archaeology. *Textile History,* 13,1: 27–45.

1985. The cast-off garments of yesterday: dresses reversed in life and death. *BIFAO,* 85: 235–45.

1986. *Egyptian Textiles.* Aylesbury: Shire Publications.

Hayes, W.C. 1990. *The Scepter of Egypt.* 2 vols. New York: Harold Abrams.

van't Hooft, P., Raven, M.J., van Rooij, E.H.C. and Vogelsang-Eastwood, G. 1994. *Pharaonic and Early Medieval Egyptian Textiles.* Leiden: Rijksmuseum van Oudheden.

James T.G.H. 1962. *The Hekanakhte Papers and Other Early Middle Kingdom Documents.* New York: MMA.

Janssen, J.J. 1975. *Commodity Prices from the Ramessid Period.* Leiden: Brill.

1980. *De Markt op de Oever.* Leiden: Brill.

Jick, M. 1988. Bead-net dress. In *Mummies and Magic* (eds. S. D'Auria, P. Lacovara and C. Roehrig). Boston: MFA, pp. 78–9.

Kamal, A.B. 1901. *Fouilles à Deir-el-Bersheh.* Cairo: SAE.

Kemp, B.J. 1989. *Ancient Egypt: Anatomy of a Civilization.* London: Routledge.

Landi, S and Hall, R. 1979. The discovery and conservation of an ancient Egyptian linen tunic. *Studies in Conservation,* 24: 141–52.

Lansing, A. and Hayes, W.C. 1937. The Egyptian expedition 1935–1936: The Museum's excavations at Thebes. *BMMA,* 32/2: 4–39.

Landström, B. 1974. *Die Schiffe der Pharaonen.* Munich.

Lichtheim, M. 1973. *Ancient Egyptian Literature* I. Berkeley CA: University of California Press.

Littauer, M.A. and Crouwel, J.H. 1985. *Chariots and Related Equipment from the Tomb of Tut'ankhamun*. Oxford: Griffith Institute.

Loret, V. 1930. Deux racines tinctoriales de l'Égypte ancienne: orcanette et garance. *Kêmi*, 3: 22–32.

Lūcas, A. 1962. *Ancient Egyptian Materials and Industries*. 4th edn., rev. J.R. Harris. London: Edward Arnold.

Macramallah, R. 1935. *Le Mastaba d'Idout*. Cairo: Service des Antiquités de l'Egypte.

Martin, G.T. 1989. *The Memphite Tomb of Horemheb*. London: EES.

Medinet Habu, VI/2: The Temple Proper. 1963. Chicago: University of Chicago Press.

Midgley, W.W. 1911. Linen of the IIIrd Dynasty. In *Historical Studies* II (eds. E.B. Knobel, W.W. Midgley, J.G. Milne, M.A. Murray and W.M.F. Petrie). London: Quaritch, pp. 37–9.

1912. Textiles. In *Labyrinth, Gerzeh and Mazguneh* (eds. W.M.F. Petrie, G.A. Wainwright and E. MacKay). London: BSAE, p. 6.

1915. Reports on early linen. In *Heliopolis, Kafr Ammar and Shurafa* (eds. W.M.F. Petrie and E. Mackay). London: BSAE, pp. 48–51.

Mond, R.L. and Myers, O.H. 1937. *The Cemeteries of Armant* I, 2 vols. London: EES.

Moran, W.L. 1992. *The Amarna Letters*. Baltimore: Johns Hopkins University Press.

Müller, H. 1940. *Die Felsgräber der Fürsten von Elephantine*. Ägyptologische Forschungen 9. Glückstadt, Hamburg and New York: J.J. Augustin.

Munro, P. 1983. Der Unas-Friedhof Nord-West 4/5, Vorbericht über die Arbeiten der Gruppe Hannover/Berlin in Saqqara. *GM*, 63: 81–109.

Newberry, P.E. n.d. *El Bersheh I*. London: EEF.

1893. *Beni Hasan* I. London: EEF.

1894. *Beni Hasan* II. London: EEF.

Parkinson, R. 1991. *Voices from Ancient Egypt*. London: BMP.

Peet, T.E., 1930. *The Great Tomb Robberies of the Twentieth Dynasty*. Oxford: Clarendon Press (repr. 1977).

1933. The so-called Ramesses girdle. *JEA*, 19: 143–9.

Peet, T.E. and Woolley, C.L. 1923. *City of Akhenaten* I. London: EES.

Petrie, W.M.F. 1908. *Athribis*. London: BSAE.

1914. The tomb of Menna. *Ancient Egypt*, 1: 95–6.

1917. *Tools and Weapons*. London: BSAE.

Petrie, W.M.F. and Quibell, J.E. 1895. *Naqada and Ballas*. London: BSAE.

Picton, J. and Mack, J. 1979. *African Textiles*. London: BMP.

Porter, B. and Moss, R.L.B. 1964. *Topographical Bibliography of Ancient Egyptian Hieroglyphic Texts, Reliefs and Paintings I: The Theban Necropolis: Part 2: Royal Tombs and Smaller Cemeteries*. 2nd edn. Oxford: Griffith Institute.

Quibell, J.E. 1900. *Hierakonpolis* I. London: BSAE.

Quirke, S., Cruickshank, P. and Morgan, H. 1995. Reawakening Resti: conservation of an eighteenth-dynasty shroud. *Egyptian Archaeology*, 6: 31–3.

Raven, M.J. 1993. *Mummies onder het mes*. Amsterdam: De Tabaafische Leeuw.

Reeves, C.N. 1990. *The Complete Tutankhamun*. London: Thames and Hudson.

Reisner, G.A. 1942. *A History of the Giza Necropolis* I. Cambridge MA: Harvard University Press.

Reisner, G.A. and Smith, W.S. 1955. *A History of the Giza Necropolis* II. Cambridge MA: Harvard University Press.

Riefstahl, E. 1944. *Patterned Textiles in Pharaonic Egypt*. Brooklyn: Brooklyn Museum.

1970. A note on ancient fashions; four early Egyptian dresses in the Museum of Fine Arts, Boston. *BMMA*, 68: 244–9.

Roth, A.M. 1988. Tomb group of a woman. In *Mummies and Magic: The Funerary Arts of Ancient Egypt* (eds. S. D'Auria *et al.*). Boston: MFA, pp. 76–7.

Roth, H.L. 1951. *Ancient Egyptian and Greek Looms*. Halifax: Bankfield Museum Notes.

Saad, Z.Y. 1951. *Royal Excavations at Helwan, 1945–7*. Cairo: Service des Antiquités de l'Égypte.

Schiaparelli, E. 1927. *Relazione sui lavori della Missione Archeologica Italiana in Egitto 1903–1920, II, La tomba intatta dell'architetto Cha nella necropoli di Tebe*. Turin: R. Museo di Antichità.

Simpson, W.K. 1978. *The Mastabas of Kawab, Khafkhufu I and II, G7110–20/30–40/50*. Boston: Museum of Fine Arts.

Smith, G.E. 1912. *The Royal Mummies. Catalogue Général des Antiquités Egyptiennes de la Musée du Caire*, Nos. 61051–61100. Cairo: SAE.

Smith, G.E. and Dawson, W.R. 1924. *Egyptian Mummies*. London: Allen and Unwin [repr. 1991 London: KPI].

Spencer, P. 1984. *The Egyptian Temple: A Lexicographical Study*. London: KPI.

Thompson. W.G. 1904. Tapestry-woven fabrics. In *The Tomb of Thoutmôsis IV* (eds. H. Carter and P.E. Newberry). Cairo: BSAE, p. 143.

Tylor, J.J. and Griffith, F.Ll. 1894. *The Tomb of Paheri at El-Kab*. London: EEF.

Vogelsang-Eastwood, G.M. 1987–88. A note on the so-called 'spinning bowls'. *Ex Oriente Lux*, 30: 78–88.

1990. Textiles from Quseir al-Qadim, Egypt. *OMRO*, 70: 195–200.

1992a. Ancient Egyptian spinning. *Profiel* 4/1: 3–17.

1992b. Deciphering a pictorial clothing list. *GM*, 128: 105–111.

1993. *Pharaonic Egyptian Clothing*. Leiden: Brill.

1994. *De Kleren van de farao*. Amsterdam: De Tabaafische Leeuw.

Vogelsang-Eastwood, G.M. and Kemp, B.J. 1999. The ancient textile industry at Amarna. In *Amarna Excavations II* (ed. B.J. Kemp). London: EES.

Wente, E. 1990. *Letters from Ancient Egypt*. Atlanta: Scholars Press.

Wild, H. 1979. *La Tombeaude Néfer-hotep I et Neb-néfer*. Cairo: IFAO.

Winlock, H.E. 1916. Ancient Egyptian kerchiefs. *BMMA*, 11: 238–42.

1926. The Egyptian expedition, 1924–1925. *BMMA*, 21: 3–28.

1940. The mummy of Wah unwrapped. *BMMA*, 35: 253–259.

1941. *Materials Used at the Embalming of King Tut-Ankh-Amun*. New York: MMA.

1945. *The Slain Soldiers of Neb-hepet-Re-Mentuhotpe*. New York: MMA.

1955. *Models of Daily Life in Ancient Egypt*. New York: MMA.

Worth Estes, J. 1989. *The Medical Skills of Ancient Egypt*. Kanton: Science History Publications.

Wreszinski, W. 1923–42. *Atlas zur altägyptischen Kulturgeschichte* (3 vols). Leipzig: Hinrichs.

12. Leatherwork and skin products

CAROL VAN DRIEL-MURRAY

Introduction

Ever since Lucas emphasised the importance and quality of leather in Pharaonic Egypt, in his ground-breaking *Ancient Egyptian Materials and Industries*, Egypt has tended to be regarded as the origin of all technical expertise in this field. Lively depictions of work scenes in tombs and the preservation of brightly coloured and complex items of leatherwork have contributed to the perception of large-scale and technologically advanced skin-processing skills. As the present study progressed, however, it became clear that Pharaonic skin processing, far from being innovative, remained essentially Neolithic in its technology, and skin products were of marginal importance in comparison to textiles and fibre. Leather-working only came into prominence at times of increased international contact or when pastoralist intruders brought their own traditions with them. Indeed, true leather – in the sense of a water-resistant, impetruscible product tanned with extracts of vegetable origin – was virtually unknown in Egypt until the massive technological changes introduced in the Greco-Roman period.*

The skin products of the Pharaonic period, although here referred to as 'leather', are in fact only lightly cured (so-called 'pseudo-tannages'): the belief in the pre-eminence of Egypt in leather technology, although widespread in the tertiary literature, appears to derive more from the unparalleled conditions of survival than from scientific analysis. These exceptional conditions have, however, resulted in the survival of considerable numbers of artefacts which not only reveal the many purposes to which skin products could be put, but also indicate the variety of processing techniques which were available in antiquity. In contrast to the ancient leather that has survived in the waterlogged conditions of northwestern Europe, Egyptian skin products have often been preserved intact, with the sewing thread still in place, thus permitting a much better appreciation of the production techniques. Other aspects, such as the astounding use of colour and the manner in which highly sophisticated effects can be produced by the simplest methods, need to be more widely recognised and are certainly dirctly relevant to all archaeological research into pre-industrial leather technology. The wealth and variety of the finds from Egypt are a forceful reminder of the limitations which climatic conditions place on our assessment of leather technology at other periods and in other regions where differential preservation may severely distort the material record.

Sources

Much of the surviving artefactual evidence for Egyptian leather-working derives from tombs, the equipment from which cannot simply be regarded as a reflection of daily life in all its aspects, particularly in view of such factors as the ceremonial and symbolic nature of the removal – or retention – of footwear in the presence of deities, kings or superiors. Similarly, the symbolic and cultic significance of tomb and temple depictions means that such scenes need to be interpreted with caution and in a clear historical perspective (see Chapter 22, this volume in particular), but this does not mean that the activities themselves bear no relation to contemporary practice.

Settlement sites such as Middle Kingdom Kahun and New Kingdom Gurob offer a more balanced picture of daily life, but the situation is complicated by the fact that Dynastic-period artefacts from such sites have often become mixed up with Romano-Coptic occupation debris. Unfortunately, it is primarily in the case of the organics – basketry, footwear and textiles – that the dating of individual items is controversial. Thus only one of the sandals from Gurob illustrated by Thomas (1981: pl. 51/470; Petrie Museum UC 28350) dates to the Pharaonic period, while the rest are late Roman. Similarly, an indigo-dyed wool skein from Kahun was recently analysed and shown to be Roman (Germer 1992: 15, 19). The extent of such contamination raises doubts as to the authenticity of the 'Predynastic tannery' at Gebelein, which is discussed below (see p. 305). Because of

---

*Technically, the term 'leather' is restricted to the products of (1) tanning, i.e. the treating of skin with tannin extracts of vegetable origin, and (2) tawing, which refers to treatment with alum. Other processes are described variously as 'curing' or 'pseudo-tannages'.

these problems, the surviving leatherwork from Ludwig Borchardt's controlled excavations at Amarna is particularly important for dating purposes.

By far the richest sources of leatherwork are the Romano-Coptic cemeteries and settlements which, however, fall outside the remit of this contribution. On the whole, the dating of these cemeteries is poorly defined, but items of footwear from recent excavations such as Qasr Ibrim and Mons Claudianus are beginning to provide some refinement within this long period (see Mills 1982; Winterbottom 1990; Petrie 1889: pls. XVIII–XXI; Frauberger 1896). Outside Egypt proper, the Nubian cemeteries reveal a rich and highly skilled leather-working tradition (though still using cured skins and rawhide) from the earliest times. This Nubian leatherwork is unequalled in Egypt, and, especially in the later periods, includes exquisite and spectacularly complex objects of daily use, such as the quivers from Qustul (Williams 1991: figs. 39–47).

In general, a rigorous chronological framework is lacking from many discussions of Egyptian material culture, thus obscuring evidence for technological development or its social and economic background. This shortcoming is particularly apparent in the treatment of Egyptian leatherwork in the secondary literature and popularising studies based on it. Ancient texts are cited without regard for their context or date, and there is little awareness of advances in either philology or interpretation: even Reed (1972: 86–9) includes incorrect translations of Mesopotamian texts, which have subsequently been quoted in numerous publications drawing on this authoritative work. All too often, classical references are inappropriately applied to earlier situations, and modern assumptions as to the advanced nature of Egyptian technology not only colour the translations given but also affect the outcome of specialist research.

Although it may be assumed that the major changes which become visible in Roman times are in fact rooted in earlier traditions, the lack of closely dated comparative material from either the Persian or Ptolemaic periods prevents any insight into the antecedents or indeed, any developments in native technology which may have made craftsmen more responsive to new influences. It is notable that changes in leather technology at this period are echoed in textiles by the major shift from linen to wool and also in basketry techniques (Germer 1992: 18 n. 4; see also Chapters 10 and 11, this volume). Ancient Egyptian leatherwork is in need of a total reassessment, and a research programme undertaking extensive analyses on well-dated samples for both curing and colouring agents is urgently required to establish a framework for future investigation.

Primary processing of animal skin

Butchery

The relative unimportance of leather could be connected to the inefficient and messy manner of butchery, for in hot climates lack of hygiene is one of the chief causes of los the leather industry (Aten *et al.* 1978: 28). From Old a Middle Kingdom tombs come particularly detailed sce depicting the slaughter of cattle and antelope (Eggebre 1973), and although all are set in a ritual context, this d not exclude a pragmatic interpretation of the actual quences (Ikram 1995: 42). Tomb chapels at Meir grap cally record the unhygienic conditions of slaughter (Blac man 1914–53: I, pls. X–XI). The vertical throat slit, whic was normal in the Old and Middle Kingdom (Eggebrec 1973: 41), would cause severe spattering of blood, but ina equate bleeding, as carcasses were not hung. Flaying doe not seem to have been recognised as a distinct activity, bu proceeded piecemeal as the animal was being jointed, thu increasing the likelihood of damage from butchers' knive and contamination with blood and viscera (Eggebrech 1973: 73–4; Davies 1922: 16, n. 3. pl. LII; Gilbert 1988: 88 see also Chapter 25, this volume). Working from a sli extending from the jaw to the belly (particularly clearly visible in the scene showing the slaughter of cattle and antelope in the Sixth-Dynasty tomb-chapel of Pepyankh at Meir, see Blackman 1914–53: V, pl. XXXV), the butchers first stripped and removed the ritually important right foreleg, leaving folds of skin hanging down from the carcass, which are visible on most depictions (first noted by Davies 1922: 16; see Fig. 12.1a). After removal of the left foreleg and the freeing of the rib-cage, the skin of the back legs was peeled back from vertical cuts, sometimes with the assistance of the butcher's hand or a paddle-like tool (Eggebrecht 1973: 75; Murray 1904: pls. VII, XXI, XIII; Blackman 1914–53: IV, pl. IX; see Fig. 12.1b). Once the beast had been dismembered, the hide was removed using knives and pummelling down with the fists (Fig. 12.1c). All the while, the carcass was rolled about on the dirty floor, with the hide of little more value than a temporary carpet. Indeed, Eggebrecht (1973: 74) suggests that the piecemeal flaying has something to do with keeping the flesh ritually pure, but it is notable that, save for the initial libation, there is no indication of the most obvious form of cleansing: rinsing with water. It is also remarkable that there is apparently no trace of water supply, sluicing or drainage facilities in the surviving remains of an Old Kingdom slaughterhouse at Abusir (Verner 1986). With the skins already heavily contaminated, further processing would be further delayed by the need for transport to a suitable location.

It is perhaps significant that as skin products came to be employed more widely in the New Kingdom, slaughterhouse practices seem to have changed and more attention was paid to the condition of the hides. The deep horizontal throat-cut, which becomes normal in the New Kingdom (Eggebrecht 1973: 49), virtually severing the head (contrast Davies 1930: II, pl. XLII and Fig. 12.1a here), would enable more complete bleeding, while the further separation of the actual slaughteryard from the temple (Haring 1996: 117–18) may have allowed for the provision of hygienic facilities.

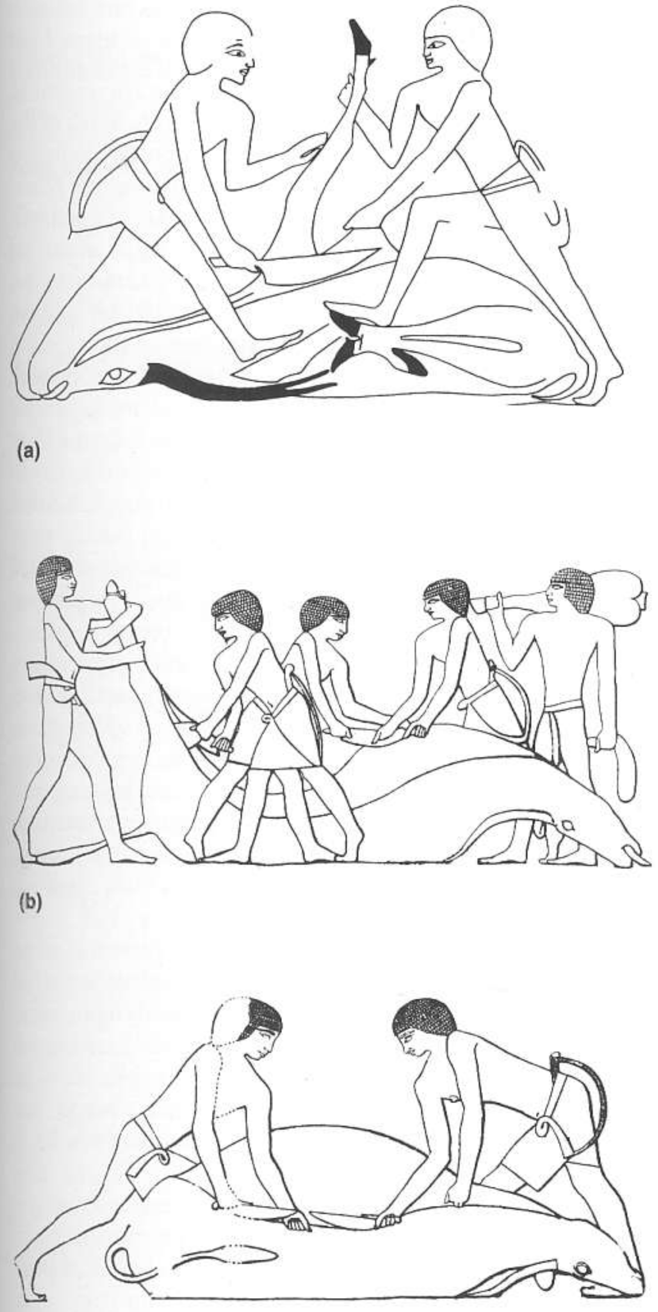


Figure 12.1 Old Kingdom butchery scenes: (a) Scene in the tomb-chapel of Pepyankh at Meir, showing the throat and belly of an antelope being cut, the skin loosened, and the right foreleg beginning to be cut off (b) Scene in the tomb-chapel of Userneter at Saqqara, showing the front leg and heart of the animal being carried away, and its hide hanging from its rib cage (c) Scene from the tomb of Ptahhotep at Saqqara, showing the slicing and pummelling of the animal's hide after the removal of its legs.

Amarna-period slaughteryards show decapitated cattle with hides hung or laid out neatly, indicating that, by the late Eighteenth Dynasty, the hide was now a recognised slaughterhouse 'product' in its own right. Cattle hides in Nubian and Nubian-influenced graves retain the horns, and these must still have been killed with the vertical throat cut of the Old Kingdom tradition (see, for instance, the laid-out ox-hide in the tomb of Iny at Gebelein; Donadoni Roveri 1989: 182–3).

The slaughter of small animals such as sheep and goats is scarcely ever depicted but these could be suspended to drain the blood, therefore flaying was easier and cleaner (Ikram 1995: 49, fig. 16). These skins can also be removed intact by inflating the skin and pummelling it free from the carcass (so-called 'cased skins', see Mann 1962: 108–9). For purposes other than water bags (see p. 309), this does seem to be a Nubian tradition. There is, for instance, a quiver made from a cased gazelle skin from the Coptic levels at Qasr Ibrim, with the legs shredded into decorative tassels (BM EA72342).

Byproducts

A further reason for the marginal position of leather may be that skins were more useful for the production of glue, which was evidently required in very large quantities indeed. The prolonged boiling necessary for glues made from animal bones and horn piths might have limited their use in Egypt, but the collagen contained in skin rejects, trimmings and the fleshings, removed while preparing skins for curing, is more accessible, with the best results obtained at a temperature of only 60–65 °C (140–150 °F). The main problem in hot climates is to cool the resulting 'soup' sufficiently, but Lucas describes a cast cake of animal glue from the Eighteenth Dynasty as little different from modern examples (Lucas 1962: 4–5; Mann 1962: 137–8).

The oil extracted from the foot bones of cattle and sheep (neatsfoot or cow-heel oil) is the thinnest of all animal fats and is still highly valued in the skin-processing trades both for curing skins and for subsequent lubrication (currying). Whether neat's-foot oil was actually exploited by the Egyptians is unknown, although small-scale extraction is apparently possible without the prolonged boiling at high temperatures recommended by Mann (1962: 61). Concentrations of metapodia in archaeological contexts could form a clue to ancient neatsfoot oil production, but most of the certain evidence for its exploitation is post-medieval (Mann 1962: 161–2; Serjeantson 1989).

Sinews can be used in sewing, and can also be twined into thicker cords. Such uses seem to be most common in Predynastic and pan-grave leatherwork and most surviving sewing thread is of vegetable origin.

Skin types

Of the material examined, cow hide is most commonly used for sandals, whilst Eighteenth-Dynasty coloured shoes are generally of goatskin. Van de Mieroop (1987: 3) notes that in Mesopotamia, skins to be coloured green are always specified as goat. An undated kohl tube in the Ashmolean Museum (1950.210) is made of the complete back leg of a small rodent; gazelle skin was used for the delicate, open-work leather loincloths of the New Kingdom (e.g. BM EA2564, see Vogelsang-Eastwood 1993: 16ff for further examples) and the green-stained skin of a lyre in the Rijksmuseum van Oudheden, Leiden (Leemans 1840: I, 469). Scraps of red-stained gazelle skin were used as edgings for a goatskin mummy-label in the Petrie Museum, London (UC 29848). On the whole, staining and surface decay frequently complicate the identification of the animal species.

Judging by the numerous depictions, hairy skins (cow as well as exotic felines) were used for quivers and shields in both the Middle and the New Kingdom with strips of differently coloured hair decoratively arranged. Exotic skins are a standard feature in New Kingdom tribute scenes (e.g. those in the tomb of Rekhmira TT100, see Davies 1943: pl. XXIX) though this is no indication of how frequent they actually were in real life. The Fourth-Dynasty princess Nefertiabet is depicted, on a funerary stele from her tomb at Giza (now in the Louvre), wearing a fetching, tight-fitting leopard-skin robe which looks rather like an imitation, and in Tutankhamun's tomb there are both real and imitation leopard skins (Vogelsang-Eastwood pers. comm.). An anti-slip surface is provided by the spines on the crocodile-skin outer sole of a Middle Kingdom two-layer sandal from Kahun (Petrie Museum, UC 7498). The British Museum possesses a ritual garment made of a complete crocodile skin (cured, but not tanned) from which the snout and claws have been removed (BM GR5473). Radiocarbon-dated to the third or fourth century AD (B. Wills pers. comm.), it was cut and prepared during the Roman period exactly as now recommended by the Food and Agriculture Organisation (see Mann 1960: 178 and fig. 74). The small size of the garment has excited comment but is consistent with dimensions from other clothing survivals.

Other scholars mention hippopotamus hide, but the writer has not been able to identify it in the material examined: in view of the thickness and the amount of fat in the hide, it would have presented the Egyptian leather-worker with considerable technical problems. Pig skin is similarly fatty, it is also edible and has an important role in the preservation of pork (in temperate climates at least). Moreover, the hairs penetrate through the entire skin thickness, leaving holes when the skin is depilated. Pig skin was, therefore, rarely used for leather before the late medieval period, when the increasing use of chemical processes in leather-working began to make such use more practicable.

Skin processing

Depictions in Egyptian tomb-chapels illustrate highly selective moments of skin processing, ignoring the essential, but unclean, stages of cleaning and depilating. Many of the noisome processes described in the handbooks are in fact post-medieval (e.g. liming, puering and bating, see Mann 1960; Serjeantson 1989) and the various curing methods, although often laborious, require fewer applications of simpler organic and mineral products. In Pharaonic Egypt, some store may, indeed, have been set by the whitish products achieved by the pseudo-tannages.

Skins could be depilated with urine and ash, or with pastes of flour mixed with salt; these also act as simple preservatives, and in some cases would seem to be the limit of Egyptian 'leather' production (see Lucas 1962: 38–9). The leather chemist G.A. Bravo (1933, 1948) suggested that the high levels of ash (*ceneri*, *c.*7 per cent) which were indicated by most of his analyses were probably associated with this preliminary cleaning, since these substances would not be removed in the subsequent curing processes. Bravo does not specify what exactly he means by *ceneri*, which literally means 'ash', but may also mean 'lye' (i.e. water alkalised by lixiviation – 'leaching' – of vegetable ashes) and hence may perhaps refer to a mineral salt. The lime (*calce*) which he notes is probably a chalk bulking, and not a depilant, for, as Reed (1972: 135) points out, there are no ancient references to the use of lime in tanning. Indeed, its use is not certainly documented until the late medieval period.

Of the processes described below, only vegetable tanning is a permanent and irreversible process: all the other treatments are in fact 'pseudo-tannages' resulting in semi-tanned or cured leathers, none of which will survive wet conditions (which is why such products do not survive in the waterlogged contexts of northwestern Europe, see Haines 1991; Sykes 1991: 10–11). Rawhide dries to a hard, yellow-white horny substance (desiccated collagen). The severe shrinkage on wetting is a property exploited in the use of rawhide for moulded containers (Petrie 1927: pls. 46–7) and especially its use as lashings for tools, furniture joints or the tying up of poor quality coffin-planks (well-illustrated by two Old Kingdom examples from Gebelein: Turin Museum Inv. sup. 13954 and 13964; Donadoni Roveri 1988: 66, pl. 96).

Smoking (aldehyde tannage)

There are numerous ethnographic parallels for the process of smoking animal skins, and it is definitely attested in Prehistoric Europe from the Late Neolithic onwards. Since the skin becomes stiff, smoking is usually practised in combination with fat/brain application. Experimental work undertaken by Professor Dr Groenman-van Waateringe (pers. comm.) revealed that burning wood releases aldehydes and phenols, the latter being responsible for the mild positive reaction to standard tests for vegetable tannins (phenols) which are occasionally noted.

Fats, oils (fat/oil curing)

The use of fats or oils in curing is depicted quite frequently in tombs of all periods, in the form of scenes of men dipping skins, both haired and depilated, into jars, then pulling the skins over a beam (a process known in the leather trade as 'staking') and rubbing them with a stone or some other tool (for a selection see Drenkhahn 1976: 7–8). Considering the lack of evidence for immersion in vegetable extracts for either dyeing or tanning, these scenes obviously depict oil-curing. In the 'Satire of the Trades' (a Twelfth-Dynasty composition in which a scribe presents hypercritical descriptions of a variety of trades), the substance in the leather-worker's vessel is actually specified as sesame oil.

The process of curing with fat or oil[*] depends on an oxidising reaction which is stimulated by kneading and manipulation, hence the usual association of immersion and staking. In view of the Egyptian artists' apparent reluctance to depict messy operations, the men scraping skins in these scenes are probably working in fats with the characteristic slicker (a blade with a small triangular hole preventing the blade from clogging) and pounding dressings into the skins with what is sometimes described as a 'stone', but which may be a hard bundle of leather snippets (e.g. UC 5704 in the Petrie Museum, which is perhaps from the Middle Kingdom town of Kahun). Alternatively, these scenes may show the removal of excess oil, rather than cutting fat and flesh from the skin prior to processing (*contra*, for example, Klebs 1934: 167; Forbes 1957: 24). The interpretation of such scenes in the literature is clearly coloured by the assumption that vegetable tanning was known at this period.

Mesopotamian craft archives (i.e. documents dating from several periods of Mesopotamian history, keeping account of the commodities delivered to institutional workshops, and the goods produced in them) also contain clear references to oil dressing (see p. 306) and this would seem to be the usual method of dealing with skins in antiquity. Mann (1960: 145, referring to 'rawhide' leather) describes a paste of flour, tallow, fat and salt (in the proportions 7:7:2:1) which, with the substitution of oil, would resemble the Egyptian pseudo-tannages, resulting in a yellowish-white product. In time, both the collagen and the oils and fats used in processing break down by hydrolysis in warm damp conditions (pH > 6.5) giving a black gelatinous mass which dries to a glossy substance, resembling resin, with which it is often confused (Cronyn 1990: 266; Landmann 1991: 31). Catalytic reactions with metals may cause similar gluey decay and the decomposition of rawhide and oiled leathers may be one reason for the apparent under-representation of leatherwork in tombs. Carter and Mace (1923: 121), comment on the poor state of the leather from Tutankhamun's tomb, which they accurately describe as 'untanned'. In general, remarks such as 'a pair of leather sandals (these were adhering to the bottom of the basket and could not be removed) . . .' (Carter and Carnarvon 1912: 72), are indicative of gelatinous decay and hence, indirectly, of oil curing.

Bravo (1948) considered that two of his samples (Turin, Museo Egizio, Suppl. nos 7681 and 281), unfortunately undated, had been oil cured, but analyses cannot differentiate between the oil used for curing and that used in finishing ('currying') leather which has already been treated in some other fashion.

Parchment

Parchment is produced from depilated, lightly cured skins with a surface bulking of chalk which are stretched while drying. Parchment is by definition stretched, but a similar, flexible, product can be obtained through manipulation in combination with pastes of flour, chalk and fats such as egg yolk or brains (Reed 1972: 119–20). Old Kingdom scenes apparently depicting 'staking' alone may be representing such a process (e.g. the tomb of Shedu at Deshasha; see Petrie 1898: pl. XXI). Since Bravo (1948) found relatively high values for calcium in the samples which he analysed, and large amounts were also present in a shoe in the Ashmolean (E2430, see Figs. 12.13, 12.15), the whitish leather from Egypt is most probably produced by such applications, and not, as is so often assumed, alum tawed. A few New Kingdom tomb-scenes show skins being stretched on a frame, which might mean that the Eighteenth-Dynasty Books of the Dead were the first texts to have been written on true parchment (Drenkhahn 1976: 7, no. IX; Martin 1987: no. 68; *cf.* Mann 1960: fig. 78; and see Fig. 12.2). As is to be expected, tests for tannins on an Eighteenth-Dynasty roll in the British Museum proved negative, but there is no indication of the curing method actually used (Leach 1995).

Mineral curing

Applications of mineral earths of indeterminate composition are useful in dehydrating skins as well as acting as mild preservatives for raw (green) skins in hot climates. Results are unpredictable and the variety of constituents (mainly common salt, NaCl, and calcium compounds) is difficult to analyse. In combination with the other pseudo-

---

[*] Fat/oil curing is also described as 'fat tawing' or 'chamoising', although properly chamoising refers only to flesh splits of sheepskin, treated with fish oil. Technically the term fat liquoring refers to the finishing of a tanned skin with fat or oil to improve its pliability.

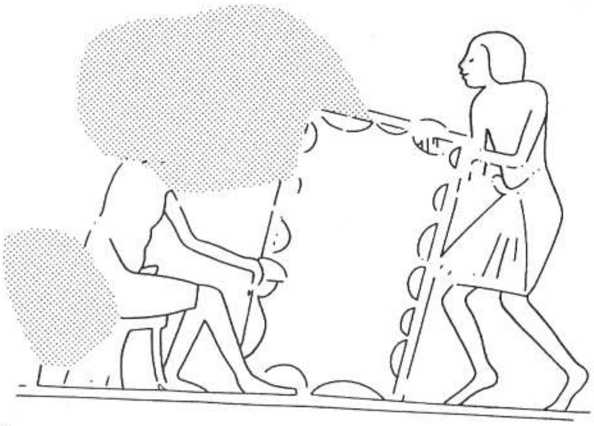


Figure 12.2 Late Eighteenth- or early Nineteenth-Dynasty relief from Saqqara, showing the process of stretching and scraping of skins (Berlin, ÄM 19782).

tannages described above, these may be the chief cause of inconclusive analytical results. Ochreous earths identified by Bravo (1948) in some Predynastic samples from the cemetery at Gebelein (excavated by Giulio Farina in 1930) could have served both to preserve and to colour the leather body wrappings.

Alum tawing

Alum ($KAl(SO_4)_2.12H_2O$), mixed with half its weight of salt ($NaCl$), together with a bulking of emulsifying fats (oil, or, traditionally, egg yolk: 25 eggs for 100 lb wet skin) and flour gives a pale, flexible, soft leather which is unstable, reverting to rawhide when the alum is washed out. The whitish colour of much Egyptian leather has tended to fuel the widespread assumption that alum tawing was practised from the earliest times. However, Lucas himself (1962: 257) states – with evident surprise – 'alum has never been discovered in connexion with ancient Egypt, and the evidence for its use is entirely circumstantial . . .' and, although he later describes the use of alum at some length, his evidence is drawn from Roman and later sources. It would appear that, as in Mesopotamia, alum was used primarily as a mordant with dyeing and not independently as a curing agent.

Quite apart from its use in the manufacture of white, tawed skins, alum is one of the most important mordants for vegetable dyestuffs, used to colour both skins and textiles (see section on dyeing methods in Chapter 11, this volume) and the two processes need, therefore, to be considered together. Renate Germer (1992: 18, 66–7, 79) has shown conclusively that mordant dyeing was first introduced into Egypt some time between the end of the Eighteenth Dynasty and the Twenty-first Dynasty, and this late recognition of the properties of alum is supported by the linguistic evidence (Harris 1961: 185ff, Helck 1975).

Although few analyses are available for leatherwork inherently unlikely that tawing would have been prac before the general use of alum in other processes. Trac aluminium in a small leather bag from grave 3148 at tagedda (BM EA63246; Second Intermediate Period) consistent with the background traces noted by Germe almost all her analyses (1992: 69–70), but the absenc aluminium from a white and red sandal with poin recurved toe (BM EA4396) may be more significant si such sandals can be dated to between the Nineteenth Twenty-first Dynasties, which is the period during wh alum mordants came to be widely employed. It shou however, be stressed that, in the absence of a control series of scans, it is inadvisable to draw far-reaching c clusions from this single example (V. Daniels pers. comm

In Mesopotamia on the other hand, alum (*gabû*, C Babylonian *allaḫarum*) had been used in conjunction wi madder since the third millennium BC as a means dyeing textiles and skins red, though there is no eviden for its use solely for tawing skins. It is, therefore, puzzlin that the Egyptians do not seem to have appreciated this lin until long after the introduction of madder dyes from th Levant during the Eighteenth Dynasty. The absence of a essential ingredient raises questions as to the manner introduction of new techniques, implying either a highl complex, piecemeal transfer of ill-understood operations a conscious rejection of certain substances by the Egyp tians. Or were dyers in the Levant also unaware of the rol of alum at this date, despite their Mesopotamian contacts Is this the secret of the lucrative exports of Mesopotamian textiles to areas such as Anatolia? Something that has been insufficiently appreciated in the literature is that the Mesopotamian records of considerable trade in Egyptian alum date predominantly to the first millennium BC (*CAD* G; Zadok 1985: 229 *gabû* (alum) from Mi-sir = Egypt); they are thus in broad agreement with Germer's evidence for the actual use of the substance (Germer 1992: 69–70). It must be stressed, however, that such records cannot be extrapolated to earlier periods, nor do they correlate with the proposed exploitation of cobalt-containing Egyptian alums as a source of the characteristic blue pigment of the Eighteenth and Nineteenth Dynasties (Kaczmarczyk 1986, 1991). In view of the lack of evidence for the use of alum in Egypt itself at this time, the exploitation of local alums during such a short-lived period requires further research, integrating the evidence from the study of textiles, leather, faience and paint.

Vegetable tanning

The process of vegetable tanning is the only means of producing true leather which is chemically stable, resistant to bacterial attack, flexible and waterproof. Given the paucity of analyses, the lack of positive indications for vegetable tanning in the Pharaonic period is hardly conclusive, though as things stand, and on visual evidence, it is likely that the process was unknown in Egypt until the Greco-Roman period. Vegetable tans are complex polyphenols occurring in two groups, the hydrolysable tannins (pyrogallols) found in such sources as oakwood, galls and sumac leaves, and the condensed tannins (catechols) found in acacia, mimosa and pine. The most common tanning agent in Europe, oak bark, contains both types of polyphenol (Bickley 1991).

Vegetable-tanned leather varies in colour depending on the extracts used, but, in contrast to the white or yellowish products of pseudo-tannages, tends to be darker through the entire thickness of the skin, ranging from ochre to red-brown. The characteristic dark colour of Greco-Roman footwear is caused by iron reactions in the soil, a reaction which also takes place in waterlogged contexts, and which forms the basis of tests for the presence of tannins (Daniels 1993; and see p. 316). Footwear dating to the period *c.* 90 BC–100 AD, from the Roman phase of occupation at the Lower Nubian settlement of Qasr Ibrim, is of tanned leather, while earlier and later native footwear is generally of rawhide (personal examination). By the 'early Christian' levels at Qasr Ibrim, sandals here – as elsewhere in Egypt – are of red-brown or black tanned hide. Bravo (1933: 87, 1948) was clearly puzzled by the total absence of vegetable tannins from his analyses: later compilers – including Lucas (1962: 34, significantly not citing any of his own analyses) – were less cautious and simply ascribed mastery of the techniques to the Egyptians.

The first records of the use of oak galls in tanning appear in Greek sources in the fourth century BC. According to Lau (1967: 56) vegetable tanning is first mentioned in classical literature by Theophrastus (*H. Plant.* III 8.6, 9.1, 14.3, 18.5 and IV 2,8.), although the linguistic differentiation between 'shoemakers' and 'tanners' which appears in the fifth century suggests that in the Greek world the separate processes may have been known earlier. Few of the other sources concerning vegetable tanning (cited by, among others, Forbes 1957; Reed 1972; Thomson 1981) date from before the first century BC.

Contrary to the impression conveyed by the secondary literature, there is no evidence for vegetable tanning in Mesopotamia at an earlier date. The generally quoted texts refer to the Hellenistic period or later, and the translation of *ḫuratu* as 'oak galls' (see *CAD* H; *contra* Sigrist 1981; and much of the tertiary literature) has long been discredited. The Mesopotamian evidence for the terminology of vegetable tanning is discussed by Stol (1983: 534–5) and Van Soldt (1990: 321–57, esp. 347) including the argument that *Puwatu* = *ḫuratu* = madder. Van de Mieroop (1987) proves without doubt that *ḫuratu* (Sumerian *e.rí.na*) is madder (*Rubia tinctorum*), which was grown in Syria and Anatolia on a considerable scale, its shoots and roots being used to colour both textiles and skins. Van Soldt (1990) notes that in the late second millennium BC at Ugarit madder is never attested without alum (*gabû*) and usually occurs in relation to flax. The references to alum in these texts again point to its use as a mordant. Van de Mieroop (1987: 153–4) extends the link between madder and alum back to the Ur III/Isin period, i.e. *c.* 2000 BC (as far back as the nature of the surviving texts allows), reconstructing the terminological association shown in Table 12.1.

Table 12.1. *The terminological associations between madder and alum in Mesopotamia (after Van der Mieroop 1987: 154).*

First millennium BC	ḫuratû + gabû	madder + alum
Old Babylonian period	ḫuratu + allaḫarum	madder + alum
Isin-Larsa period	ú-háb + allaḫarum	madder + alum

Thus all texts cited in support of tanning with oak galls in fact describe dyeing with madder and its mordant, alum. In northern Europe, tanned leather first seems to appear with the Roman conquest and any prehistoric skin products have survived as a result of exceptional conditions such as frozen deposits, dry salt mines or bogs, where it is subjected to a kind of secondary tannage. In Europe, as in Egypt and Mesopotamia, simple curing methods must have been the norm. In part, the late acceptance of true leather technology has to do with the protracted and complex preliminary working of the hides and skins, the large installations required, the length of time necessary for complete penetration of the liquors (up to two years for ox-hides) and, consequently the high level of skill and investment that was necessary.

A problem in the discussion of the history of true tanning is the status of the so-called 'Predynastic tannery' at Gebelein, where goatskins, supposedly awaiting processing, were found together with large quantities of acacia pods. Although such pods are still used today in local tanning industries, acacia also has many other uses (see Germer 1985), so the presence of pods and leaves alone does not automatically indicate that vegetable tanning was being practised. However, the excavator of the site at Gebelein, Schiaparelli (1921b), seems to have succeeded in convincing Bravo (1933: 86), and through him many others, including Lucas (1962: 34), and thus the 'earliest tannery in the world' has become an established fact, even though, as Bravo himself notes, there was no evidence for vegetable tanning in ancient Egypt, prior to his analyses of material from this site. In fact, the exceedingly summary report of Schiaparelli's excavations makes no mention of any 'tannery', while later accounts stress the long history of occupation of the site, with a major expansion under the Ptolemies when the garrison also housed soldiers of Greek extraction (Schiaparelli 1921b: 126–8; Donadoni Roveri 1989: 134–6). The Greek connection may be the significant factor here: if correct, this could reveal the way in which new technology was introduced. The implication is that analysis of material should take account of both the ethnicity of the settlement from which the finds come as well as the date of the finds in the assessment of results. Under the circumstances, it is perhaps more likely that the Gebelein tannery dates to the later first millennium BC than to the Predynastic period.

Secondary processing: staining and decorative techniques

Colour

The application of colour is inextricably linked to the curing processes. Although it has been suggested that the use of vegetable extracts may have developed from attempts to colour leathers prepared by other methods (Thomson 1981: 143), it is questionable whether there was any awareness that attempts to stain skin with pomegranate or sumac simultaneously enhanced the quality of the leather. The lack of immersion probably prevented the tanning action from penetrating deeply enough to be noticeable, and the same may be true of the alum mordants. The evidence for the sophisticated use of dyes and mordants marshalled by Lucas (1962: 152–4) in fact refers exclusively to the Roman period and later. Even the limited amount of evidence from the Dynastic period is consistent with Germer's finding for textiles (Germer 1992: 137): mineral colours predominate until the Eighteenth Dynasty, when vegetable dyes – madder (red) indigo (blue) and pomegranate (yellow and black) – begin to appear. On leather, colour is generally confined to the grain surface, leaving the lower surface white and indicative of painting or surface staining only. The poor, gelatinous state of much of the decorated work examined makes it difficult to establish the full range of colours, nor is it at present possible to distinguish changes or the emergence of new combinations through time. Red, green, yellow and white seem to be the most popular, but blue was not identified on the material available for study. This is curious, for the blue pigments identified by Kaczmarczyk (1986) could have been applied as a paint like the other mineral colours. Certain shades may, however, be more susceptible to discoloration: circular patches on a pair of green stained shoes in the British Museum (BM EA4408/9), for instance, seem to have been corroded by black metallic pigment decay products. An identical pair from Abydos retain their red stained patches and XRF analysis confirmed that mineral pigments were employed (see Fig.12.15). Red was achieved with iron and perhaps lead compounds, and green was created with copper compounds.

The range of colours appearing on Queen Istemkheb's funerary tent (Cairo) may point to improved knowledge of the properties of mordants and dyestuffs by the Twenty-first Dynasty, although in the absence of modern analyses, further speculation is unfounded. The pink pigment is said to consist of haematite with some lime, the blue i vegetable origin and the leather is said to be vegeta tanned (Villiers Stuart 1882). However, the extractive t for tannins used at that period probably record vegeta dyes rather than tanned skin.

The Mesopotamian craft archive of the Isin period 2000 BC.) discussed by Van de Mieroop (1987) illumina Egyptian practices in the New Kingdom and later. though he assumes that skins were cured with alum, t listing of the products used in the workshops in fact sho that the skins were oil-cured before being coloured. Fo colours were obtained: there is no mention of products f 'white', which must have been regarded as the basic shad Black was obtained with pomegranate (*nu-úr-ma*) and orp ment (*im-KÙ.GI*: literally 'gold-coloured earth' *cf.* Stol 198 35, however, in view of the black deposit caused by th reaction between tannins and iron salts, some other sub stance may be intended): here, as probably in Egypt, the pomegranate was not used as a tanning agent, but indirectly for the reaction between the tannins and the minerals, giving black. Red leather was already produced with madder and alum, see Table 12.1. From this it is clear that *úháb* is madder and not 'oak galls', since the latter would produce black, leaving the alum superfluous. Finally, copper was used to obtain green: about thirty to thirty-five grams of copper being required for a single skin. For Egypt, a late Nineteenth-Dynasty ostracon from Deir el-Medina (Cairo JE 25596; see Cerny 1935: 33–4) refers to a similar process: oil-cured skins coloured red with *ip* (madder) and *ibnw* (alum).

Decorative techniques

Although Pliny (*Nat. Hist.* XXXV: 42) marvels at the ingenious use made by the Egyptians of the properties of mordants, this expertise must be regarded as a late technological innovation, for New Kingdom leather goods achieve their colourful aspect by intricate and laborious arrangements of separately coloured strips, open-work, appliqué and mosaic patterns. One sandal (BM EA36200; Fig. 12.3) – unfortunately undated and unprovenanced, but, judging from the shape, probably late Eighteenth- or Nineteenth-Dynasty, combines several techniques in a lurid display of colour. Ankle and toe straps are wound round with red stained skin (now faded to pink), the green instep triangle is edged with red, and shapes are scraped away to expose the white surface underneath. Narrow strips of red leather (another dark colour may also be present) are woven through slits in the green-stained insole in a clear imitation of fibre sandals (an interesting and characteristic inversion: in Europe, wooden and fibre shoes imitate leather, whereas in Egypt it is fibre which is the model) and the insole and the thicker rawhide outer sole are attached using a red binding.

Weaving narrow strips of coloured leather through slits

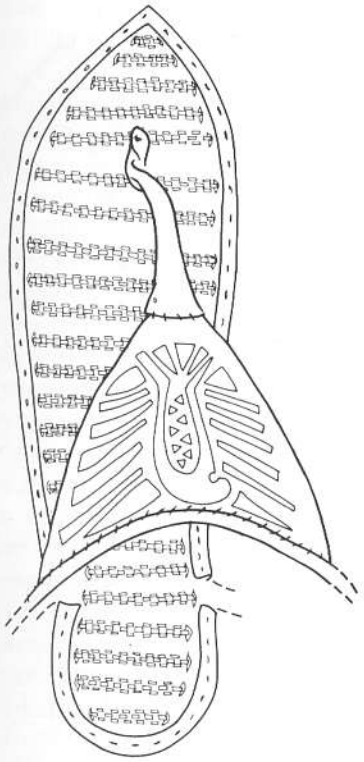


Figure 12.3 *Multi-coloured sandal (BM EA36200). Length 268 mm.*

is a common decorative technique, also used on quivers and lyres (Ziegler 1978: 113). Similarly laborious is a distinctive technique apparently favoured in the later Eighteenth Dynasty and used on footwear as well as on furnishings and other goods from the city at Amarna. Thin leather strips of slightly different widths are superimposed to give very narrow lines of alternating colours. Sometimes these are made up as separate strips up to three centimetres wide and cut into suitable lengths, but usually they were individually sewn to the backing. Despite being remarkably fiddly to sew, with all these different thicknesses, stitching could be varied to give extra effects, such as the zig-zags and ruffles on certain items from Amarna (Fig. 12.4).

Larger patterns were achieved by appliqués, with openwork revealing differently coloured backgrounds. In view of the knife slips, delicate tools were not employed and the patterns are frequently irregular and coarsely executed. Leather mosaic comes mainly from funerary contexts, and may have been a substitute for other materials, especially jewellery (Schiaparelli 1921a: 14), such as a set of leather plaits with spacers (BM EA23059). Queen Istemkheb's funerary tent with its multicoloured patchwork and elaborate appliqués may also come into this category, for it is surely too hot and airless for actual use in Egypt, although leather tents are well attested in the Roman Period in Europe (van Driel-Murray 1990). On the other hand, the lack of recognisable pieces of coloured mosaic in the extensive collection of leather from Amarna in the Ägyptisches Museum, Berlin could mean that such work only came into fashion after the Eighteenth Dynasty.

Now all too often obscured by dark decay products, these technically simple, but extremely labour-intensive methods must have produced bright and highly effective decoration. Presumably, the explanation for the persistence of such laborious methods is that colours could only be applied to complete skins and that the complex methods of staining and gilding (on the more intractable vegetable tanned leather), common in the Coptic period, were unknown. Instead, patterns were achieved by cutting, arranging and time-consuming stitching or gluing. Appliqué is wasteful of leather since layers are duplicated and snippets from open-work are discarded. The irregular scraps of red goat or gazelle skin used to edge the white rawhide mummy-braces, with their block-stamped presentation scenes, make use of such left-overs. Tooled and stamped designs were used on various items, such as quivers and archers' guards. Lavish use of stamps and tooled lines on sandal insoles is characteristic of the Roman period.

Historical survey

The Predynastic and Early Dynastic periods (c. 5500–2649 BC)

The very survival of anything as fragile as leather from Predynastic graves is quite remarkable: even more remarkable is the care that Flinders Petrie took in the excavation, curation and publication of these fragmentary and unprepossessing organic materials. In the Predynastic period – in contrast to the Dynastic – leather was widely used, and was also handled with considerable skill and confidence, although in the absence of scientific analyses the exact nature of the curing methods is unknown. Brunton and Caton-Thompson (1928: 40) comment on goat and antelope skin garments and wrappings from Predynastic graves at Badari, skin cloaks being worn primarily by men.

Predynastic garments seem to have been simple, some being fastened with toggles made from bone, teeth or tusks (e.g. Petrie and Quibell 1896: pl. LXII, no. 28 with

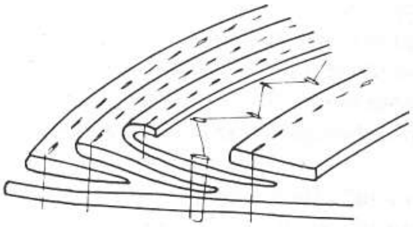


Figure 12.4 *Diagrammatic section detail of multi-coloured strips edging an artefact from Amarna (UC 35939). Not to scale (edging c. 30–35 mm wide).*

leather thong; Petrie 1920: pl. XXXIII, nos. 28–52) and others knotted on the shoulder (as on a figure of the king on the Early Dynastic Narmer Palette from Hierakonpolis). The tight creases of a large leather knot from grave 1743 at Naqada (Petrie Museum UC 5925) reveals just how supple the leather for such cloaks could be. In addition, a variety of fine stitching and lacing techniques using sinews, twisted thongs and twined thread attest to more complex garments. A small fragment of a bag from grave 1587 at Naqada (Petrie Museum UC 4372) shows the use of a beading strip between seams. Wrappings, covers and pillows were placed in many graves, along with bundles of folded skins, often still covered in hair. Predynastic cowhide, sheep, goat and possibly also gazelle skin can be identified in the collection of the Petrie Museum. Painted fragments of animal skin in some graves are suggestive of decorative leather hangings. Lashings, two-ply thongs and thicker, twisted cables of hide are common in the grave-goods at Naqada and Badari.

Also excavated from a grave at Naqada is a red-painted moulded rawhide container (Petrie Museum UC 36104; see Petrie and Quibell 1896: 29), perhaps confirming the suggestion that some Predynastic vessel shapes are derived from leather vessels. There are also more enigmatic objects such as leather-covered clay cones (e.g. Petrie Museum UC 4372 from tomb 1587 at Naqada, cf. Fig. 12.5a) and a large number of sticks wound about with rawhide thong, which may perhaps be the starting edges of woven leather mats or pot supports; several examples of are in the collection of the Petrie Museum (Fig.12.5). A variety of decorative techniques were employed, including stamping (UC 5053; grave 1592 at Naqada), tooling, in one case resembling basketry (UC 5051; grave 1589 at Naqada) and painting, as in the case of a belt with a pattern of black branches, in imitation of thonged decoration (Petrie and Quibell 1896: 48, no. 103).

Colours on Predynastic leather, presumably mineral-based, include black, red, white and yellow. The frequency of red pigment on objects in graves may well possess a ritual connotation, as in the case of a roughly cut oval of goatskin painted red on both sides from Naqada grave 1611 (Petrie Museum, UC 5924). Petrie suggests that a fragment painted black and yellow was imitating rows of small skins, which, if correct, implies the existence of furry cloaks with free-hanging tails (Petrie and Quibell 1896: 48, pl. LXVII/18). Brunton (1937: 47) also reports 'fur' from burials at Mostagedda. The frequent presence of bone and copper awls is further evidence for the importance of leather as a raw material in these communities (Brunton and Caton Thompson 1928: pl. XX.16). Nibbi (1993) makes a good case for the use of hide-covered boats in the Predynastic and Early Dynastic period: such skins would have had to be oil-cured.

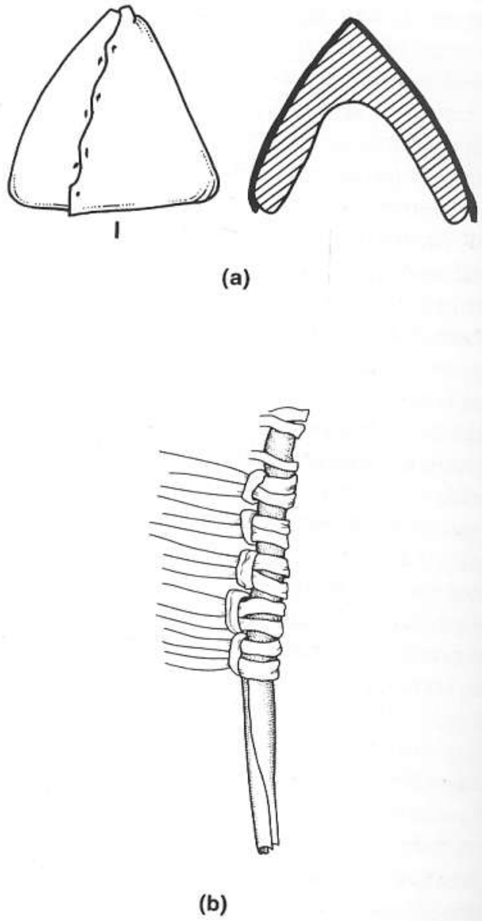


Figure 12.5 *(a) Leather-covered clay cone (Petrie Museum UC 4369; height* c. *28 mm) and (b) stick wound round with rawhide (Petrie Museum UC 5058; length* c. *110 mm).*

The Old and Middle Kingdoms (c. 2649–1640 BC)

In complete contrast to the more leather-oriented Predynastic, Nubian and pan-grave societies, Egyptian Old and Middle Kingdoms material culture was much more fibre- and textile-dominated. The decline in leather use seems to be quite abrupt, perhaps in consequence of the increasing use of textile clothing at this period, although metal tools suitable for leather-working do occur in Early Dynastic graves, while Old Kingdom texts and tomb depictions attest to the making of leather sandals and document cases. These two very different leather products could apparently both be made in the same establishment, judging from an inscription on the sarcophagus of Weta, an Old Kingdom official (Junker 1957: 7). However, for Forbes (1957: 27) to state that Weta was 'deeply involved in the leather trade' is a gross exaggeration and a complete misinterpretation of the nature of the text. The general impression from survivals is of a restricted range of leather products and the simplest of manufacturing techniques.

Domestic skin products from the Middle Kingdom town of Kahun seem to be confined to rawhide axe-lashings and moulded rawhide containers such as a rectangular cup containing fat and an oval bird tray, both now in the Petrie Museum (Petrie 1927: pl. 46.37; 47.76; UC 7116, 7128). Remnants of stitched leather were found in a slaughterhouse-cum-workshop at the Middle Kingdom fortress of Mirgissa in Lower Nubia, together with unworked skins in association with tethering stones (incorrectly described as anchors) and wooden pulley wheels (Nibbi 1993: fig. 11, Vila 1970: 189–90). This suggests the processing of the skins by some simple and rapid method (oiling?) directly after slaughter, and then their immediate use. In view of the twenty-two wooden shield grips found in the same room, they were probably used for shield manufacture at Mirgissa. The wooden pulley wheels might even point to the suspension of carcasses to ensure cleaner flaying. The narrow strips of stitched leather are a significant find, given that depictions and models at this time show shields made of differently coloured strips sewn together, as well as of single hides. The Middle Kingdom tombs at Asyut, for instance, include a wooden boss and spine, presumably deriving from a decayed hide shield, and wooden shields and quivers painted to resemble animal skins or coloured strips of hide (Chassinat and Palanque 1911: pls. II/2, XII/3, XIII/1, XIII/3). Winlock (1945: pl. IV) also discusses examples of hide wrist guards.

Cased skins have a very long history of use, and are still widely employed in the Near East as water containers. Small water skins carried on poles are depicted in tombs of the Middle and New Kingdoms (e.g. the Twelfth-Dynasty tomb of Khety at Beni Hasan, BH17; see Newberry and Griffith 1894: pl. XIV) or could be slung over the shoulder on hunting expeditions (as in the Twelfth-Dynasty tomb of Senbi I, no. B1 at Meir, see Blackman 1914–53: I, pl. VII) and a fragment of the tied nozzle of a goatskin bag was preserved at house Q46.2 in the southern part of the Eighteenth-Dynasty city at Amarna (Berlin, ÄM, 1912/13 no. 781). The water bags used by the Roman-period quarriers at Mons Claudianus were larger, employing complex waterproof seams as well as shaped pouring spouts (see Fig. 12.6 and Winterbottom 1990: 78–81). This is just one example of a category of equipment which must have been common on Roman military sites throughout the Empire, but which has only been preserved in Egypt.

Leather balls, made of between four and twelve segments, either in alternating colours or plain white, first appear in Middle Kingdom graves, such as a yellow and red ball from the Twelfth-Dynasty cemetery A at Riqqa (Petrie Museum, UC 31433, see Fig. 12.7). Anthes (1943: 66) mentions a set of six balls, each comprising four segments. Three of the balls are green and red, the others red and white (the latter being described as 'ungefärbt', i.e. the naturally white, cured skin).

The pan-grave culture

In many respects the pan-grave culture of the Second Intermediate Period (*c.* 1640–1532 BC) represents the continuation of Predynastic traditions and skills outside Egypt proper, but with an even stronger pastoral emphasis (e.g. the role of cattle hides and heads in the burial ritual, see Donadoni Roveri 1988: 182–3). Pan-grave leather goods share many traits with contemporary and later Nubian products. The quality of leatherwork in the pan graves excavated at Balabish and Mostagedda is extremely high, exploiting complex decorative techniques – similar to those used in Nubia (see Williams 1983: 65, pl. 106) – to enhance a wide range of items, such as garments, containers, covers and pouches (Wainwright 1920: 28–9, pls. III, IV, XI/2; Brunton 1937: 133). A number of the women's graves included fringed leather cloaks (sometimes stained red), while some of the men's graves included pierced kilts. The careful stitching, sometimes incorporating beads, often adds to the decorative effect, in particular when small pieces of leather have been used in the manner of patchwork (Wainwright 1920: pl. XI/1). Pan-grave footwear is the same as that found in Egyptian burials of the Dynastic period, but the pan-grave examples are usually more neatly finished off (see Fig. 12.8a).

Among the most typical pan-grave leather products are lobate archers' braces, which, although different in overall style compared with those current in the Middle or New Kingdoms, carry purely Egyptian stamped and tooled designs (Brunton 1937: 117, pls. LXXIV/1c, LXXV/49; Wainwright 1920: pl. XII/1–3; Raven 1988: 84–5, found together with a self bow and six arrows). Most drawings ignore the hole at the top of the lobe, through which a cord is looped round the thumb. Similar designs, but in a different medium, appear 2,000 years later in Nubia on the gold and silver braces in Meroitic and X-Group tombs (see Emery 1938: 232–3, fig. 86). The strong, stitched containers found in graves at Mostagedda were interpreted by Brunton (1937: 130) as milk pails (*cf.* BM 63223; and see Fig.12.8b).

The New Kingdom and Third Intermediate Period (c. 1550–712 BC)

Leather was more widely used in the Eighteenth Dynasty, perhaps partly as a result of the introduction of the new weapons technology from the Levant. Colour became increasingly important and elaborate decorative techniques added to the impression of wealth and display, although technologically, the methods of skin processing remained unchanged. Drenkhahn (1976: 130) notes that unlike other processes, the manufacture of chariots combined several skills and materials in integrated workshops which made

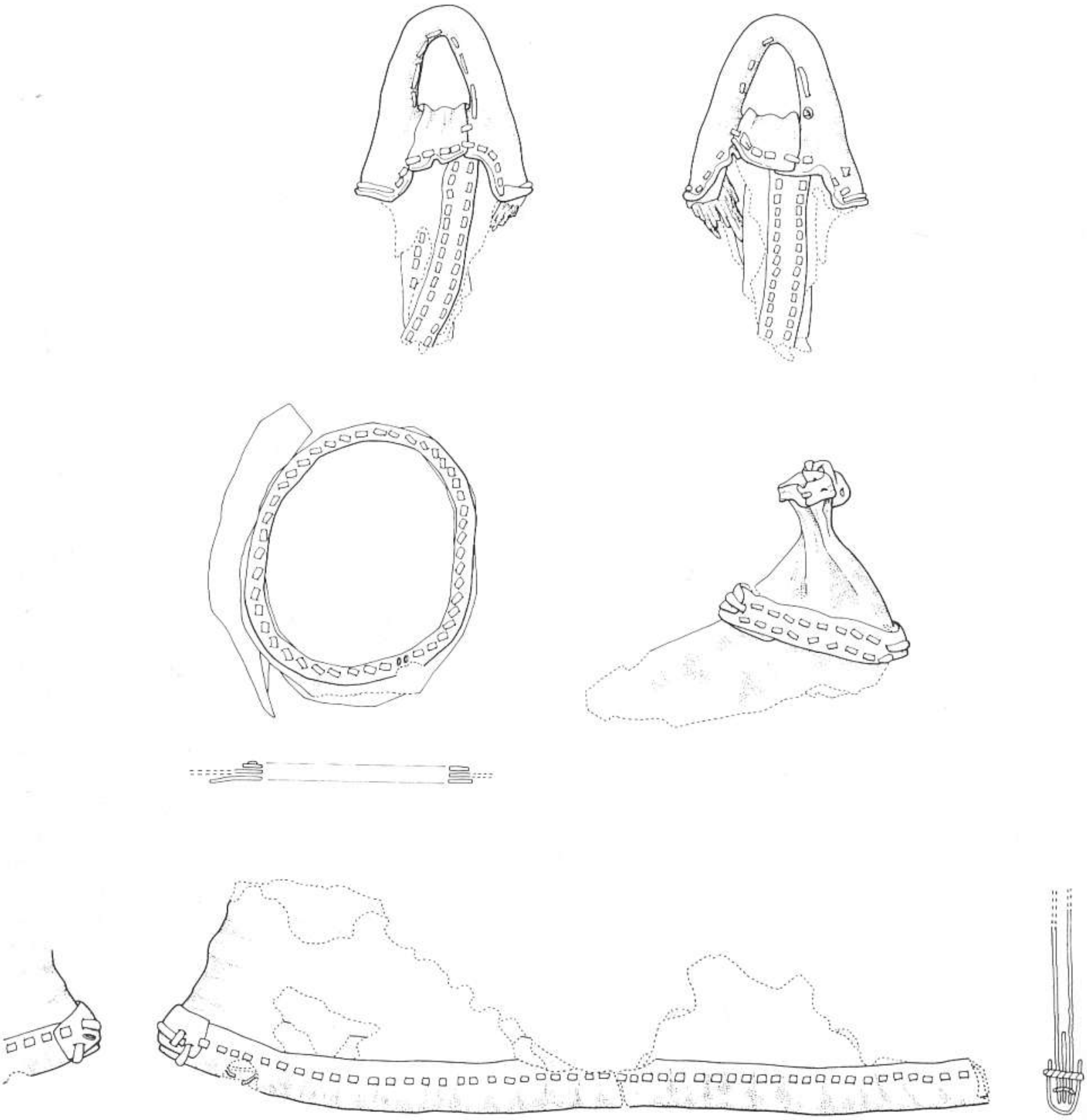


Figure 12.6 Characteristic elements of Roman-period water skins from Mons Claudianus. Scale 1:2.

not only the chariots themselves but also the necessary leather for thongs and harnessing, in addition to the associated equipment such as shields, arm guards and quivers (e.g. those depicted in the Eighteenth-Dynasty tombs of Rekhmira [TT100] and Kenamun [TT93] at Thebes; see Davies 1930: pls. XVI–XX, 1943: pls. LII–LIV). It is not, however, always clear from depictions whether leather, textiles or some other material are intended – the blinkers for Tutankhamun's horses, for instance, are of wood (Littauer and Crouwel 1985: 28).

The manufacture of chariots made sophisticated use of the properties of rawhide, leather and probably also skin-based glues. All surfaces which took stress or abrasion were sheathed in leather, while thick rawhide tyres (shrunk over the composite wheels) stabilised the construction. For display purposes there were even removable red leather tyres (Quibell 1908: 65). Heavy traces, securing the yoke to the central pole served to keep the horses in position (Hansen 1994; Littauer and Crouwel 1985). The introduction of the composite bow stimulated changes in

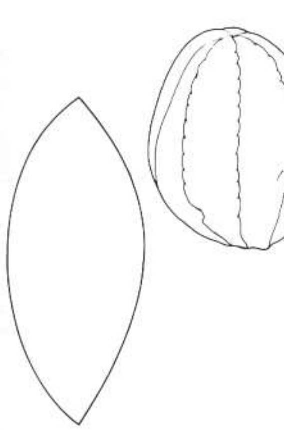


Figure 12.7 *Six-segment red and yellow leather ball from el-Riqqa (Petrie Museum UC 31433) with segment pattern. Scale 1 : 2.*

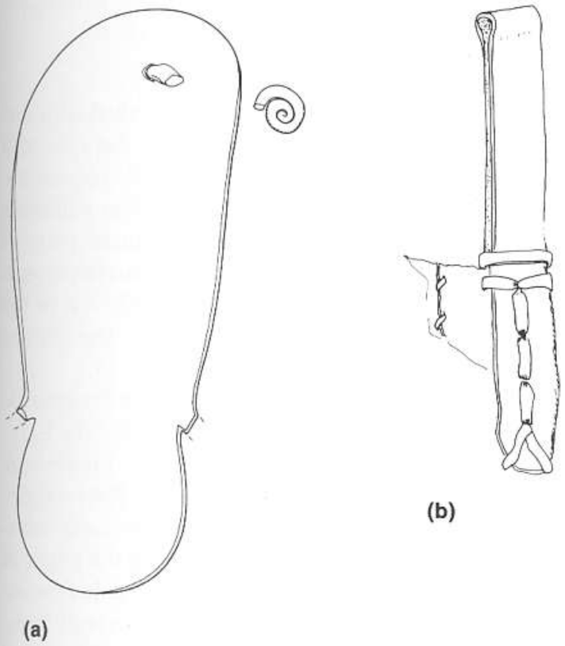


Figure 12.8 *(a) a sandal (BM EA63216; grave 3120; length 234 mm) and (b) reinforced loop from a 'milk pail' (BM EA63223; grave 3133; length c. 186 mm), both from Mostagedda.*

the form of arm guards and quivers. The brightly coloured guards, as depicted in tombs, are tied at wrist and elbow and, in contrast to earlier types, cover much of the lower arm. None seems to have survived and they may have been of padded textile.

The tubular arrow-quivers of the Middle Kingdom were replaced by tapered, round-bottomed types, sometimes using complete animal skins. Though now almost invisible under gelatinous decay, a red quiver in Berlin (ÄM 12476) combines openwork appliqués and couchwork with panels of superimposed coloured strips in red, white, green and black (?), with green, pinked edgings in typically New Kingdom fashion. A quiver from the Eighteenth-Dynasty tomb of Maiherpri in the Valley of the Kings (KV36, dating to the reign of Thutmose III) is unusual not only for its almost perfect preservation, but also for its finely executed, crisp, designs in raised relief (block stamped?), revealing a quality of workmanship which has rarely survived (Daressy 1902: pl. X, nos. 24071–2).

Associated with Nubian mercenaries in the Eighteenth Dynasty, and springing from the pan-grave tradition of pierced leather (see p. 309), are the gazelle-skin net kilts or loincloths (e.g. BM 21999, 2564). The very delicate nets of surviving examples can hardly have served to 'protect' linen loincloths, and they should perhaps be regarded as ethnic markers (Vogelsang-Eastwood 1993: 16–31). Not all such work dates to the Eighteenth Dynasty: a late Roman-period tanned-skin hair-net from Akhmim (Berlin, ÄM 10639) is identical in construction to the 'loincloths' but circular in shape (and a similar Roman netted 'turban' of brown and red wool is described by Winlock 1926: 31–2).

The leatherwork from the Eighteenth-Dynasty city at Armana, much of which is now preserved in the Ägyptisches Museum, Berlin and the Ashmolean Museum, Oxford, is of particular importance in establishing the range of leather goods used in a domestic context in the New Kingdom, especially as finds are in many cases traceable to specific rooms (Borchardt and Ricke 1980). Sandals are common in all houses, as are the rawhide lashings of tool hafting, some of considerable length and intricacy. Larger fragments, suggestive of furnishings or covers, reveal the widespread use of coloured borders and appliqué designs on items of household use. From house N50.1 come at least four sandals, three tool lashings, assorted thongs and straps, odd thongs bound together as handles, several fragments of larger objects edged with coloured strips, a large piece of red rawhide with a green palmette appliqué

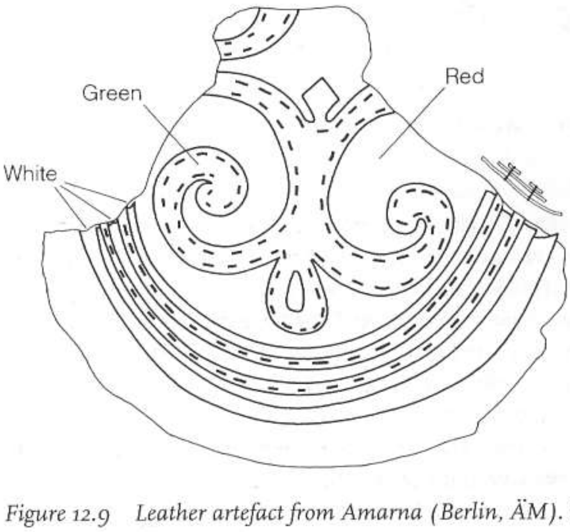


Figure 12.9 *Leather artefact from Amarna (Berlin, ÄM). Scale 1:2.*

(Fig.12.9), and a wide band of composite coloured strips. The excavation of a neighbouring house yielded a small rawhide sheath sewn with red thong or sinew and several rolled up strips that look like buttons. Rawhide belt fragments display an ingenious 'zip fastening', whereby the overlapping ends are interwoven by means of a vertical thong passing through alternating slits.

Offcuts (including both skin edges and the pieces left after cutting out shaped items) are present in the Berlin collection, while Peet and Woolley (1923: 32–3) mention quantities of leather from house P46.14, including unused pieces and numerous trimmings. It is unfortunate that none of the offcuts from P46.14 survives, since this would probably be the earliest attested Egyptian leather-worker's shop.

Many New Kingdom wooden chairs are provided with fibre seats, but folding stools and some Eighteenth-Dynasty 'U-shaped' stools have leather seating-strips. The royal woman named Ahmose, whose tomb in the Valley of the Queens was excavated by Schiaparelli (1921a: 14), was not only buried with leather shoes and substitute jewellery but was also provided with a fine mat, woven of green leather thongs in a large diamond twill pattern.

Skin membranes were also used for lutes, tambourines and lyres (Manniche 1973; Ziegler 1977). Typical for the Twenty-second Dynasty are rawhide mummy-braces: a set of four concave labels (Berlin ÄM 6964/65) still has the red-painted rawhide straps intact.

Footwear

In most cultures, the most common leather artefact is footwear, although in Pharaonic Egypt fibre was more frequently used for this purpose. On the basis of certain surviving Egyptian magic spells, Bongrani-Fanfoni (1978) proposes that sandals may have fulfilled a protective function in tombs, but the significance of footwear may be more complex than this. Since footwear only appears as an optional extra in tombs already evidencing a moderate degree of wealth, it is possible that sandals may not have been considered appropriate footwear in death, even if, by the New Kingdom, they were widely worn in life (Smith 1992: 219). A statistic according to type (sandals or shoes), materials (fibre, leather or even gold), use (real or models) as well as the sex and occupation of the recipient over a longer period might clarify the role of footwear in tombs. It is, for example, noticeable that Kha, the Eighteenth-Dynasty workman buried in tomb TT8 at Deir el-Medina, had three pairs of sandals, while his wife had none (Schiaparelli 1927: 85), although Mera, a Fifth-Dynasty priestess of Hathor buried at Deshasha possessed two pairs of model sandals, one pair being placed inside her coffin (Petrie 1898: 20). Many of the New Kingdom sandals that the writer was able to examine had indeed been worn: a pair of red-stained sandals from the Eighteenth-Dynasty Tomb N at Gurob (Ashmolean 1889.1086; see Fig 12.11c) are caked with dirt typical of outdoor use with bare feet, as is the colourful example now in the British Museum (BM EA36200; see Fig. 12.3). Although sizes may seem to vary, they still seem to be personal possessions: one of Kha's three pairs of sandals is apparently much larger, but comparison reveals that the largeness lies in the length and width, not in the dimensions of the foot fitting within the straps (Schiaparelli 1927: 85).

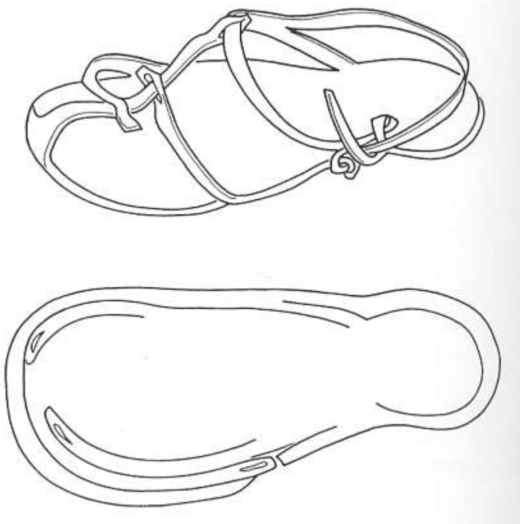


Figure 12.10 Predynastic sandal from Gebelein with reconstructed cutting pattern (Turin, Museo Egizio; dimensions unknown).

No sandals appear to have been found in the Predynastic cemeteries at Badari, Naqada or Mostagedda, but the Egyptian Museum of Turin possesses some Predynastic examples, possibly from Gebelein (Donadoni Roveri 1988: pl. 5). Unlike later Egyptian sandals, these possess interlaced strap-work, formed by partially severing the edges of the sole (Fig. 12.10). Petrie's excavation of a Naqada I-period grave (*c.* 4000–3500 BC) at the cemetery of Diospolis Parva yielded a pair of model sandals painted red, the ragged outline of which resembles the edge-cut strap-work of the Gebelein pair (Petrie 1901: pl. X/U160). Sandals with an apparently similar construction from Nahal Mishmar (a Ghassulian cave-site in Israel; Bar-Adon 1980: 187) may point to a common footwear tradition in the Levant and Egypt for a short time in the Chalcolithic/Early Bronze Age.

In the Old Kingdom, few people other than the king are depicted wearing sandals, although wooden models of sandals begin to appear in tombs, placed in or near the coffin and usually painted white. Although no actual sandals were contained in them, Petrie's so-called 'sandal trays' from graves at Tarkhan may be indicative of the value of footwear in the Early Dynastic period (Petrie 1913: 11, pls. XI/24, XII/10).

There are sandal-making scenes in the tombs of Anta and Shedu at the rather poor Fifth-Dynasty cemetery of

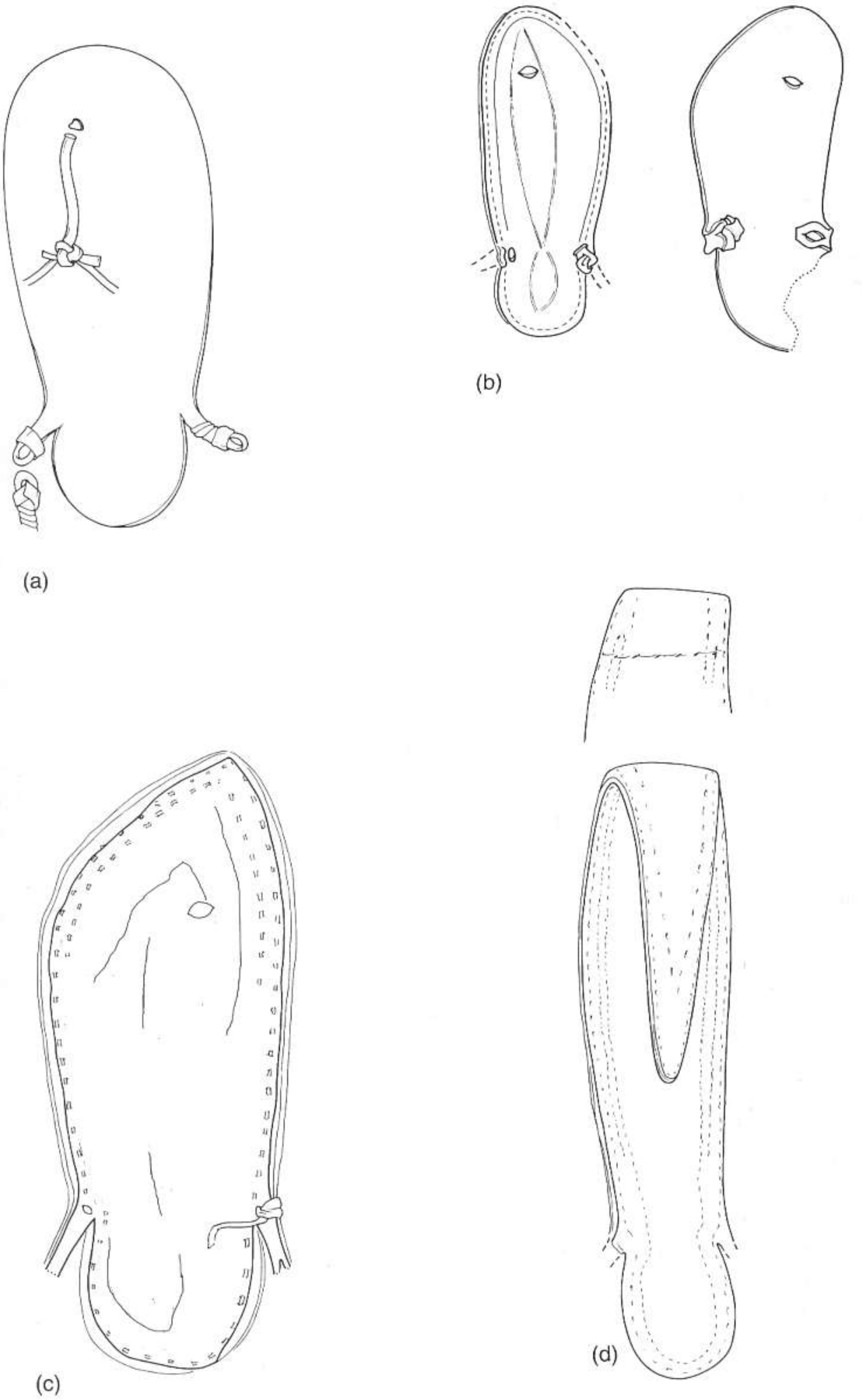
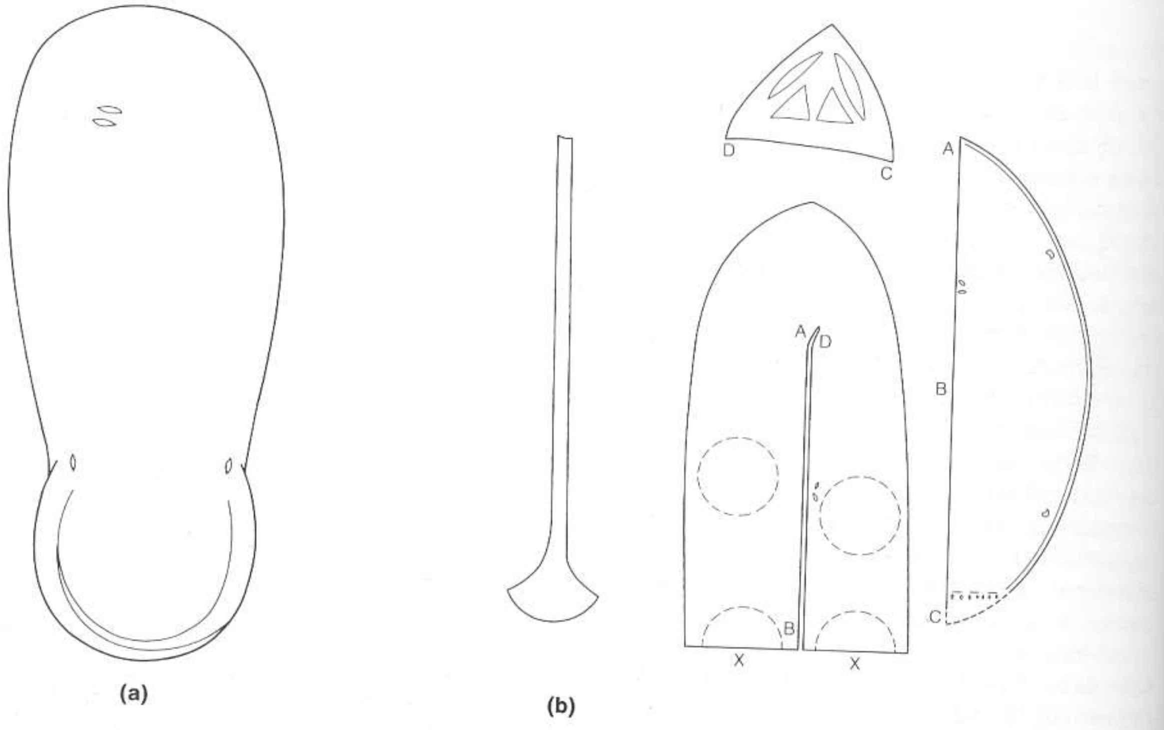


Figure 12.11 *Egyptian sandals: (a) Eleventh-Dynasty sandal (BM EA41674; length 211 mm). (b) Two Eighteenth-Dynasty children's sandals from Amarna (Berlin, ÄM; length 146 and 150 mm). (c) Late Eighteenth-early Nineteenth-Dynasty two-layer sandal with red stained surface from Gurob Tomb N (Ashmolean 1889: 1068). (d) Ramesside three-layer padded sandal with white goatskin insole and red stained outside point cover, from Gurob (UC 28350; total length 415 mm). 12a–d all at scale 1:3.*

Deshasha (Petrie 1898: pls. XIII, XXI), but apparently only one servant-statue portrays a leather-worker (from tomb 275 at Beni Hasan; see Garstang 1907: fig. 129). The scenes at Deshasha reveal that the standard, characteristically Egyptian 'eared' cutting pattern (Fig. 12.11a) was already in vogue, and that left and right feet were clearly distinguished from the earliest times. Sandals are made of one or more layers of skin (usually cow-hide), with strips cut loose from the seat being turned up to hold the ankle strap. The ends of these ears could be simply pierced, or if cut concentrically as on the diagram, folded down to form a loop (Fig. 12.11a, b). Of utmost simplicity, this ingenious technique lasts the entire span of Pharaonic history, and the break in continuity represented by the Roman occupation is well-illustrated by its total disappearance at this point (being replaced by a style of sandal in which the side straps tend to be either inserted separately or woven into the thickness of the sole leather). Where two or more layers of leather were used, the lobes of each layer are twisted together to form thicker attachment points, and these may also be wound round with a strip of differently coloured leather. Toe and ankle straps could be T- or Y-shaped, sometimes going right round the back of the foot and increasing in width and elaboration in the New Kingdom (Alfano 1987). In contrast to the white-painted wooden models and the yellow-white of cured and rawhide sandals surviving from the Old and Middle Kingdom, New Kingdom sandals are colourful, with red-stained soles and contrasting straps, sometimes broadened to take additional decoration and further embellished with coloured strips sewn round the edge of the sole, as in the examples in the Ägyptisches Museum, Berlin (Inv. no. 20998 from Deir el-Medina; see Anthes 1943: 66, Taf.17) and the British Museum (BM EA4389 and BM EA36200). Numerous examples of such sandals can be cited from tombs (e.g. at Gurob and Deir el-Medina), settlements (e.g. Kahun and Amarna) and funerary sandal-making scenes (Drenkhahn 1976: 7).

Tutankhamun's sandals are predominately made of fibre, with elaboration confined to an overload of gold and decoration rather than any technological sophistication: they are basically identical to Old and Middle kingdom sandals, although with a slightly stumpy point, while his 'shoes' are merely sandals with a strip attached to cover the edge of the foot (similar to the child's shoe in Fig. 12.13). Sandals with some partial covering for the toes also occur in more modest circumstances (Bruyère 1937: 64, fig. 33 bottom centre). The sandals from those tombs at Deir el-Medina identified as pre-Amarna by Smith (1992) are also generally rounded, and although mild points appear among the sandals from Amarna, Sennefer still has broad, round-toed sandals (Bruyère 1929: 68, fig. 34) while a pair of sandals from the very end of the Eighteenth Dynasty from Tomb N at Gurob (Ashmolean Museum 1889.1086; Petrie 1890:39) are also only mildly pointed (Fig. 12.11c). These have a red-stained upper surface which has faded to



(a)

(b)

Figure 12.12 Basic patterns of Egyptian footwear: (a) Eared sandal sole. (b) Split oval upper with strip to increase its height, instep flap, separately attached point. Pattern based on BM EA4408/9 and Ashmolean E2430. Not to scale.

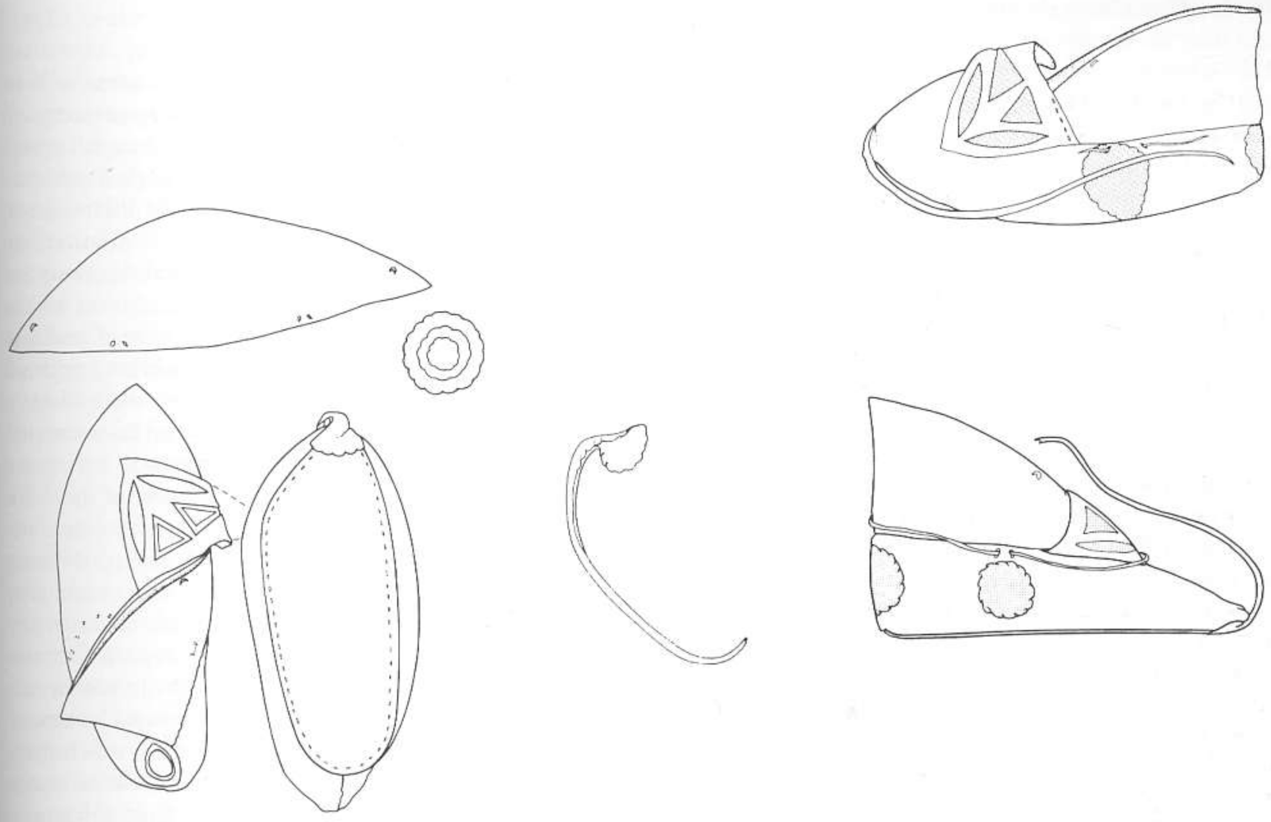


Figure 12.13 Green ankle boots with coloured patterns and cut outs. Composite reconstruction based on BM EA4408/9 and Ashmolean E2430 (length of sole: 138–140 mm).

a pale pink and the resinous decay products on the outer sole are suggestive of oil-cured hide.

Only during the Nineteenth Dynasty does any real sign of fashion change become noticeable, with the appearance of narrow, colourful, sandals, with long, recurved points (Fig. 12.11d). A pair belonging to Tanut, a singer and dancer of Amun have a yellow edging, green straps and red goat-skin insole over a hair padding and can be dated to the Twenty-first Dynasty (Gall 1961: 106). Such sandals are apparently first worn by women, but depictions from the Twenty-second Dynasty also show men with recurved toes of such dimensions that the point is attached to the ankle strap. Such sandals occur more commonly in fibre, as do the enclosed sandals. In funerary scenes, the size of the curl is seemingly related to status. Perez-Die and Vernus (1992: fig. 13) note a scene in a Twenty-first- or Twenty-second-Dynasty tomb, showing a servant wearing modest sandals before a seated personage with stupendous curled toes.

In the Roman period, pointed sandals again become fashionable, but Pharaonic-period examples can be differentiated by the use of cured, not tanned, leather, the eared cutting pattern, two or three lines of through stitching around the edges, the use of colour and the attachment of a triangle in a contrasting colour to the outside of the curled toe (Thomas 1981: pl. 51/470 Pharaonic, 51/469, 471 Roman).

Shoes covering the entire foot were much less frequent, and may not have appeared until the very end of the Eighteenth Dynasty. From the sizes of the surviving examples, all belonged to women and girls, and they were apparently never depicted in tomb decorations. One group of coloured shoes or ankle boots with long curled points attached separately (Figs. 12.12b and 12.13) is particularly interesting. Two virtually identical pairs were examined, one in the British Museum (BM EA4408–9, unprovenanced) and another in the Ashmolean (E2430). The provenance of the latter pair is given on the inventory card as the late Eighteenth- or early Nineteenth-Dynasty grave W2 at Abydos, although they are not mentioned in the rather summary account of this tomb, with its remarkable pottery. Their small size, however, accords with the fact that a 'fourteen-year-old girl' was buried there (Ayrton *et al.* 1904: 49–50). Schiaparelli (1921a: figs. 15, 38) describes green ankle boots found in burials in the Valley of the Queens. The only pair of pointed shoes recovered from Deir el-Medina derives from tomb 1386, which contained a re-used coffin of the second half of the Eighteenth Dynasty (Bruyère 1937: 65, fig. 33 middle row centre).

Shoes may have been a post-Amarna introduction, given that first they do not seem to be present among the finds from the city at Amarna, and secondly no true shoes were found in the tomb of Tutankhamun. It is tempting to link the arrival of shoes in Egypt with the pointed boots worn by their Hittite rivals in the late New Kingdom, although to substantiate such a claim would require considerably better dating of the Egyptian finds, as well as comparative material from the Levant.

The basic elements of these shoes are very simple, the upper being just a slit oval, while the long curl is made of a rolled strip of leather sewn under the sole (Fig. 12.12b). The soles are often red, the uppers green, and coloured roundels may be sewn to the back and sides. A pair of red slippers from Deir el-Medina (Berlin, ÄM 21767; Anthes 1943: 66, Abb.30) has an extra strip inserted between sole and upper to improve the fit around the indented big toe, which resembles Coptic socks. This raises the question whether these delicate, coloured slippers may originally have been worn together with fibre sandals, especially as the coloured soles do not show any signs of real wear. Conversely, leather soles were occasionally attached to fibre sandals, as in the case of Tutankhamun's court slippers (Carter and Mace 1923: 167–9).

Unfortunately unprovenanced, but said to be 'Ptolemaic', is a curious group of shoes in the British Museum (EA4402, 4413, 4415; see Fig. 12.14). Here the 'ears' cut from the sole are considerably lengthened and are utilised to stiffen the sides of the upper, now made of properly tanned leather, but still following the slit-oval cutting pattern of the Eighteenth-Dynasty shoes. What is particularly interesting is the combination of tanned and rawhide sole layers in these shoes. If they are indeed Ptolemaic, they may reveal a slow marriage of traditions, rudely broken off by the complete change brought about by the Roman occupation.

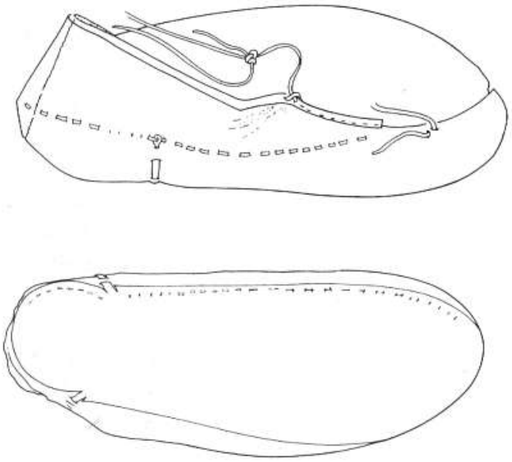


Figure 12.14 'Ptolemaic' red leather shoe with slit oval upper and eared sole (BM EA4402/3; length of sole: 183 mm).

Methods of scientific analysis

Certain methodological problems have already been touched on in the sections dealing with skin processing and colour above. Egyptian 'tanning' never seems to have progressed beyond *ad hoc* applications with unpredictable results. Although modern methods are clearly differentiated, there is considerable overlap between the various curing techniques, and chemical analysis of ancient skins may not always pick up sufficient characteristic substances for the exact method to be established. Interpretation of results is therefore highly complex: alternatives should be considered especially in conjunction with simple presence/absence tests. The combination of processes may lead to unexpected results and such effects need to be recognised.

The various curing methods utilise many of the same substances, but in different combinations and proportions: vegetable oil, animal fats (cholesterols), chemical traces from urine or fermenting flour, calcium compounds, various mineral salts, some of which, like ochre, common salt (NaCl) or alum in higher percentages, were deliberately chosen, while others (like traces of aluminium/alum, *cf.* Germer 1992: 69–70) were evidently randomly present as natural constituents of mineral earths, all of which may, depending on the type of analysis chosen, leave some recognisable trace. In the 1930s and 1940s, G.A. Bravo was already acutely aware of the effects of the combination of processes, even down to the possibility of contamination from multi-purpose vessels. It is unfortunate that his caution has not been followed by later researchers and that the chemical complexity of the curing methods has gone largely unnoticed.

The general assumption that vegetable tanning was a well-known procedure from the earliest of times has hampered active research, with far too great a value being placed on faintly positive tannin reactions, even though Bravo already recognised that these faint reactions were probably caused by vegetable dyestuffs applied to cured (oiled) leather. Consequently all extractive methods as well as the ultraviolet (UV) inspection described by Reed (1972: 260) to distinguish tanned from untreated skins, should be applied with caution to ancient Egyptian material, since the presence of vegetable-based dyes will affect the result. Reed's interpretation of a pattern of fluorescence obtained from a sandal with a bright red surface dating to the first millennium BC is contradictory and can more logically be explained as an application of a madder infusion combined with an alum mordant to a cured, probably oiled, hide (Reed 1972: 260). Similarly, the so-called 'vegetable tanned horse trappings' (Reed 1972: 194, fig. 6) from Tutankhamun's tomb are probably cured skin with vegetable colouring on the surface. A useful test for tannins, recently assessed by Daniels (1993), relies on the characteristic darkening of tanned fibres when treated with ferrous sulphate (2 per cent $FeSO_4$ w/v in distilled water, see Leach

1995 for description of the method). This method is quick and simple, which should make widespread application feasible for the first time. Because it relies on a spot colour change, it is particularly appropriate for use on painted or stained items, since the coloured surfaces can be separated from the body of the leather. Potentially, this is a very powerful tool in the search for the first regular use of tannins in leather processing in Egypt. However, considering the migration of copper salts right through the Ashmolean shoe E2430, revealed by XRF, but invisible to the eye, further research into the depth of penetration of colouring agents is perhaps called for (see Fig. 12.15).

Alum plays a vital role in several, unrelated technological processes: analytical results should not, therefore, be interpreted in isolation. Considering the importance of the substance, a programme of research centred on alum/aluminium itself would be desirable. In particular, the exploitation of Egyptian alum needs to be more closely dated. At present analyses are scarce. Although difficult to detect with x-ray fluorescence spectroscopy, aluminium can be detected with a scanning electron microscope using energy dispersive x-ray analysis (EDXA; V. Daniels pers. comm.). Other techniques sensitive to aluminium could also be applied, but it is important that aluminium is actively sought in all analyses of Egyptian leatherwork otherwise essential information on skin processing methods will be overlooked.

Methods used for the identification of colouring agents on textiles are equally applicable to leather goods as both mineral and vegetable colours could be used (Germer 1992). The XRF scan in Figure 12.15 identifies the mineral-based colours clearly, as well as one of the substances (Ca) used at some stage in processing, but does not reveal details of the curing method or whether alum was used. Furthermore, account needs to be taken of the overlap between mordants and curing agents.

Entrenched assumptions as to the 'antiquity' of many substances and the processes using them have severely hampered scientific investigation. It can only be hoped that a heightened awareness of the importance of undertaking analysis within a clear chronological framework will stimulate research.

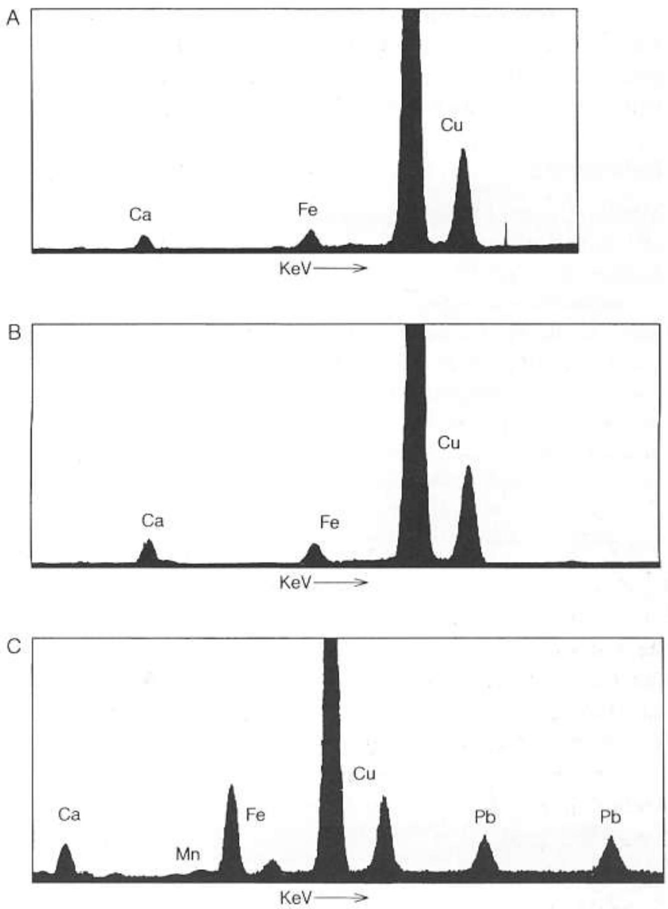


Figure 12.15 XRF scans of three different parts of an ankle-boot: (A) inner surface, (B) top surface and (C) red sole (Ashmolean E2430).

Acknowledgements

This contribution was made possible by a travel grant from the Netherlands Organisation for Pure Research (NWO) which enabled me to examine leather in the collection of several institutions in Britain. I would like to express my thanks to the following for permission to refer to the leather finds in their possession and for valuable and unstinting assistance: Dr H. Whitehouse, Department of Antiquities, Ashmolean Museum, Oxford; Dr J. Spencer and Dr S. Quirke, Department of Egyptian Antiquities, British Museum, London; Dr B. Adams, curator of the Petrie Museum of Egyptian Archaeology, University College, London; Professor Dr G. Wildung and Dr. H. Kischkewitz, Staatliche Museen zu Berlin, Preussischer Kulturbesitz, Ägyptisches Museum und Papyrussammlung. Permission to use objects from their collections for illustrative purposes was generously given by all these institutions. The XRF analysis of Ashmolean E2430, from Abydos tomb W2 was kindly carried out by the Conservation Laboratory staff at the Ashmolean, with the aid of equipment at the Research Laboratory for Archaeology and the History of Art, Oxford, and the results are deposited in the archives of the Department of Antiquities, Ashmolean Museum; I am indebted to Dr Whitehouse for arranging the analyis, and to Dr V. Daniels, British Museum Department of Conservation, for information on analyses and analytical methods as well as permission to refer to unpublished reports. My thanks are also due to Ms B. Wills, Organics Conservation, British Museum for her assistance in locating samples of hippopotamus hide for comparison, and for her advice on this and other matters of identification. I am grateful to Dr C. Cavallo for obtaining copies of the publications by Bravo

(1933, 1948) and for translations of the Italian. With the exception of Figs 12.5, 12.6 and 12.15 the drawings were produced by B. Brouwenstijn and B. Donker (Institute of Pre- and Proto-history, Amsterdam).

References

Alfano, C. 1987. *I Sandali: moda e rituale nell' Antico Egitto*. Città di Castello: Tibergraph.

Anthes, R. 1943. Die Deutschen Grabungen auf der Westseite vom Theben in den Jahren 1911 und 1913. *MDAIK*, 12: 1–68.

Aten, A., Innes, R.F. and Knew, E. 1978. *Flaying and Curing of Hides and Skins as a Rural Industry*. Rome: Food and Agriculture Organization of the United Nations.

Ayrton, E.R., Currely, C.T. and Weigall, A.E.P. 1904. *Abydos* III. London, EES.

Bar-Adon, P. 1980. *The Cave of the Treasure: the Finds from the Caves in Nahal Mishmar*. Jerusalem: Israel Exploration Society.

Bickley, J.C. 1991. Vegetable tannins. In *Leather – its Composition and Changes with Time* (eds. C. Calnan and B.M. Haines). Northampton: Leather Conservation Centre Northampton, pp. 16–23.

Blackman, A.M. 1914–53. *The Rock Tombs of Meir* I–VI. London: EES.

Bongrani-Fanfoni, L. 1978. I sandali e il cammino del' 'Aldila'. *Vincino Oriente*, 1: 1–3.

Borchardt, L. and Ricke, H. 1980. *Die Wohnhäuser in Tell el-Amarna*. Berlin: DOG.

Bravo, G. A. 1933. La lavorazione delle pelli e del cuoio nell'Egitto antico. *Bollettino Ufficiale della R. Stazione Sperimentale per l'industria delle Pelli e delle Materie concianti*, 11: 75–92.

1948. Unpublished typescript in the Egyptian Museum, Turin, dated 15 January, 1948.

Brunton, G. 1937. *Mostagedda and the Tasian Culture: British Museum Expedition to Middle Egypt 1928–29*. London: BMP.

Brunton, G. and Caton-Tompson, G. 1928. *The Badarian Civilization and Predynastic Remains near Badari*. London: BSEA.

Bruyère, B. 1929. *Rapport sur les fouilles de Deir el Medineh (1928)*. Cairo: IFAO.

1937. *Rapport sur les fouilles de Deir el Medineh (1934–5)*. Cairo: IFAO.

CAD 1955 = *Chicago Assyrian Dictionary*. Chicago : Chicago University Press.

Carter, H. and Mace, A.C. 1923. *The Tomb of Tutankhamun I*, 3 vols. London: Cassel.

Carter, H. and Earl of Carnarvon, 1912. *Five Years' Exploration at Thebes*. Oxford: OUP.

Cerny, J. 1935. *Ostraca Hiératiques* I. Catalogue géneral des antiquités égyptiennes du Musée du Caire nos 255501–25832. Cairo: SAE.

Chassinat, É. and Palanque, Ch. 1911. *Une campagne de fouilles dans la nécropole d'Assiout*. Cairo: IFAO.

Cronyn, J.M. 1990. *The Elements of Archaeological Conservation*. London: Routledge.

Daniels, V. 1993. Evaluation of a test for tannin in leather. British Museum Conservation Research Report no. CA1993/1, unpublished manuscript.

Daressy, M.G. 1902. *Fouilles de la Vallée des Rois (1898–1899)*. Cairo: SAE.

Davies, N. de G. 1922. *The Tomb of Puyemre at Thebes*. New York: MMA.

1930. *The Tomb of Ken-Amun at Thebes*. 2 vols. New York: MMA.

1943. *The Tomb of Rekh-mi-Re at Thebes*. New York: MMA.

Donadoni Roveri, A.M. 1988. *Egyptian Civilization: Religious Beliefs*. Milan: Electa.

(ed.) 1989. *Dal museo al museo: passato e futuro del Museo Egizio di Torino*. Turin: Umberto Allemandi and Co.

Drenkhahn, R. 1976. *Die Handwerker und ihre Tätigkeiten im alter Ägypten*. Wiesbaden: Harrassowitz.

Driel-Murray, C. van, 1990. New light on old tents. *Journal of Roman Military Equipment Studies*, 1: 109–37.

Eggebrecht, A. 1973. Schlachtungsbräuche im alten Ägypten und ihre Wiedergabe im Flachbild bis zum ende des mittleren Reiches. Doctoral dissertation. Department of Egyptology, University of Munich.

Emery, W.B. 1938. *The Royal Tombs of Ballana and Qustul*. Cairo: SAE.

Forbes, R.J. 1957. *Studies in Ancient Technology* V Leiden: Brill.

Frauberger, H. 1896. *Antike und Frähmittelalterliche Fussbekleidungen aus Achmin-Panopolis*. Düsseldorf: private publication.

Gall, G. 1961. *Deutsches Ledermuseum*. Offenbach am Main.

Garstang, J. 1907. *Burial customs of ancient Egypt*. London: Constable.

Germer, R. 1985. *Flora des pharaonischen Ägypten*. Deutsches Archäologisches Institut, Abteilung Kairo, Sonderschrift 14. Mainz am Rhein: von Zabern.

1992. *Die Textilfärberei und die Verwendung gefärbter Textilien im Alten Ägypten*. Ägyptologische Abhandlungen 53. Wiesbaden: Harrassowitz.

Gilbert, A.S. 1988. Zooarchaeological observations on the slaughterhouse of Meketre. *JEA*, 74: 69–89.

Haines, B.M. 1991. Mineral, alum, aldehyde and oil tannage. In *Leather – its Composition and Changes with Time* (eds. C. Calnan and B.M. Haines). Northampton: Leather Conservation Centre Northampton, pp. 24–8.

Hansen, K. 1994. The chariot in Egypt's age of chivalry. *KMT*, 5: 50–61.

Haring, B. 1996. Divine households: administrative and economic aspects of the New Kingdom royal memorial temples in Western Thebes. Doctoral dissertation. University of Leiden [publication forthcoming in the Egyptological Series of the Nederlands Instituut voor het Nabije Oosten].

Harris, J.R. 1961. *Lexicographical Studies in Ancient Egyptian Minerals*. Berlin: Akademie-Verlag.

Helck, W. 1975. Alaun. *LÄ*: 130.

Ikram, S. 1995. *Choice Cuts. Meat Production in Ancient Egypt*. Leuven.

Junker, H. 1957. *Weta und das Lederkunsthandwerk in Alten Reich*. Vienna: Sitzungsbericht Österreichische Akademie der Wissenschaften Phil. Hist. Klasse.

Kaczmarczyk, A. 1986. The source of cobalt in ancient Egyptian pigments. In *Proceedings of the 24th International Archaeometry Symposium* (eds. J.S. Olin, and M.J. Blackman). Washington DC: Smithsonian Institution, pp. 369–76.

1991. The identity of *wšbt* alum. *JEA*, 77: 195.

Klebs, L. 1934. *Die Reliefs und Malereien des Neuen Reiches*. Heidelberg: Carl Winters.

Landmann, A. W. 1991. Lubricants. In *Leather – its Composition and Changes with Time* (eds. C. Calnan and B.M. Haines).

Northampton: Leather Conservation Centre Northampton, pp. 22–33.

Lau, O. 1967. Schuster und Schusterhandwerk in der griechisch-römischen Literatur und Kunst. Doctoral dissertation. University of Bonn.

Leach, B. 1995. Tanning tests for two documents written on animal skin. *JEA*, 81: 241–3.

Leemans, C. 1840. *Description Raisonné des Monuments Egyptiens du Musée d'Antiquités des Pays-Bas, à Leide*. Leiden: H.W. Hazenberg.

Littauer, M.A. and Crouwel, J.H. 1985. *Chariots and Related Equipment from the Tomb of Tutankhamun*. Oxford: Griffith Institute.

Lucas, A. 1962. *Ancient Egyptian Materials and Industries*, 4th edn., rev. J.R. Harris. London: Arnold.

Mann, I. 1960. *Rural Tanning Techniques*. Rome: Food and Agriculture Organization of the United Nations.

1962. *Animal By-products: Processing and Utilization*. Rome: Food and Agriculture Organization of the United Nations.

Manniche, L. 1973. Rare fragments of a round tambourine in the Ashmolean Museum, Oxford. *Acta Orientalis*, 35: 29–34.

Martin, G.T. 1987. *Corpus of Reliefs of the New Kingdom from the Memphite Necropolis and Lower Egypt* I. London: KPI.

Mieroop, M. van de, 1987. *Crafts in the Early Isin Period: a Study of the Isin Craft Archive from the Reigns of Išbi-Erra and Šû-Ilišu*. Leuven: Departement Oriëntalistiek.

Mills, A.J. 1982. *The Cemeteries of Qasr Ibrim*. London: EES.

Murray, M.A. 1904. *Saqqara Mastabas* I. London: BSEA.

Newberry, P.E. and Griffith, F.Ll. 1894. *Beni Hassan* II. London: EES.

Nibbi, A. 1993. An early dynastic hide-covered model papyrus boat. *RdE*, 44: 81–101.

Peet, T.E. and Woolley, C.L. 1923. *The City of Akhenaten* I. London: EES.

Perez-Die, M. C. and Vernus, P. 1992. *Excavaciones en Ehnasya el Medineh (Herakleopolis Magna)*. Madrid: Minsterio de Cultura.

Petrie, W.M.F. 1889. *Hawara, Biahmu and Arsinoe*. London: EES.

1890. *Kahun, Gurob and Hawara*. London: EES.

1898. *Deshasheh*. London: EES.

1901. *Diospolis Parva*. London: EES.

1913. *Tarkhan and Memphis V*. London: BSAE.

1920. *Prehistoric Egypt*. London: BSAE.

1927. *Objects of Daily Use*. London: BSAE.

Petrie, W.M.F. and Quibell, J.E. 1896. *Naqada and Ballas*. London: Quaritch.

Quibell, J. E. 1908. *The Tomb of Yuaa and Thuiu*. Cairo: SAE.

Raven, M. J. 1988. The Antef diadem reconsidered. *OMRO*, 68: 84–5.

Reed, R. 1972. *Ancient Skins, Parchments and Leathers*. London: Seminar Press.

Schiaparelli, E. 1921a. *Relazione sui lavori della missione archeologica italiana in Egitto I: Esplorazione della 'Valle delle Regine' nella necropoli di Tebe*. Turin: Museo di Antichita.

1921b. La missione italiana a Ghebelein. *ASAE*, 21: 126–8.

1927. *Relazione sui lavori della missione archeologica italiana in Egitto II: La tomba intatta dell'architetto Cha*. Turin: Museo di Antichita.

Serjeantson, D. 1989. Animal bones and the tanning trade. In *Diet and Crafts in Towns* (eds. D. Serjeantson and T. Waldron). BAR 199. Oxford: BAR, pp. 129–46.

Sigrist, M. 1981. Le travail des cuirs et peaux à Umma sous la Dynastie d'Ur III. *Journal of Cuneiform Studies*, 33: 141–90.

Smith, S.T. 1992. Intact tombs of the seventeenth and eighteenth Dynasties from Thebes and the New Kingdom burial system. *MDAIK*, 48: 193–231.

Soldt, W.H. van, 1990. Fabrics and dyes at Ugarit. *Ugarit Forschungen*, 22: 321–57.

Stol, M. 1983. Leder(industrie). *Reallexikon der Assyriologie und vorderasiatischen Archäologie*. Berlin: Walter de Gruyter, pp. 534–5.

Sykes, R.L. 1991. The principles of tanning. In *Leather – its Composition and Changes with Time* (eds. C. Calnan and B.M. Haines). Northampton: Leather Conservation Centre Northampton, pp. 10–11.

Thomas, A.P. 1981. *Gurob: a New Kingdom Town*. Warminster: Aris and Phillips.

Thomson, R.S. 1981. Tanning – man's first manufacturing process? *Transactions of the Newcomen Society*, 53: 139–56.

Verner, M. 1986. A slaughterhouse from the Old Kindom. *MDAIK*, 42: 181–9.

Vila, A. 1970. L'armement de la forteresse de Mirgissa-Iken. *RdE*, 22: 171–99.

Villiers Stuart, H. 1882. *The Funeral Tent of an Egyptian Queen*. London: John Murray.

Vogelsang-Eastwood, G.M. 1993. *Pharaonic Egyptian Clothing*. Leiden: Brill.

Wainwright, G. 1920. *Balabish*. London: EES.

Williams, B. 1983. *C-Group, Pan Grave and Kerma Remains at Adindan Cemeteries T, K, U and J*. Chicago: OIP.

1991. *Nubadian X-Group Remins from Royal Complexes and from Private Cemeteries at Qustul and Ballana*. Chicago: OIP.

Winlock, H.E. 1926. The Egyptian expedition 1924–25. *BMMA*, Sect. II, March 1926: 5–32.

1945. *The Slain Soldiers of Neb-Hepet-Re Mentuhhotpe*. New York: MMA.

Winterbottom, S. 1990. The leather objects. In J. Bingen, Quatrième Campagne de fouilles au Mons Claudianus. *BIFAO*, 90: 78–81.

Zadok, R. 1985. *Geographical Names According to New and Late Babylonian Texts*. Répertoire Géographique des Textes Cunéiformes 8. Wiesbaden: Reichert.

Ziegler, C. 1977. Tambours conservés au musée du Louvre. *RdE*, 29: 203–14.

1978. *Catalogue des Instruments de Musique Egyptiens*. Paris: Musée du Louvre.