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MARBLES AND OTHER ORNAMENTAL STONES

By ROBERT WEBSTER, F.G.A.

NAMED from the Latin word *marmor* (a shining stone), marble may be said to cover a considerable number of rock-like formations ; indeed all marbles are typically rocks. What is marble ? To the geologist marble is usually defined as a crystalline aggregate of calcite, often with a saccharoidal texture. From the point of view of the ornamental stonemasons—or shall it be said the commercial view—marble is widely interpreted and may be said to include all ornamental stones harder than gypsum, and indeed, in popular parlance the massive form of gypsum known as alabaster is thought of as marble.

For the purpose of this study the subject of marbles is divided into the true marbles—the often colourful compact limestones, and the stalagmitic calcites, miscalled the " onyxes." The quartzites, porphyries, alabasters and some other types of rocks, so like marble and therefore termed marble in commercial parlance, also demand inclusion. The pale coloured " onyxes," as used in decorative wares, are often relieved by inlaying with a "marble " of contrasting colour. Many of these are well-known minerals which, from the earliest of civilizations to the present-day, have been the sign of magnificence and regal splendour.

THE TRUE MARBLES

Marbles, as the geologist knows them, the true marbles, are the product of the alteration of an existing calcareous rock by the agency of heat and, maybe, pressure, which occurred through geologic upheavals in past ages. Such geological alteration of existing rocks is termed *metamorphism*, and a rock altered by such a process is called a *metamorphic rock*. There are a number of different types of metamorphism but the type which produces the true marbles is that known as *contact metamorphism*. Such an effect occurs when a mass of igneous rock at a high temperature intrudes into an existing rock formation, the heat of the slowly cooling intrusive rock causing the surrounding country rock to alter. The extent of the alteration away from the margin of contact may be anything from several inches to many miles, the size and completeness of this *metamorphic aureole*, as it is often called, depending upon the size and temperature of the intrusion, the rate of cooling and the nature of the rocks. True marbles are the result of contact metamorphism of pre-existing pure or impure limestone rocks.

When the country rock is a very pure limestone the only change which can be produced is recrystallization, since the action of heat on calcium carbonate is a reversible one and soon stops unless one of the products of dissociation is removed as fast as it is formed. Heating pure limestone ($CaCO_3$), a rock which has been laid down as a sediment, produces quicklime (CaO) and carbon dioxide (CO_2), but under the deep-seated conditions of contact metamorphism the carbon dioxide is not dissipated and the quicklime and carbon dioxide recombine. The rock recrystallizes out as an interlocking mosaic of calcite crystals, in fact a pure white granular marble.

It is by such a cause that the white statuary marbles have been formed. Such a white marble is the *Marmor Pentelicum*, or Pentelikon marble, which is quarried on Mount Pentelicus some eight miles north-east of Athens. Another of the Greek white sub-translucent statuary marbles was mined—it is said as early as the sixth century B.C.—on the Island of Paros in the Aegean Sea.

What are probably the most important of the white marbles are those found in the Apuan Alps around Carrara in Tuscany, Italy. The purest white marble from this locality is quarried on Monte Altissimo about eight miles from Serravezza. This mountain rises to a height of 5440 feet and its precipitous crags are practically pure white marble. When the marbles of the Apuan Alps are less pure they become clouded with greyish veins, and such a marble is often called " Sicilian marble," a misnomer originally adopted in England. Various reasons have been put forward to explain the use of this name, one of which is that the first cargo came over in a ship called " Sicilia " and this gave the name to the marble. Others assert that the vessel carrying the first cargo was damaged by a storm and put into a Sicilian port for repairs, and when the ship finally reached England it was thought that the cargo had come from Sicily. A third suggestion takes the view that the first cargo of these marbles came from Italy when Napoleonic rule prevailed and export of Italian goods to Great Britain was prohibited, and to overcome the difficulty the traders resorted to false Customs declarations and used as the country of origin the island of Sicily.

Hundreds of marble quarries are dotted about the twenty-five miles between Pisa and Spezia on the west coast of Northern Italy. These quarries, generally in groups, are mainly in the valleys of Rayaccione and Sagro near Carrara, and also around Massa and Serravezza.

The limestones which have suffered metamorphism may have contained impurities and such impure rocks will produce attractively coloured marbles. A marble rock may be shattered by subsequent earth movements and the fissures so produced in the marble may be reconsolidated by other, often coloured, mineralization, thus producing the beautiful veined marbles. If the fissures are very numerous and are filled with secondary minerals of many colours the product is then a *variegated marble.*

A marble which suffers great stresses subsequent to its formation may break up into angular fragments which are subsequently recemented together by infiltration or by pressure. Such a rock is a *brecciated marble* and can be very attractive.

Limestones which contain siliceous or clay (aluminous) impurities may, under the influence of contact metamorphism, cause the lime (CaO) to unite with the foreign material with the elimination of carbon dioxide. Such a change might, if silica be present, result in the formation of the simple lime-silicate, wollastonite. Such a change may be illustrated by the following chemical equation :—

$$CaCO_3 + SiO_2 = CaSiO_3 + CO_2$$

Should the silica be insufficient to decompose all the lime, a *wollastonite marble* results. This is a marble which has little interest as an ornamental stone, but the chemical changes occurring in its production will serve as an example of the changes which can occur in the metamorphism of rocks.

Many limestones contain more or less magnesia without being dolomite (calcium magnesium carbonate), and on contact metamorphism the magnesia reacts with any silica and alumina present to form amphiboles and pyroxenes. The changes which occur in pure or nearly pure dolomitic rocks under low-pressure contact metamorphism are governed by the greater reactivity of the magnesia part than the calcite part and result in the dissociation of the magnesium carbonate with crystallization of calcite. The following equation will explain this *dedolomitization effect*, as it is termed :—

$$\underset{\text{(dolomite)}}{CaMg(CO_3)_2} = \underset{\text{(Calcite)}}{CaCO_3} + \underset{\text{(Periclase)}}{MgO} + \underset{\text{(Carbon dioxide)}}{CO_2}$$

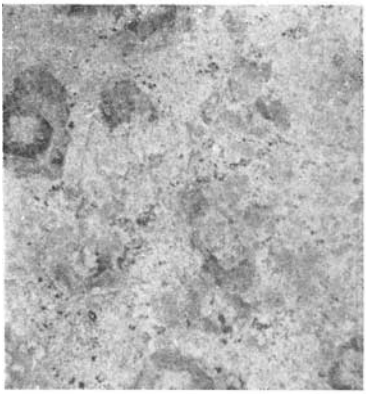
The magnesia (periclase) formed is highly hygroscopic and undergoes hydration, forming brucite ($Mg(OH)_2$; the resulting rock being a mixture of brucite and calcite may be classed as a *brucite marble*, and such a rock is found in the Austrian Tyrol.

When silica is present in a dolomitic rock, various silicates of lime and magnesia are formed. Should there be only a little silica, so that the bases are in excess, the silica combines with the magnesia to form an orthosilicate of the olivine group—forsterite (Mg_2SiO_4)—while the lime molecule forms calcite :—

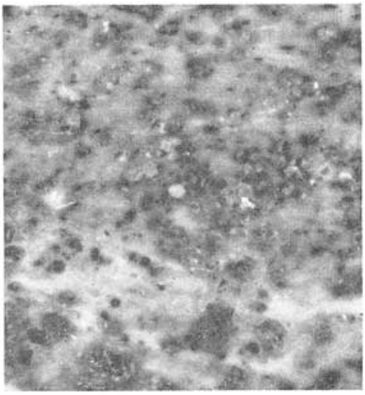
$$2CaMg(CO_3)_2 + SiO_2 = 2CaCO_3 + Mg_2SiO_4 + 2CO_2.$$

Thus a *forsterite marble* is produced. If the silica be in excess the lime molecule enters the silicate forming diopside, $CaMgSi_2O_6$, or tremolite, $CaMg_3Si_4O_{12}$. Since the original rock may contain calcite as well as dolomite the resulting rock is a crystalline aggregate of diopside or tremolite and is thus a *diopside marble* or a *tremolite marble.*

These magnesium silicates, which frequently contain traces of iron, become readily altered by later chemical action into green serpentine. The resulting serpentinous marbles are known as *ophicalcite*, and examples of such rocks are the well-known Connemara marble or Irish green marble, which is found in County Galway, Ireland. Iona stone, found near the Bay of Port-na-Carrack on the



Xalostocite, a marble containing pink crystals of grossular garnet.



Tiree marble, a marble having green diopside crystals in a pink ground-mass.

small Inner Hebridean island of Iona, is a similar serpentine marble, and another source of ophicalcite is at Glen Tilt in Perthshire, Scotland.

The metamorphism of impure limestones may produce a marble which has comparatively large euhedral crystals embedded in the calcite groundmass. The gemmologist knows well that the ruby found at the Mogok Stone Tract of Upper Burma has crystallized in white marble, and, indeed the white marble which is obtained from the Sagyin quarries, thirty miles north of Mandalay, occasionally has rubies embedded in it. In Xalostoc, Morelos, Mexico, is found an ornamental marble which consists of large crystals of pink grossular garnet in a creamy-white marble. This marble is called *xalostocite* (after the locality) or *landerite* (after Carlos F. de Landers) or *roselite* (after the colour). A similar material is said to have been found at Jaurez, Lower California. The so-called *Tiree marble*, which is found on the small island of Tiree, which lies off the island of Mull, Argyllshire, on the west Scottish coast, is another such marble which contains visible crystals, in this case crystals of diopside in a pink ground-mass.

The names applied to the various types of marble are legion and there would be little value in repeating what may well be local quarry names. In general there are two main types of nomenclature, one consisting of the name of the quarry and the other referring in some manner to the colour of the marble, and these may often be combined. Thus, *Cipollino* is the name given to marbles which have alternate bands of white and green. The name is particularly applied to the marble from the quarries on the Greek island of Euboea (Negroponte), a marble which was known as the " Marble of Carystus." The modern name, cipollino, relates to the well-defined layers resembling an onion (cipolla). The name *Pavonazzo* which is given to a group of white or pale yellow marbles traversed with coloured veins, is said to have originated from the supposed resemblance between the colour of the purple veins and the plumage of a peacock (pavone).

When the marble is brecciated the name *Breccia*, or *Breche*, may be incorporated in the title, and *Griottes* are red marbles whose colour resembles that of the Griotte cherry. To illustrate the impossibility of attempting to identify a marble by the name alone, the so-called " Molina rosa," a reddish marble from the Garfagnana quarries of Tuscany, owes its name to the Spanish marble quarried near the town of Molina.

The second type of marble to consider is the massive crystalline calcium carbonate deposits which form from waters charged with calcium bicarbonate. These are the so-called *travertines* and *stalagmitic marbles*. Although calcium carbonate is almost insoluble in pure water, when the water contains carbon dioxide, as all natural waters do, the calcium carbonate from the limestone rocks, over which the water flows, will be acted upon, producing the more water-soluble calcium bicarbonate, as expressed in the following equation :—

$$CaCO_3 + H_2O + CO_2 = H_2Ca(CO_3)_2.$$

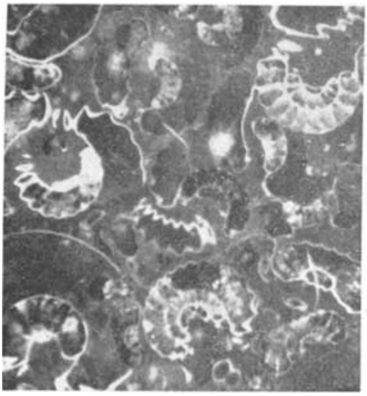
Pressure increases—and heat, by driving off the carbon dioxide, decreases—the solubility of the carbonate. On decrease of pressure, or on heating the water, or by its evaporation—all processes which lead to the loss of the gas carbon dioxide—this will result in the precipitation of crystalline calcium carbonate producing beds of travertine or stalagtites and stalagmites, which in general have a layered structure. This physico-chemical description of the deposition may not, however, tell all the story, for organisms such as algae and bacteria may assist in the deposition, and it is not always possible to separate the purely inorganic deposition from the biochemical processes.

The travertines and stalagmitic calcites are often banded and they are commercially known as the " Onyx marbles " or " Oriental alabaster," both terms which are misnomers ; for the true onyx is a banded chalcedony (agate), while the name *alabaster*, in correct mineralogical nomenclature, means a massive gypsum—a hydrous calcium sulphate. The origin of the use of these mineralogically incorrect names is a matter of conjecture. It seems clear that the name *alabaster* was applied to the stalagmitic marbles in Biblical times, and also that at different times the material was successively known as " Oriental alabaster " and then " Alabaster onyx," while more recently the term " Onyx marble " was mostly used.

There seems some doubt of the origin of the name *Alabaster*, for some writers assert that the name was derived from the town of Alabastron in Egypt, where the stone was first quarried and worked. Alternatively the name may well have received its genesis from the use made of this type of marble in making the slender narrow-necked vase or cruse without handles, called *alabastron.*

Normally the ground colour of these " onyx marbles " is white, but invariably they are veined by coloured fissures or tinted in areas by the infiltration of metallic oxides. It is owing to their translucency and their soft delicate bands of colour in amber, orange and green, that these stalagmitic calcites have won such esteem with the makers of small *objects d'art* and at the present time are popular for fine quality clock cases, when the soft effect of the marble is offset by inlaying with other minerals having a stronger or more contrasting colour.

Deposits of " onyx marble " are widely distributed in almost every region of the world, but it is only in a few places that the deposits are of sufficient importance to be commercially worked. The most abundant supply of the marble comes from Algeria, where it is found in quantity in the provinces of Oran and Constantine. The major quarries are close to Bon-Hanifa, a village about ten miles north-east of the modern town of Mascara. Bon-Hanifa lies near to the ancient Roman town of Aquæ Sirenses, which was noted for its hot springs, and it may well be that the deposits originated from these springs. The Constantine deposits lie about ten miles from Constantine, the capital of the department of the same name, and much of the marble from this locality is bright red in colour. On the Moroccan side of the border with Algeria is another deposit of stalagmitic marble, which may be considered an offshoot of the Algerian deposits. Like the Oran marble the colour of Moroccan marble is normally white with coloured veins, but



" *Fossil marble.*" *A fossil limestone containing ammonite shells.*

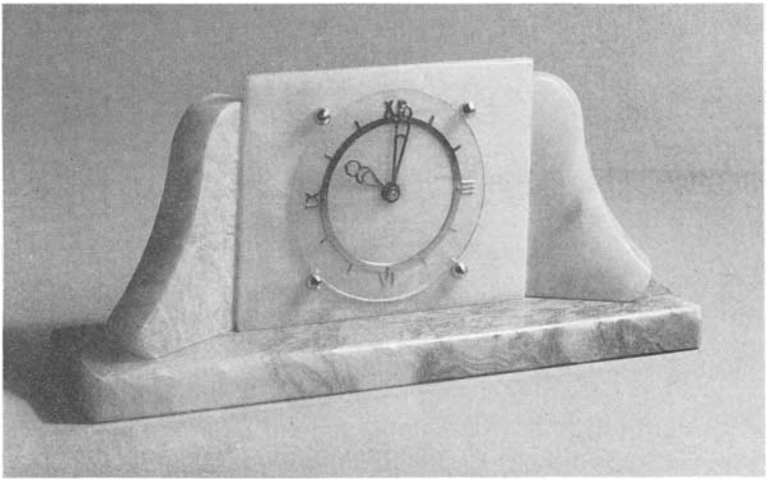
Brecciated agate.

material of a blue, grey or pink colour mixed with green, as well as a bright red, is found.

Another North African deposit is that of Egypt, where stalagmitic marble, in early times known as " Egyptian alabaster," was found near the town of Alabastron, and was extensively used in Egypt from the First Dynasty. The Egyptian material, a translucent light amber-coloured rock marked with wavy bands, was formerly worked over a large area of the Nile Valley, but the little material quarried in recent years is obtained from workings on the lower flanks of the Asyut mountains, some twenty miles from the town of Asyut. During the nineteenth century some stalagmitic marble was obtained from the caves near Beni Suef in the Nile Valley, and material from this deposit was used for embellishing the famous " alabaster " mosque at Cairo.

About three hundred miles south of San Diego lie the Pedrara quarries of Lower California, Mexico, where a deposit of stalagmitic marble is exposed on the surface or is not more than eight or ten feet below. After being mined, this white or green translucent rock, veined with dark orange, amber or brown and known as " Pedrara onyx," is sent to Santa Caterina which is the nearest port. Other sources of " onyx marble " in Mexico are in the States of Puebla and Oaxaco. " Mexican onyx," as the marble is commonly called, is in America sometimes called *Tecali marble*, a name given to it by the Aztecs, the ancient inhabitants of Mexico, who deemed the stone too sacred for it to be used by the common people. The marble was almost solely devoted to the ornamentation of religious buildings or the making of sacrificial vessels. Indeed, Tecali is but a corruption of the Aztec name *Teocall* given by Mexican Indians to their temples. It is from the Mexican localities that most of the " onyx marbles " used in England for the modern marble clock-cases, cigarette boxes and other small ornamental pieces comes.

The commercially used, and in England comparatively well-known, term " Brazilian onyx " is a misnomer, for the material to which it is applied is found in the province of San Luis in the Argentine Republic. The marble from San Luis differs little in appearance from that found in Mexico. A similar marble is found and mined in Yavapai Co., Arizona, in the southern part of the United States. This marble, which is commercially called " Yava onyx," is found in irregular and somewhat lenticular layers from one inch to two feet in thickness interbedded with a coarse breccia formed of schistose and dioritic fragments in a sandy and calcareous matrix. Near Lehi, some twenty miles from Salt Lake City in Utah, occurs a vein of highly translucent stalagmitic marble of a bright lemon-yellow colour traversed with orange-coloured sinuous veins. This " Utah onyx," as it is called, is not an important source of marble.

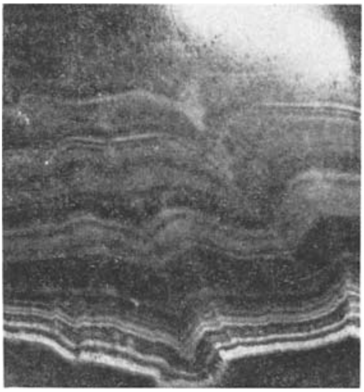


Clock in alabaster.

" Onyx marble " is found near Laasee in the valley of the Vintschgau. This slightly translucent marble with orange-coloured veins is known as " Tyrolese onyx " and is mainly worked in Vienna. The *Stalagmite de Bédat* is found in the Department of Hautes-Pyrénées, where it is obtained from the roof and walls of caverns and grottos on the banks of the river Ariège, which rises near Andorra and flows northwards through the Departments of Ariège and Haute-Garonne. Another deposit is found at Manère, in the French Department of Pyrénées-Orientales.

Gibraltar stone is a stalagmitic deposit found in the caves which abound in the limestone rocks which form the Rock of Gibraltar. The material is a translucent travertine with brown and amber-coloured sinuous veins. The marble is mainly used for the production of small ornamental objects for sale to tourists. " Java onyx " is a stalagmitic marble, usually dull white in colour or variegated with amber-coloured wavy banding. The rock, which is found around the town of Kediri (Wadjak), which lies some sixty miles south-east of Surabaja (Surabaya) in the Toeloeng Agoeng district of Java, has not the translucency met with in stalagmitic marbles from other localities.

A crystalline marble, which consists of fibrous crystals of calcite, is known as *satin-spar* (cf., gypsum). The material is found in veins and the fibrous crystals stretch across the vein from side to side. When polished with a flat surface the material shows a silky lustre and the " marble " has been used as an inlay and for bead necklaces. Calcite satin-spar, which occurs in England at



A polished flat cabochon of Gibraltar Stone.

Alston Moor in veins one to four inches in thickness, in Scotland at Glen Tilt, Perthshire, and in several states of North America, is now rather scarce.

Some few years ago there were marketed, under the fanciful misnomers " Imperial Mexican Jade " or just " Mexican Jade," carved and fashioned pieces of a green material which was subsequently identified as calcite (marble). It was further suggested that the colour of these pieces was due to artificial staining.

LIMESTONES

Many architectural marbles—and some of these are used for small ornamental pieces—are simply limestones which owe their attraction to colour and to the patterning caused by included fossils. Unlike the marbles already mentioned, limestones are sedimentary rocks consisting mainly of calcium carbonate with varying amounts of impurities to which their colour may be due. They are sometimes laid down in layers, producing stratified rocks, although the stratification may be of any thickness from paper thin to layers so thick that no layering can be seen in pieces of average size. Indeed, in certain limestones stratification is entirely absent.

The deposition of lime rocks may occur through physico-chemical conditions, by the loss of carbon dioxide from bicarbonate-rich water, as has been explained for the formation of stalagmitic marbles. Such occurrences may also happen with organic formation, which illustrates the difficulty, if not impossibility, of truly deciding the group to which a marble belongs.

Most limestones owe their origin to organic processes and these may be either biochemical or biomechanical. In the first of these it is the vital activities of the organisms which promote a chemical condition favouring precipitation of lime ; the bacterial limestones are of this type. Biomechanical deposits are due to the rock being formed from the detrital accumulation of organic materials, as in the case of coral, encrinital and shelly limestones. The grain-size of such mechanically formed rocks depends upon the initial sizes of the component organisms or upon the size of the fragments into which they naturally break. Such limestones may be heterogeneous in composition, consisting of a great variety of organic fragments embedded in a calcareous mud due to their comminution, one group of organisms often predominating to give character to the rock. Such rocks are the " Fossil marbles."

Probably the most common marble is the so-called " Black marble," which was so often used for casing clocks in the late Victorian and Edwardian periods, and the use of which did not entirely disappear until just before the beginning of the Second World War. These black marbles, often veined with white, are mostly obtained from the Lower Carboniferous series which lie in the Provinces of Hainault and Namur of Belgium. These marbles, known as the " Noir Belge " (Belgian black), are found along the Sambre and Meuse rivers. The more important quarries are those of Basècles, a small town close to the French frontier about thirteen miles south-east of Tournai. The other main quarries run parallel to the left bank of the river Meuse a little to the north of the towns of Mazy and Golzinnes, near Charleroi. Much black marble is found in the Departments of Nord and Pas de Calais in Northern France. That from the first-mentioned locality is known as " Grande Antique " and that from the Pas de Calais is called " Noir Français." Other black marbles of note—for there are quite a number of localities which provide such marbles—are the " Irish Black " found in County Carlow, Ireland.

Many of the compact limestones are brightly coloured in reds, browns, yellows and greens of varying tones and may be in variegated colours. However, neither monochrome photography nor the written word can adequately describe the multitude of effects shown by such " marbles." There are so many of these marbles, often named from local quarries, that an attempt to name them would be confusing and have little value.

The " fossil marbles," owing to their obvious characteristics, do allow some grouping and description. The fossils visible in limestones may be either shelly (mainly the shells of the mollusca), coralline (various corals), or encrinital (containing the remains of crinoids, or, as they are sometimes known, *sea lilies*). Of the first type the best known is the " Purbeck marble." This is a light blue-grey to reddish-brown marble made up of countless fossil shells of fresh water snails (*Paludina carinifera*), hence the " marble " is sometimes known as *Paludina limestone*. The quarries supplying this marble stretch westwards from the Dorset town of Swanage as far as Kingston, four or five miles distant. A similar " marble " is found near East Grinstead and Netherfield, near Battle, in Sussex. It is known as the " Petworth marble " or " Bethersden marble," depending upon the locality where it has been obtained,

" Purbeck marble," a "fossil marble " from Dorset. A limestone containing masses of freshwater snail shells.

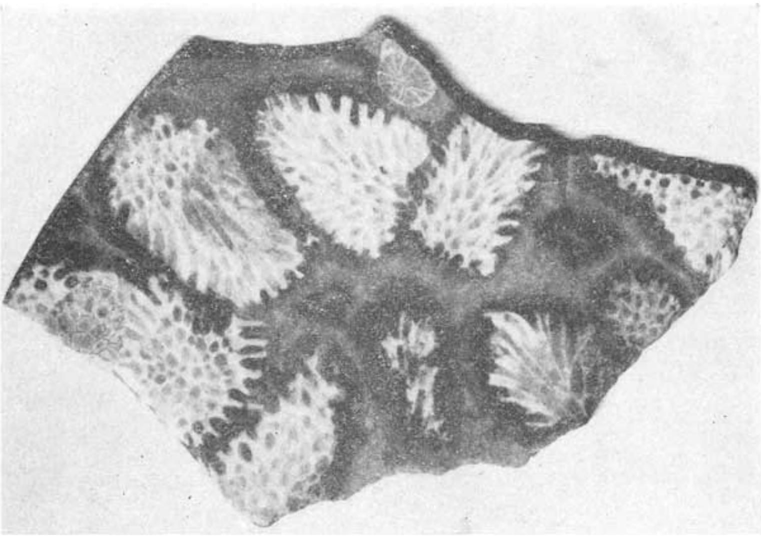
A small ashtray turned from reddish-brown " encrinital marble."

and, although resembling the " Purbeck marble," the fossil shells are those of *Paludina fluviorum*, which is a larger species. A striking " fossil marble " is that which contains fossil ammonites in a dark brown ground-mass. The Irish " black marble "—the Kilkenny black " fossil marble "—is picked out by white circles which are abundant brachiopod shells.

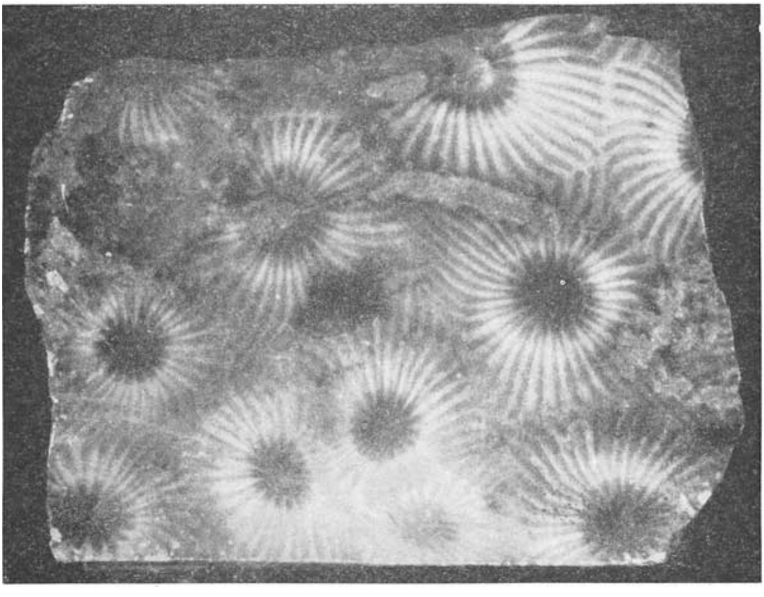
A most beautiful " fossil marble " is the so-called " fire marble," known also as *lumachella*, *lumachelle* or *lumachello*, a word which means " little snail," This somewhat rare " marble," which has been cut for the tops of snuff boxes and other ornamental articles, is a dark brown " marble " marked throughout with small whitish shells, possibly ammonites, which in certain parts exhibit iridescent colours rather like opal, and indeed the " marble " may be mistaken for opal in matrix. The " marble " is found in veins forming the roof of the lead mines at Bleiberg in Carinthia, Austria, and also in Astrakhan, Russia.

Fossil coral limestones produce intriguing " marbles " and the fossils form diverse patterns. Such is the " red Ogwell marble," which contains the coral known as *favosites*. The so-called *Petoskey stone* from Michigan in the United States is a fossil coral limestone.

The encrinital limestones are usually fawn to reddish-brown in colour and are prettily marked by the broken stems of the crinoids (sea lilies). Such marbles are abundant in the Derbyshire quarries.



"Fossil marble." A limestone containing the fossil coral Favosites cervicornis, *from Torquay, Devon.*



"Fossil marble." A fossil coral limestone. The coral is Thamnastræa.

The so-called " Hopton Wood marble " from Middleton and the " Bird's-eye marble " from Ashford are Derbyshire encrinital " marbles," and many such " fossil marbles " are found elsewhere.

The " landscape," or " Cotham, marble " is a light fawn-coloured rock, having dark brown, nearly black, dendritic markings throughout, which are said to have been caused by the infiltration of ores of manganese and iron into the soft calcareous mud from which the rock originated. These dendritic or arborescent (tree-like) markings frequently show patterns on the polished surface of the rock which simulate trees and other vegetation. The "marble " is somewhat scarce and specimens are mostly reserved for museums. The " marble " is found near the base of the White Lias of the Rhaetic beds and is mined at Cotham, a district north of Bristol.

" Florence marble," or, as it is better known, " Ruin marble," is a calcareous marl of greyish-green colour which has suffered fracture in straight angular pieces. A polished slice of the "marble" shows, owing to infiltration of iron oxide, yellowish sections, and the general picture appears like a panorama of ruined buildings, and when viewed at a distance appears like a drawing in bistre. It is a common occurrence in the Val d'Arno near Florence in Italy.

PROCESSES OF MANUFACTURE

The working of " marble " may best be described by telling how " onyx marble " articles are manufactured. The large blocks of " marble," often six or more feet long and weighing two to four tons, are first " slabbed." This is carried out by using a battery of thin soft iron blades some four inches in width, which are held in an iron frame suspended above the block of stone. The saw, which has the blades set about three-quarters of an inch apart, is swung to and fro in a flat arc, and is gradually lowered so as to cut through the stone, which it does at the rate of about one inch in an hour. The cutting action is obtained by the use of carborundum powder, sand and water, which is continually sprayed over the saws and stone.

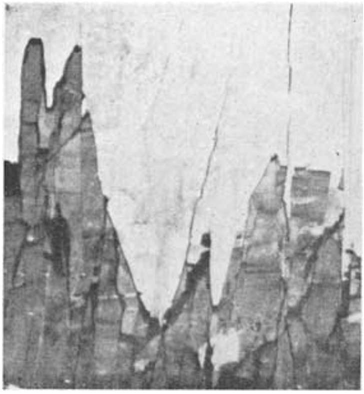
The slabs are then examined for cracks and " sugary " veins, areas which do not take a good polish, by splashing with water, which shows up the flaws. The clean areas are then marked and cut out by thin carborundum wheels (between one-eighth to one-quarter of an inch in thickness), which are lubricated by a slow stream of water.

These good slabs are then marked out by the aid of templates to the size and shape required for the article to be made. The piece is roughly ground to shape on a rotating wheel, and then to a more accurate outline on another and smoother wheel.

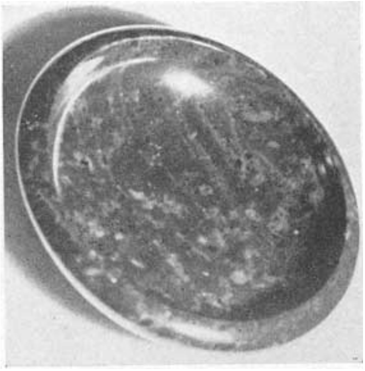
The processes so far described apply to the thin slabs required for the manufacture of cigarette boxes and some clock cases. When the piece is for ashtrays and larger objects with curved surfaces a suitably sized piece of marble is turned on a lathe, using high-speed steel turning tools to cut the marble. The rough turning is followed by a fine grinding, using a mixture of carborundum and snakestone which smooths away the rough marks made by the grinding.

The initial polishing is carried out on a lathe running at high speed, using spirits of salts (hydrochloric acid) and putty powder (tin oxide) as polishing media. In the case of flat pieces this initial polishing is carried out after any necessary milling of grooves to take hinges or inlays, but, instead of using a lathe, the polishing is carried out on a large horizontal felt lap dressed with putty powder and salt of sorrel (an acid potassium oxalate). The final polishing is done by hand, using a felt-covered board impregnated with putty powder and salt of sorrel, which gives to the marble a fine glass-like gloss.

The hardness of pure crystals of calcite is 3, calcite being the standard 3 for Mohs's scale, but owing to the admixture of impurities marble may in some cases be slightly harder. The purest true



" Ruin marble."



A brownish-red serpentine ashtray. Lizard, Cornwall.

marbles, such as the white statuary marbles from Carrara, break with a sugary (saccharoidal) surface, while the fracture in limestones is usually much smoother. The refractive indices of calcite are 1·658 for the ordinary ray and 1·486 for the extraordinary ray, but in the compact and granular marbles the most pronounced edge seen on the refractometer is that of the extraordinary ray at 1·48, which can sometimes be seen to move upward on rotation of the specimen, but the ordinary ray is seen with difficulty, if at all, much depending on the granular size of the calcite crystals. The limestones generally show an indistinct edge at about 1·50.

The density of pure calcite is 2·71, but in marbles and limestones there may be, and usually is, a lowering of the density due to the granular nature of the crystal aggregates, or the density may be raised owing to the inclusion of other minerals. The range of density for marbles (and limestones) varies from 2·58 to 2·75.

The absorption spectra of marbles are too vague to be of value in identification, nor does the fluorescence under ultra-violet light help. The luminescent glows exhibited under either wave-band of ultra-violet light, if any fluorescence is shown at all, are patchy, some of the veined material showing up the veins as a whitish glow. Some of the travertines, including Gibraltar Stone, show a bright greenish-yellow glow and a strong phosphorescence under both wavelengths of ultra-violet light. Under X-ray stimulation most true marbles and many limestones show the typical orange glow shown by calcite. As calcite is a carbonate, a spot of acid placed on marble will produce an effervescence. This effervescence is a sure test for marble against some other, but not all, marble-like rocks.

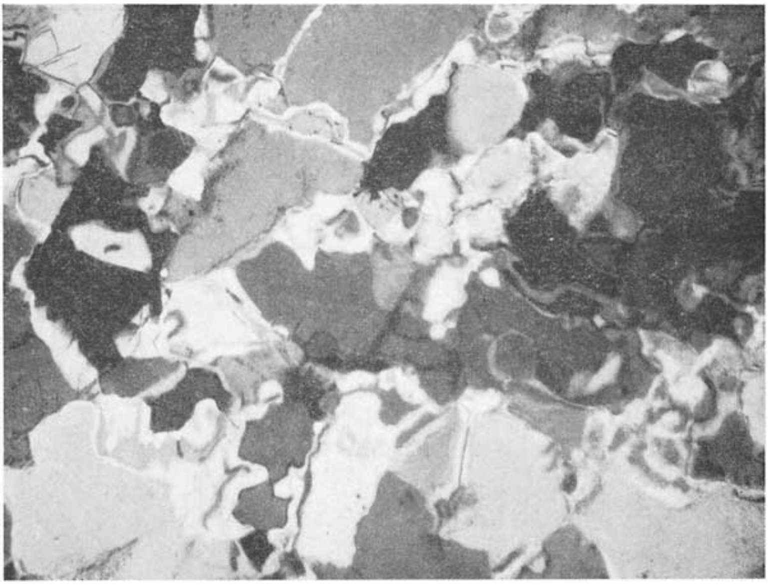
ALABASTER

The marble-like massive variety of the mineral gypsum, *alabaster*, a hydrous calcium sulphate ($CaSO_42H_2O$), was known from the days of the Phoenicians, the Assyrians and the Egyptians. These peoples made all kinds of beautiful vases and amphorae, and were the first to find out and use its translucent beauty as a medium for direct and indirect lighting. The delicately wrought alabaster vases that were found in the tomb of Tutank-amen were used to illuminate the temples in the land of the Pharoahs.

The purest form of alabaster is white and translucent, but the material is often associated with a trace of ferric oxide, which produces light-brown and orange-coloured bands and veins, or with other impurities which colour the stone in yellows, browns and black in veins or patches. The softness of the rock, especially when freshly quarried, enables it to be easily carved. Alabaster can be scratched by a finger nail, but to a slight extent the mineral hardens after exposure to the air and then will take a good polish. Moreover, alabaster is sufficiently porous to allow it to be stained and artificial coloration is often carried out.

The formation of alabaster is usually by the evaporation of an enclosed sea-basin, or occasionally the mineral may be deposited from desert lakes. Gypsum is frequently formed in mineral veins where sulphuric acid, derived from the oxidation of pyrites and other sulphides, has acted upon limestone.

Massive gypsum is of world-wide occurrence, but in relatively few localities are quarries worked for ornamental alabaster One of the most important localities is at Castellina in the district of



A thin section of quartzite as seen between crossed nicols. The different optical directions of the various quartz grains are shown in this monochrome photograph by the tones of grey.

Volterra, about twenty-five miles north-west of Pisa in Tuscany, Italy. The alabaster of the Volterra district is found in nodular masses embedded in limestone interstratified with marls. The mineral is mainly worked by mining through underground galleries.

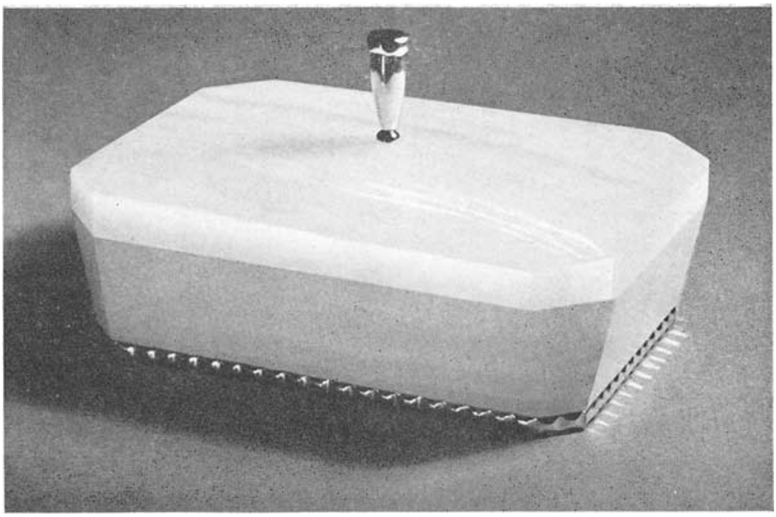
The carving of the Tuscan alabaster is carried out not only at Florence and Pisa, but in other cities of Central Italy, and the industry dates from Etruscan times. Some of the pure white alabaster from Tuscany, after carving, is treated by immersion in cold water which is then slowly raised to boiling point. The stone is allowed to cool very gradually and is afterwards thoroughly dried. This treatment is said to make the alabaster scarcely distinguishable from white marble.

The most important quarries for ornamental alabaster in England are in Derbyshire and Staffordshire. The Derbyshire alabaster is found in the south-eastern part of the county, in the neighbourhood of Chellaston, where the mineral is found in thick nodular beds or " floors " and in small lenticular masses termed " cakes." These deposits, which were known prior to the fourteenth century, are close to the surface and are worked by open pit mining. The major Staffordshire quarries are at Fauld near Hanbury, and near Weston, which lies close to the Derbyshire border. There are occasional thin bands of fine granular gypsum of a pinkish colour found along the coastal plain of Glamorgan in South Wales. It is known as pink Welsh Alabaster but is not commercially important.

The fibrous crystalline variety of alabaster which fills veins in rock formations with parallel fibrous crystals stretching across the vein from side to side is called *satin spar,* but it is softer than the similar calcite type of deposit to which the same name is applied. Gypsum satin spar is found at Matlock, Derbyshire, and at Newark, Nottinghamshire.

Alabaster is fashioned, not only for the bowls of indirect ceiling lighting fittings, but for attractive " marble " powder bowls, ashtrays, cigarette boxes, letter weights, pen stands, book ends and other *objets d'art.* The pure white Tuscan material is often carved into figurines having a religious significance.

The hardness of gypsum is given as 1½ to 2 on Mohs's scale, but most alabaster is found to be slightly harder than 2. The fractured surface is more finely granular than the saccharoidal fracture of true marble. Alabaster may vary from material that is highly



" Onyx " box with metal-gilt base and lid attachment.

translucent to that which is practically opaque, and the lustre is glistening. The refractive indices of gypsum are 1·52 – 1·53, and in the case of the massive variety—alabaster—a shadow edge about this value is moderately clearly seen on the refractometer scale. The density of alabaster lies between 2·30 and 2·33. There is no absorption spectrum of value to be seen in alabaster, and the luminescence under ultra-violet light, usually a brownish shade, gives little aid in distinction. Under X-rays the material is inert.

THE PORPHYRIES

Types of igneous rock which show comparatively large and well-formed crystals embedded in a ground-mass of much finer texture are the porphyries. The cause of the porphyritic structure is considered to be a two-stage crystallization, or solidification, of the igneous magma at the time of its intrusion into the surrounding rock or extrusion on to the earth's surface, when the magma contained already-formed crystals enclosed in the molten liquid which subsequently solidified as a fine-grained ground-mass.

Porphyritic structure is common in rocks and it might well be expected that a wide range of such a type of rock could be used as an ornamental " marble." This does not seem to be the case and only two porphyries have an interest in this work. Moreover, they are interesting for historical reasons rather than as ornamental stones of modern application.

The first of these is the green porphyry found in the Province of Laconia in Greece, a rock with an olive-green ground-mass and light green feldspar crystals sprinkled abundantly through it. The green colour is due to included epidote and chlorite throughout the rock, a rock known in classical times, when, as Pliny records, it was known as *Marmor Lacedœmonium Viride.* It was later known as *Perfido serpentino,* but the rock is not a serpentine. The quarries yielding this rock lie between the towns of Sparta and Marathonisi.

The other, and perhaps more important, porphyry is the famous red porphyry of Egypt, which was known in classical times as *Porphyrites leptosephos* or later as *Perfido Rosso Antico.* This rock has a dark red ground-mass, the colour being due to included piedmontite, a manganese mineral. In this ground-mass is an abundance of small white and light pink feldspar crystals. The rock is quarried from a dyke some eighty to ninety feet in thickness on the Jebel Dhokan mountain, which lies some twenty-five miles inland from the junction of the Red Sea with the Gulf of Suez and about fifty miles eastwards from the Nile. It is doubtful whether the rock was known to the Egyptians ; it was most probably discovered by the Romans in the reign of Claudius, who took it to Rome where it was called *Lapis porphyrites,* and later " The Stone of Rome." During the Roman occupation of Egypt thousands of workmen were employed in the quarries and the stone was transported to the Nile *en route* for the Imperial City of Rome. There may be seen in the British Museum a carved head of the Emperor Hadrian in Egyptian red porphyry. It is said that the carving of this head was carried out by using copper tools fed with sand and emery ; it is presumed to have been made in Egypt near the time of Hadrian's visit to that country about A.D. 130.

SERPENTINE

Gemmologists meet serpentine in two main forms, the hard massive variety known as *bowenite,* and the " serpentine marble " which occurs in rock masses mixed with other minerals. It is this second type which demands inclusion as a " marble," but bowenite is now so often used for carvings that some mention of this variety is necessary. The origin of the name *serpentine* is in some doubt. One explanation suggests that the name arose from the ancient view that the mineral was a cure for a serpent's bite ; another, perhaps better, derives the name from the resemblance of the dark-green mottled variety to the skin of a serpent.

Serpentine is a hydrated silicate of magnesium, $H_4Mg_3Si_2O_9$, and crystallizes in the monoclinic system, but the mineral is always massive and is never encountered as crystals. Much has been written on the origin of serpentine and, indeed, there are a number of different geological processes which may produce the mineral by alteration of basic rocks of igneous origin or metamorphic pyroxenes. One of these processes, dedolomitization, has been referred to earlier in this article. Serpentine is soft, about 2½ on Mohs's scale, except in the variety bowenite which reaches 4 or more. The rock-like types may vary also in their hardness owing to the admixture of other minerals.

Most of the bowenite variety of serpentine used so much to-day for carvings and other articles of virtu is a translucent yellowish-green material, which often contains whitish cloudy patches. The density is 2·58 and the mean refractive index—all that is likely to be seen on a refractometer—is 1·52. The absorption spectrum shows bands at 4970Å and 4640Å, but they have little diagnostic value. There is, owing to the iron content which in part gives the green colour to serpentine, little, if any, luminescence under any excitation (X-rays or ultra-violet light).

There is a translucent deep green variety of bowenite found in the South Island, New Zealand, which was used by the Maories, but little dark green bowenite is encountered to-day, nor is the rather coarser dark green bowenite from the Delaware river, Pennsylvania, and Smithfield, Rhode Island, seemingly used. As a matter of interest the density of a Maori ear-pendant in dark translucent green bowenite serpentine was determined as 2·617.

Much light yellowish-green bowenite, in the form of carved figurines, has been exported from China to the Western World under the misnomer " New Jade." It is possible that this material has emanated from Tuoyuan in Hunan province. Bowenite, known to the Persians as *sang-i-yashm*, is found in Afghanistan, and this material is utilized at Bhera in the Shahpur district of the Punjab for the manufacture of dagger hilts, knife handles, caskets, amulets and other articles. Afghan bowenite appears to occur in rock masses at the head of one of the mountain gorges that run down from the Safed Koh into the valley of the Kabul river.

The most notable source of the " serpentine marble " in classical times was the brecciated serpentine quarried at Casambala, a few miles north-east of Larissa in Thessaly, and known as *verde antico*, or as it was known to the Romans as *lapis Atracius*, for the quarries were near the ancient town of Atrax. It has been reported that the quarries were destroyed by the Germans. Some authorities class the *verde antique* with the ophicalcites. Much fine serpentine is found near Genoa and Levanto in Liguria, and near Prato in Tuscany. These Italian serpentines vary from green to brownish red in colour and often the material is veined with white steatite.

In England the best known " serpentine marble " is that found on the southern promontory of the Lizard peninsula, Cornwall. The Cornish serpentines, of which the major quarries are at Kennack Cove, Kynance Cove, Spernic Cove and Carleon Cove, vary considerably in colour and texture and may be green-veined or spotted with red, brown, or white ; while others may be red or purple to nearly black and relieved by coloured veining. The Lizard serpentine is usually fashioned locally into small wares suitable for the tourist. " Serpentine marble " is found at Rhoscolyn, Holy Island, which lies off Anglesey, Wales. It is known locally as " Mona marble." Another source is at Portsoy, Banffshire, Scotland.

" Serpentine marble " is also found at St. Paul in the French Basses-Alpes and south of Innsbruck in the Austrian Tyrol and at Hof Garstein in the province of Salzburg.

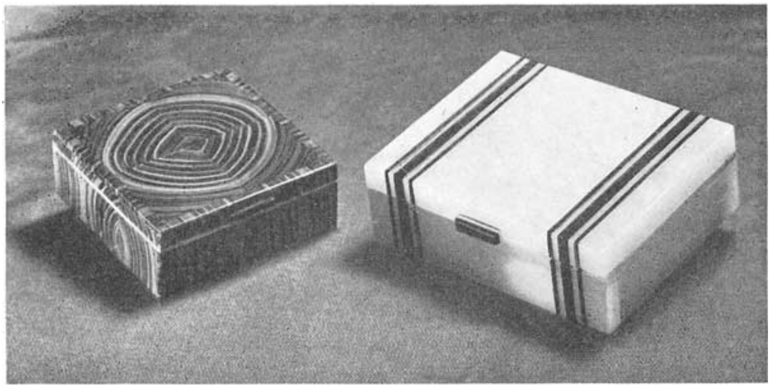
The density of the " serpentine marbles " varies somewhat, as might be expected in such an impure rock as serpentine. The values between 2·5 and 2·6 are those most commonly found in serpentine and in a few cases only have densities been recorded outside this range. The other properties agree, in general, with those given for the bowenite variety, except for the hardness.

A variety of aluminous serpentine is *pseudophite*, or, as it is often miscalled, " Styrian Jade "—a material which has been used to fashion small bowls and ornamental pieces. The material is found at Bernstein, Burgenland, Austria, about 57 miles south of Vienna on the borders of Styria and Austria, a place which, before the Versailles Treaty, was in Hungary. Another material of similar appearance is found at Gurtipohl near St. Gallenkirch, Montafon Valley, Vorarlberg, a province of Austria which lies between the Tyrol and Lichtenstein. This material is worked as an ornamental stone under the name " miskeyite." Pseudophite is soft, with a hardness of $2\frac{1}{2}$ on Mohs's scale ; the refractive index is about 1·57 and the density 2·69.

QUARTZITE

Just as limestone metamorphoses by heat and pressure into marble so does sandstone recrystallize into a granular mass of quartz crystals. This quartz rock is known as *quartzite,* and such material has been used for carvings and small objects. Often this quartzite rock contains small crystals of mica, or an iron mineral may outline the quartz granules or be scattered as inclusions throughout the rock. In such a manner is produced the well-known aventurine quartzes. When the inclusions are the green chrome mica, called *fuchsite,* the green aventurine quartz is produced, a rock which is often used for beads and other small articles of jewellery, and which is sometimes miscalled " Indian jade." A variety of green aventurine quartz, which is so impregnated with fuchsite mica that it is practically opaque and is often banded with lighter and darker green zones, may be readily mistaken for the green copper mineral, malachite.

The iron-coloured types of aventurine quartz vary from a creamy white to a reddish brown in colour, and a grey quartzite with mica inclusions is known. The creamy white to brown



The box on the right is "Onyx" inlaid with malachite. On the left is a box in agate.

aventurine quartz is obtained from Siberia. The beautiful Murchison vase in the Geological Survey Museum at South Kensington is such an aventurine quartz ; the rock from which it is carved came from the Korgon Mountains in the Tomsk division, U.S.S.R. A fine reddish-brown type of aventurine quartz is found at Cap de Gata, near Almeria on the south coast of Spain, and a grey variety comes from Chile.

The green variety of aventurine quartz is mostly found in India, where the rock is obtained from a number of localities. A rich bluish-green aventurine is found near Belvadi in the Hassan district of Mysore, and about three miles north-west, at Sindagere, occurs a banded variety. Other sources in India are in the Coimbatore and Nellore districts of Madras, where, in the latter locality, is found a large-grained quartzite of a delicate pale aquamarine-green colour, banded with deep purple. A vase cut from a nearly pure mica rock of green colour was found at Mohenjo-Daro and was dated not later than 2750 B.C. Some green aventurine quartz is found in Siberia.

The refractive indices of quartzite correspond to those of crystal quartz, but owing to the confused mass of disoriented crystals with which the mineral is composed, a refractometer reading may not be clearer than a vague shadow edge at 1·55. The density, owing to the admixture of other minerals and to the facts that it is not completely homogeneous and may be slightly porous, may be as low as 2·64 and as high as 2·69. The green aventurine quartz shows a red residual colour under the Chelsea colour-filter and this may be used to distinguish it from malachite.

Two other siliceous rocks may be mentioned at this stage. These are the *agate breccia*, in which broken angular fragments of agate have become cemented together by secondary silica, and a conglomerate in which siliceous pebbles have similarly been recemented ; such a conglomerate is the *Hertfordshire pudding-stone.*

The modern tendency to inlay the " onyx marbles " with a mineral of contrasting colour calls for some reference to be made to these colourful minerals.

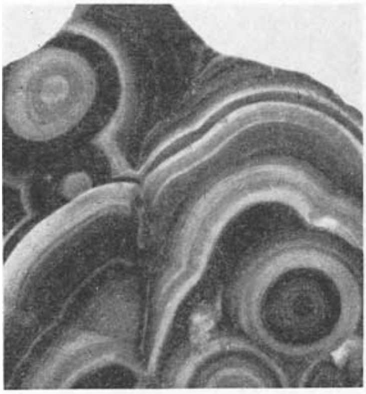
MALACHITE

The lovely green colour of malachite with its agate-like bandings makes an ideal foil for the creamy-white " onyx marble," and this mineral is extensively used as an inlay in " onyx " clock cases and cigarette boxes.

Essentially a hydrated copper carbonate, $Cu_2(OH)_2CO_3$, malachite is formed by the dissolving of copper ores and subsequent deposition in rock cavities and veins as botryoidal, reniform or stalagmitic masses. These masses are composed of closely packed slender monoclinic crystals in divergent arrangement which produces the botryoidal forms and the circular banding shown by many polished pieces. The hardness of malachite is low, about 4 on Mohs's scale, and the massive material fractures rather easily, although with care it can be turned on a lathe.

The density of the ornamental material—malachite may also be found as an incrustation on other copper minerals—has a mean value of 3·8 but varies somewhat according to the compactness of the crystal aggregates. The refractive indices of the crystals are $\alpha = 1{\cdot}655$, $\beta = 1{\cdot}875$ and $\gamma = 1{\cdot}909$, but all that can be seen on the refractometer scale is an indistinct edge at about 1·65. Malachite is a carbonate mineral and will therefore effervesce when touched with a spot of acid ; it has no distinctive absorption spectrum and does not luminesce under ultra-violet light or X-rays.

Compact malachite, which is now becoming quite scarce, in earlier days came mostly from the copper mines around the Ural Mountains, notably near Nizhne Tagilsk, Perm, Siberia, U.S.S.R. Malachite suitable for cutting is obtained from Queensland, New South Wales, and from the Burra Burra mine, which lies about one hundred miles north-east of Adelaide, South Australia. The



A polished slab of malachite.

Rhodochrosite, showing the banded structure mines of the Northern Rhodesian copper belt supply malachite, some of which is characterized by the banding being in slender parallel pencil-like lines instead of in curved or wavy forms.

Malachite is often found in intimate association with the other copper carbonate, the deep blue *azurite.* When so associated the two minerals are occasionally cut together to give a banded green and blue material. Such a combination of the two copper carbonates is termed *azur malachite.*

VERDITE

Less commonly known than some other ornamental materials, *verdite,* so named from its colour, a deep green which is often speckled with yellow or red spots, was first found during 1907 on the south bank of the Nord Kaap river in the Barberton district of Transvaal, South Africa.

Verdite is essentially a rock and may be referred to as a massive muscovite rock coloured green by the chromiferous mica, fuchsite. The material, although rather soft (3 on Mohs's scale), does take a good polish. The density varies from 2·80 to 2·99 and the refractive index is near 1·58. The absorption spectrum shows three lines in the deep red and a vague line in the blue, a spectrum typically that of a chromium-coloured mineral. Verdite does not luminesce either under ultra-violet light or X-rays.

A similar material has been reported from the Piggs Peak mines, Swaziland, South Africa, and from the western slopes of the Green Mountain range near Shrewsbury, Vermont, U.S.A. This latter material is known as the " green marble of Shrewsbury."

LAPIS LAZULI

The beautiful blue stone called *lapis lazuli* has been known from ancient times. The material owes its name, as do several other blue minerals, to the Persian word *lazhward,* which means blue. The colour of lapis lazuli varies from a blue tending to greenish, to a rich purple-blue, the perfection colour being a dark blue of extraordinary depth and intensity. Owing to the inclusion of iron pyrites most specimens show bright brassy specks, which, if not too prominent, are valued as a sign that the mineral is genuine. (This may not be such a sure sign as was previously thought, for it has been reported from America that pyrites has been seen in the blue sodalite from Canada). In olden days the stone was known as *sapphirus*, a name which is now applied to blue corundum. That *sapphirus* of classical times referred to lapis lazuli is well shown by Pliny—" In the blue sapphire shine golden specks ; it is like a serene sky adorned with stars, on account of the golden points "—an apt description of lapis lazuli.

Unlike nearly all other gem materials lapis lazuli is a complex aggregate of several minerals, particularly *hauynite* (to which lapis lazuli owes to some extent its beautiful colour), *sodalite* (of which more will be said later), and *noselite*. *Lazurite*, an isomorphous combination of hauynite and sodalite, is also present. In mineralogical works lapis lazuli is often known as lazurite. These four minerals, all belonging to the cubic system, are members of the group of rock-forming minerals known as felspathoids, which are produced when the silica content of the rock is insufficient to complete the formation of true feldspar. There are always present in lapis lazuli both calcite, which produces the whitish parts of the poorer quality material, and, as previously mentioned, iron pyrites. Small amounts of diopside, augite, mica and hornblende are generally present. Lapis lazuli is therefore a rock and not a true mineral.

The indefinite nature of the composition naturally affects the physical properties of lapis lazuli. The refractive index is generally somewhat vague, but a fairly definite shadow edge can be seen on the refractometer at about 1·50. Earlier text books gave the density of lapis lazuli as 2·38 to 2·45, values determined a century ago on small fragments of rather pure material. The commercial type of lapis has a density near to 2·8, but may be anything between 2·7 to 2·9, or over if much pyrites be present. The hardness is 5½. The material is decomposed by hydrochloric acid, giving off the obnoxious smell of hydrogen sulphide. The luminescence of lapis lazuli is not very diagnostic and is limited to orange or copper-coloured patchy glows, usually stronger in the Chilean material than in that from Afghanistan.

The most famous locality for lapis lazuli is in the Badakshan district in the mountainous north-eastern part of Afghanistan, the mines of which have been intermittently worked for six thousand years. They were visited and described by Marco Polo in 1271, but owing to their inaccessibility and remoteness little is known of them. They are near a place called Firgamu on the upper reaches of the Kokcha river, which is a tributary of the Oxus, the rock being found in a black and white limestone. What are probably the same mines, or another part of them, were described by A. E. Fersman, who visited them in 1930 as one of an expedition to find the " lazurit " which legend said existed in the Pamirs. The party found the way exceedingly difficult, and after reaching some 11,500 feet had to leave the horses and continue on foot along one of the rivers which had the name Liadjuar-Dar , which means " River of Lazurite." On reaching 16,500 feet the party found a great glacier-field covered by immense stones which had fallen from the adjacent steep wall of marble and gneiss. In this snow-white marble were veins and nests of lazurite (lapis lazuli), some bright blue, some delicate blue with beautiful passages into violet and green tints. That the natives knew of this place was given credence when one of the guides said that he had heard of it from his father and that he, with others, tried to reach the place but all contracted mountain sickness and turned back.

The mining of these Afghanistan mines is primitively carried out by heating and quenching the rock in order to obtain pieces of a size, about 10 lbs. each, convenient for bringing out of the inhospitable locality. A quantity of this material reaches Northern India and is made up into jewellery at Lahore.

Amidst the wild Sayan Mountains light blue boulders of lapis lazuli are found in the Slyudanka rivulet which flows into the southern end of Lake Baikal bordering on Mongolia. A paler coloured lapis lazuli is mined in the Chilean Andes, the most important localities being at Ovalle Cordillera, Coquimbo Province, and further north near Antofagasta. On Italian Mountain, high in the Sawatch Range of the Colorado Rockies, lapis lazuli is found in stringers in a limestone rock. This source was discovered in 1939 but has only been worked spasmodically owing to the short season, high altitude and the necessity of removing badly fractured overburden for safety. This material is almost black to an intense blue in colour, contains narrow veins and spots of calcite and is heavily charged with pyrites. The density varies from 2·82 to 2·85. An occurrence of lapis lazuli has been found near the summit of Ontario Peak in the San Gabriel Mountains, Bernardino Co., California, which lies about 40 miles west of Los Angeles. Lapis lazuli is also found in the Mogok Stone Tract, Upper Burma, and some poor quality material has been obtained from Baffin Island, north of the Labrador Peninsula.

SODALITE

Best known to gemmologists as one of the components of the richly-prized lapis lazuli, sodalite became of importance as an ornamental mineral on the discovery in Canada, about 1905, of masses of a rich blue colour.

In composition sodalite is a sodium aluminium silicate with sodium chloride, $3NaAlSiO_4NaCl$. The hardness of the mineral is 5½ to 6 on Mohs's scale and the density varies from 2·15 to 2·35, the massive blue material usually having a value near 2·28. The refractive index, a single index for the mineral is cubic in crystallization, is 1·48.

Blue sodalite has been found in the Langesunde Fiord district of Southern Norway, at Litchfield and West Gardiner, Kennebec, Maine, and at Salem, Essex County, Massachusetts in the U.S.A. The mineral is found, also, in the State of Rajasthan (Rajputana), India. The major commercial source of sodalite is the massive blue material, often speckled with bright red, pink or orange spots, found near Bancroft in the township of Dungannon, Hastings Co., Ontario, where it occurs in segregations in a belt of nepheline-syenite. Other Canadian localities are in the counties of Peterborough and Haliburton, Ontario, and in the rocks of Mount Royal in the City of Montreal in the Province of Quebec.

The Canadian sodalite never reaches the beautiful rich blue of lapis lazuli, the colour being more of a Royal blue. In recent times the material, now often used as an inlay with " onyx marble," has been called *Canadian Bluestone*, or just *Bluestone.*

RHODONITE

A beautiful rose-red translucent marble-like mineral is the massive variety of rhodonite, which in composition is a silicate of manganese, $MnSiO_3$. The material is often veined with black patches and streaks, where part of the manganese oxide has been further oxidized by weathering. Although rhodonite has a wide occurrence, the major localities for the massive material are in the Sverdlovsk district (formerly Ekaterinburg) of the Ural Mountains of Russia Other deposits are in the Vremland district of Sweden, a number of localities in the United States, in Mexico, and in the Broken Hill district of New South Wales, Australia. A small quantity of colourful rhodonite is found in Cornwall, England.

Rhodonite takes a good polish ; the hardness is about 6 on Mohs's scale and the density for the massive material used for ornamental work lies between 3·6 and 3·7. With such material only a vague shadow-edge near 1·73 can be seen on the refractometer. There is no luminescence shown by the material and the absorption spectrum is not sufficiently distinctive to use for certain identification. Rhodonite so often contains some manganese carbonate that it will effervesce with warm acid, thus this test for the distinction of rhodonite—the silicate—from the manganese carbonate—rhodochrosite—will not be completely satisfactory.

RHODOCHROSITE

The massive rhodochrosite (for the mineral is also found as crystals and granular) usually has a paler and more delicate rose-red colour than rhodonite. Rhodochrosite, the manganese carbonate, $MnCO_3$, is characterized by the lovely pink shade of colour, variegated and in bands. The material may be likened in its banding, but not in colour, to the green malachite ; indeed, as in malachite, the banding is due to stalagmitic formation, the prismatic rhombohedral crystals tending to a radial arrangement.

Although rhodochrosite is found in many different localities, only a few supply the compact material usable as an ornamental stone. The use of rhodochrosite as an ornamental mineral may be said to have begun just before the Second World War, when a quantity of this veined rose-coloured stone came from Argentina. The deposit from which it came was stated to have been found in a long disused mine. The mine, situated on a mountain fissure, at a high altitude, was thought to have been worked by the Incas for silver and copper during the thirteenth century. It was owing to this connexion that the name " Rosinca " was given to the stone. Colorado, Montana and other States of the North American continent are sources of the mineral. Roumania, Hungary and Freiberg, in Saxony, are other localities, but these are unimportant as sources of supply.

The hardness of rhodochrosite is near 4 on Mohs's scale ; the density lies between 3·45 and 3·60 (although higher values have been recorded—possibly for the purer crystals) The refractive indices are 1·820 for the ordinary ray and 1·600 for the extraordinary ray, the large double refraction being characteristic of a carbonate mineral. The fact that ornamental rhodochrosite is a crystalline aggregate precludes the large double refraction being of value, for only a diffuse shadow-edge will be seen on the refractometer. The absorption spectrum of the mineral shows a band at 5510Å (and other vaguer lines), but they scarcely assist identification. Under the stimulation of ultra-violet light a dull red glow was observed in samples of the mineral from Argentina and from Colorado. The material effervesces with acid, but, as mentioned under rhodonite, the test is not conclusive.

THULITE

The massive pink variety of zoisite known as thulite, after Thule, the ancient name for Norway, is occasionally used as an ornamental stone. The mineral has a pleasing pink colour which is often variegated with white areas, but thulite is less common than many other ornamental minerals used as inlays with " onyx marbles."

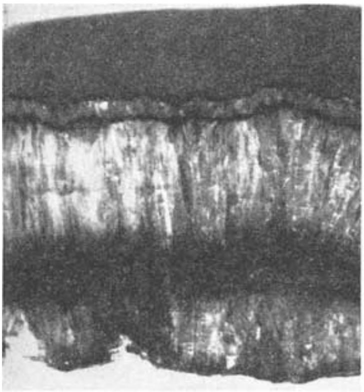
Zoisite is a hydrous calcium-aluminium silicate, $Ca_2Al_3(SiO_4)_3(OH)$, and crystallizes in the orthorhombic system. Thulite has a hardness of 6 on Mohs's scale and the material has a density which does not vary greatly from 3·10. The refractive index, at least as far as concerns the vague shadow-edge that can be seen on a refractometer scale, is near 1·70. There is no typical absorption spectrum, and, except in the type from North Carolina, which is said to glow orange-yellow under long-wave ultra-violet light, thulite does not fluoresce, although a weak rose-coloured glow with slight phosphorescence may be seen with X-rays.

Thulite is found in the parish of Souland in Telemark, in Trondhjeim and near Arendal, Norway. Other localities are in the Zillertal, Tyrol and Mitchell Co., North Carolina, U.S.A.

Mention may be made that the massive granular green zoisite in which the magnificent, but opaque, ruby crystals from Tanganyika are found, has been cut complete with the included rubies as a bowl.

FLUORITE (FLUORSPAR)

Apart from its occasional use as an inlay, massive fluorspar, particularly the *blue-john* variety, has been worked in its entirety. The most important is *Derbyshire spar*, or, as it is more popularly called, *blue-john*, a mineral which has been used since Roman times for making vases and other decorative objects. Prettily patterned in curved bands of blue, violet and purple, the last often so deep in colour as to appear black, on a reddish or a colourless ground, blue-john is unique in having only one source of supply, that is at



A polished slice of blue-john.

Treak Cliff, an outlier of the Mam Tor range near Castleton, in the Kinderscout district of Derbyshire—a source which is now said to be exhausted. The blue-john mine was driven for lead ore and consists of a number of workings opening out of a fine range of caverns, where often the beautiful fluorite is not at first seen owing to the complete covering of the rock face by stalagmitic formations. The mineral is in nodular masses and veins in oolitic limestone (aggregates of little spherical deposits of carbonate of lime which have formed as concentric crusts around nuclei—sometimes a grain of sand or a minute organism), and tends to be botryoidal in form and shows when broken the typical radial and banded structure.

The amethystine colour of blue-john has been variously said to be due to traces of manganese, impurities of a vegetable origin and/or crude petroleum, and also to a physical disarrangement of the crystal lattice, possibly from radio-active emanations. The most usual explanation given to account for the colour is that a pulsating flow of hydrocarbon-rich liquid during the crystallization of the fluorite caused the banded colour.

The fashioning of small objects of blue-john is carried out by first rough grinding the piece of rock to the requisite shape by the use of a foot lathe, a method which gives complete control through varying speeds. The roughly shaped piece is then finely surfaced with a Water-of-Ayr stone, after which crocus powder (a coarse-grained iron oxide, a coarse rouge) is used on a revolving felt pad to smooth the surfaces and put on a semi-polish The final glazed polish is put on by using putty powder (tin oxide) in conjunction with a power-driven lathe. For larger pieces, owing to the fact that the rock is chiefly composed of an aggregate of friable crystals, it is necessary to " bond " them after the piece has been cut to a suitable shape by a copper disc charged with emery or carborundum powder. The sawn piece is therefore heated in a natural resin which runs between the cracks of the aggregate of crystals, effectively " bonding " them. The bonding process needs to be repeated continuously as the work of turning on the lathe is carried out. This turning is done with high-speed steel tools.

While not exhibiting the beautiful bands of colour shown by blue-john, several other types of massive fluorspar have been used for carving and inlays. One variety is nearly colourless but veined with yellowish-brown markings, and another type has a strong violet-blue colour in which the aggregate nature of the crystals forming the piece can be clearly seen. Massive fluorite of a full yellow colour is the so-called *Ashover spar* obtained from the Ashover quarries, Derbyshire, and a massive green fluorspar also has a vogue for carved pieces.

A table lamp in massive green fluorspar.
Photo : B. W. Anderson.

Fluorspar is crystallized calcium fluoride (CaF_2), which has, for crystals, a density of 3·18, but the massive types, owing to contamination with impurities and the crystalline aggregate nature, may vary in density between 3·00 and 3·25. The refractive index is 1·434, there being only one index since the mineral is of cubic crystallization. The absorption spectrum of fluorspar is in general too vague and indecisive to be of value as a test, and, unlike most crystallized fluospar, blue-john does not luminesce ; nor to any extent do the other massive types. The hardness of fluospar is 4.

LEPIDOLITE

The massive fine-grained granular lepidolite, or *Lithia mica* as it is well known, has been polished into slabs when the mineral is of a rich rose-red to lilac-red colour. It could make excellent inlay material. The hardness of the massive lepidolite is about 3½ on Mohs's scale and the density, according to most authorities, varies from 2·8 to 3·3. A determination on an actual piece of the massive material gave a value of 2·82. There is no distinctive absorption spectrum and no luminescence with lepidolite. Massive lepidolite is found in the Ural Mountains of Russia, in Madagascar, and in California, Maine and Connecticut, U.S.A.

FELDSPAR

The variety of oligoclase feldspar known as *sunstone* or *aventurine feldspar* was first described from the southern coast of Norway, where it is found at Tvedestrand and Hitero. The material contains microscopically thin platy crystals of hematite which reflect the light as sparkling red-gold rays. Oligoclase is an intermediate member of the series of triclinic feldspars known as the plagioclases, the end members of which are albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$). The hardness of the mineral approximates to 6 on Mohs's scale and any fracture is overshadowed by the two directions of easy cleavage—a dangerous weakness in fashioned material. The density of sunstone is 2·64, and the refractive indices are 1·535–1·544, but only a vague reading may be seen on the refractometer. Apart from the Norwegian source, where the mineral occurs as irregular masses in veins of white quartz traversing gneiss, the other localities for sunstone are at Verkhne Udinsk on the Selenga river near Lake Baikal, U.S.S.R., and at Mineral Hill, Delaware Co., Pennsylvania, U.S.A.

The greyish feldspar known as *labradorite* shows the most brilliant interference colours in sweeping flashes of blue, green, gold, red and orange and shows them best when in plates of fair size with flat polished surfaces. Labradorite is nearer the anorthite end of the plagioclase series, hence the refractive indices are higher than for sunstone, the values being 1·56–1·57, and the density is 2·69. There is no significant absorption spectrum nor is there any luminescence. The coast of Labrador, Canada, is the source of most ornamental labradorite. Canada also provides another ornamental feldspar, *peristerite*, a pale flesh-pink feldspar with an attractive pale-blue flash. Peristerite is a variety of albite and in this case the constants will be lower. The density is 2·62 and the refractive indices 1·53–1·54.

There is no end to the number of rocks and minerals that could be utilized for ornamental purposes, but those which have been mentioned are undoubtedly the more important. One more " marble " may be mentioned, particularly as from its appearance it might be thought to be a " fossil marble." This rock is the orbicular diorite of Corsica (*corsite* or *napoleonite*). The orbicular structure shows orbs and spheroids composed of the same minerals as the parent rock arranged in light and dark concentric layers with a radial or tangential arrangement. The structure is believed to be due to crystallization around solid fragments in varying conditions of temperature, pressure or condition of volatiles in solution. Liesegang, in 1913, ascribed the structure to rhythmic supersaturation and precipitation in a crystallizing magma. Orbicular diorite has been used for the bodies of large ornamental vases.

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ASSOCIATION NOTICES

HERBERT SMITH MEMORIAL LECTURE

THE fourth Herbert Smith Memorial Lecture was given by Professor S. Tolansky, F.R.S., in the lecture theatre of the Science Museum, South Kensington, London, on 2nd April, 1958. This lecture has become one of the annual highlights of gemmology. Professor Tolansky chose as the title of his talk " Studies on the surfaces of diamonds " and though he did not delve farther into the diamond than a few atoms' depth below the surface, depth of interest was unfathomed. For the trigons and etch-marks on the surface of every diamond—and Professor Tolansky has proved by his searching photographic methods that every octahedral face of diamond bears these marks and pits—made an entrancing subject that turned an hour, seemingly, into little more than a minute. The chairman, Mr. Knowles-Brown, introduced the speaker.

Professor Tolansky has been working on diamond for some ten years, and in the course of his researches he has developed special recording instruments. Many years ago, he was handed a fine diamond on which, said the owner, he defied him to find any trigons. Professor Tolansky set to work. On one side, true, there were only about a million, on the other about a million and a half. So shaken was the owner, that he thereupon gave Professor Tolansky the diamond.

Professor Tolansky's work has been concerned entirely with the surface of the stone, and he has christened his study " microtopography." He showed the close relationship between this work and that of the geographer by a series of photographs of the contours of the diamond's surface. The technique he uses is one of multiple beam interference, based on the theory of Newton's Rings, which gives a contour map of the surface, and by means of which extremely minute variations in the surface can be measured. Silver is evaporated on to the surface of the diamond and on to the lens being used for detection and by this means the masses of trigons can be detected—looking like a thousand wigwams, but in truth only a few atoms deep. Professor Tolansky's technique of crossed fringes gives very sharp definition of the surface variations, and he believes trigons, which are found only on the octahedral faces, to be growth marks. Diamond, he considers, grows in sheets travelling in three directions at 60 degrees to one another. If the process is stopped, one is bound, therefore, to get an equilateral triangle, a trigon. For this reason, too, all the trigons are orientated in the same way.

Etch pits, on the other hand, are not quite rectilinear, and are not orientated in the same way. Professor Tolansky contends that it is very easy to etch diamond, at the very critical temperature of 475 to 500°C. An etched octahedral face will show trigons with their points to the side, etch pits parallel to the side ; etch pits will eat into one another, though they are still extremely shallow, and will form a pattern of blocks, each at an angle of 60 degrees, that looks like " the Manhattan skyline."

The etching of cleavage planes produced a most interesting effect. By etching matched faces of a cleaved diamond, the one part showed an exact 1 : 1 correspondence with the other part. This showed, therefore, that etching revealed something of the molecular growth of diamond, the etching preferentially attacking slight flaws or weaknesses in the planes of growth. If the surface was cracked, Professor Tolansky likewise found that the diamond took the etching preferentially. Diamond cracked far more easily than most scientists thought, and, in conjunction with the late Dr. Grodzinski, he had found that a hemisphere of diamond pressed into the surface of another diamond would crack with as little as 10 to 15 lb. load. He had been able to watch these cracks grow, and to photograph them. They were shallow, with the inside of the crack flat, bounded by two sharp " hills," perhaps either plastic flow, though the crack was produced at room temperature, or elastic. Multiple cracks showed the tiny heights to be jagged. On the dodecahedral faces, the cracks tended to be distorted, but on cubic faces there was a tendency towards squareness, even though the pressure was exerted by a round ball.

Ring-cracks found on diamond were probably due, believed Professor Tolansky, to the crushing machine, for diamond did not seem to be so hard that minute surface variations could not be caused quite easily. Etching brought out these ring-cracks, the hot oxygen eating into them. Etching was produced in nature providing the critical temperature and oxidation conditions were present.

Professor Tolansky, answering a number of questions from members of the audience, said that he would not commit himself about the genesis of diamond, but he believed that it was laid down in sheets, judging from the cleavage and etch patterns he had observed. The significance of trigons seemed to be that there was no sign of a spiral growth in the diamond crystal. Asked by Mr. B. W. Anderson if he had any evidence of change of habit during the growth of the crystal, Professor Tolansky said that he had not, but that some diamonds showed a change from Type I to Type II cleavage, that is, from irregular cleavage to smooth, almost perfect cleavage.

The meeting concluded with a vote of thanks from the vice-chairman, Mr. Norman Harper.

EXAMINATIONS IN GEMMOLOGY

The 1958 examinations of the Association were held at the end of May in the United Kingdom and various oversea centres including the U.S.A., Canada, the Netherlands, Norway, Australia, Southern Rhodesia, India, Ceylon, Switzerland, New Zealand, Thailand, South Africa, Hong Kong, Indonesia.

The Council of the Association is grateful to the gemmological organizations, universities, colleges and other educational authorities who kindly assisted in the proctoring of the examinations. In all 143 candidates sat for the preliminary examination and 100 for the diploma.

BRANCH MEETINGS

West of Scotland. The guest speaker at a meeting arranged by the West of Scotland Branch on 8th May was Mr. B. W. Anderson, B.Sc., F.G.A., who gave a talk on synthetic gemstones and their detection.

A successful summer outing was also arranged by the Branch on 8th June, when mineral localities in East of Scotland were visited.

The fifth annual meeting of the West of Scotland Branch was held at the Royal Hotel, Glasgow, on 5th May, 1958.

The Chairman, in reporting upon the work of the year, thanked those members who had contributed to the success of the branch.

The retiring office bearers, Mr. J. D. S. Wade, Chairman, and Mr. C. D. Wade, Secretary, were re-elected. Messrs. S. Ramsay, E. Macdonald and W. Ferguson were elected to serve on the committee.

Midlands. On 4th May members of the Midlands Branch visited the blue-john mines at Castleton and Chatsworth House, home of the Duke of Devonshire.

GIFTS TO THE ASSOCIATION

The following gifts to the Sir James Walton Memorial Library are gratefully acknowledged by the Council :

A fine copy of the first edition of Max Bauer's *Edelsteinkunde*, from Mr. T. Stern.
A selection of mineralogical books, from Mr. R. Webster.
Samples of emerald and beryl from the Belingwe district of Southern Rhodesia, from Mr. Lewis Jason.

Two note-books of the late B. J. Tully and other books, from Mrs. F. L. Tully.

Synthetic emerald crystals made by Professor Nacker in 1926, emerald-coloured tourmaline from Usakos, S.W. Africa, and an emerald-green glass from Czecho-Slovakia, from Mr. George Wild.

COUNCIL MEETING

A meeting of the Council was held at Saint Dunstan's House, Carey Lane, London, E.C.2, on 17th June, 1958. Mr. F. H. Knowles-Brown presided.

The Council decided that, as from 1st January, 1959, the Fellowship and Ordinary Membership subscriptions should be £2 2s. 0d.

A report on the holding of the London section of the examinations at Goldsmith's Hall was considered and the Council recorded their indebtedness to the Goldsmiths' Company for so kindly making the Livery Hall available. The Council also recorded their appreciation of the work of Mr. R. Webster in connexion with the examinations.

The following were elected to membership :—

Fellowship

Crichton, John M., London D.1955
Harkins, Thomas, Glasgow D.1949
Lauvland, Karl, Norway D.1957
Swettenham, George W., Cranham D.1951

Probationary

de Lema, Audrey (Mrs.), Medellin Colombia
Mowbray, Terence W., London
Tungate, James B., London

Ordinary

Britchfield, Charles F., Gravesend
Brown, John C., Broxbourne
Cheng, Cho-Cheong, Hong Kong
Etienne, Lorette (Mrs.), Bangkok Thailand
Gryska, Stephen, Worksop
Hiralal, Manu M., London
Millar, Hugh H., Detroit, Mich., U.S.A.
Relwani, Arjan C., Calcutta India
Schoppy, John D., Ventnor City New Jersey, U.S.A.
Smith, Charles W., Baltimore, Maryland, U.S.A.
Thomson, Patrick N., London
Tolat, Fulchand C., London

Removal from Register

The Council authorized the removal from the Register of the following :

Fellows

Gale, Herbert C.
Pyke, William
Stockwell, James C.
Yaghobi, Hadi

Ordinary Member

Law, Leslie

Elections to membership at the October, 1957, meeting of the Council were:—

Fellowship

Armbrecht, Bertram J., London	D.1957
Blackmore, Howard L., Caterham	D.1957
Cook, Walter G., Liverpool	D.1957
Cooper, Colin Lester, Cape Town, S. Africa	D.1957
Cope, John R., Nottingham	D.1957
Gaudernack, Rolf, Oslo, Norway	D.1957
Holland, Norman A., Birmingham	D.1957
Kelly, William H., Glasgow	D.1957
Lauder, Angus D., Edinburgh	D.1957
Leake, Douglas M., Nuneaton	D.1957
McKay, Robin I., Thames Ditton	D.1957
Meanwell, Brian S., Birmingham	D.1957
Pedersen, Erik M., Lillehammer, Norway	D.1957
Strange, Peter J., London	D.1957
Warrender, John S., Sutton	D.1957
Weiss, Kurt, London	D.1957
Ystad, Per T., Porsgrunn, Norway	D.1957

Transfer from Probationary Membership to Fellowship

Weatherill, John, Cardiff	D.1957
Hatcher, June A. (Miss), Birmingham	D.1957
Drapkin, Clive M., Birmingham	D.1957
Cassarino, Joseph A., New York, U.S.A.	D.1957

Transfer from Ordinary Membership to Fellowship

Weaver, Gerald, O. London	D.1957
Diss, Geoffrey D., Barrow-in-Furness	D.1957
Flapper, Jan, Arnhem, Holland	D.1957
Grimsdell, John L., London	D.1957
Hadjizade, Ahron, London	D.1957
Jones, Wilfred R., Auckland, New Zealand	D.1957
Solman, Barbara (Mrs.), Worcester Park	D.1957
Macleod, Hector M., Glasgow	D.1957
Seager, Philip, Abingdon	D.1957
Seneviratne, D., London	D.1957
Hopkins, Iris P. (Miss) London	D.1957
Jank, Robert A., Boscombe	D.1957

Probationary

Coakley, Brian, Manchester

Rushworth, Jack, Halifax

Ordinary

Baeta, Carlos, Lisbon, Portugal
Baldinger, Kurk, Cape Town, S. Africa
Barwell, Alfred H., London
Biggers, Willard B., London
Bruford, Alan P. W., London
Carr, Arthur G., Rio de Janeiro, Brazil
Crawford, Andrew, Birmingham
Delario, Anthony J., Paterson, N.J., U.S.A.
Hamilton, Douglas P., Glasgow
Norris, Aubrey, Maidenhead
Rafee, M. A., Karachi, Pakistan
Rose, Jack A., Newcastle-upon-Tyne
Safiyulla, M. T., Colombo, Ceylon
Stern, Hermann, London
Suresh, Choksi, London
Welford, Dorothy A. (Mrs.), Winchester
Wells, Charles L., Jr., Jacksonville, Florida, U.S.A.

ITALIAN GEMMOLOGICAL LABORATORY

The British Consul in Turin and the First Secretary (Commercial) of the British Embassy in Rome recently paid a visit to the gemmological laboratory at Valenza which is run by Professor Speranza Cavenago-Bignami, a member of the Association.

TALKS BY MEMBERS

LEIPER, H. : " The fascination of faceting," California Federation of Mineralogical Societies, San Bernardino, Cal., 21st June, 1958. Mr. Leiper, a Fellow of the Association, is now associate editor of the Lapidary Journal, Del Mar, California.

MELROSE, R. A. : " Diamond and diamond cutting," North Shields Rotary Club, 18th February ; " Synthetic Gemstones," Newcastle-upon-Tyne Hadrian Round Table, 26th February ; " Art of the Jeweller," Association of Home Economists, 7th March ; " Gemstones," Tynemouth Business and Professional Women's Clubs, 2nd April ; " Story of Diamonds," Chester le Street Business and Professional Women's Club, 15th April ; " Antique and Modern Silver-ware," Newcastle Business and Professional Women's Club, 30th April ; " Precious Stones," Ashington Business and Professional Women's Club, 27th May ; " Gemstones," Newcastle-upon-Tyne Round Table, 1st July.

OLIVER, R. J. N. : " Gemstones," to Liverpool Round Table No. 8, 4th June, 1958.

FORTHCOMING MEETINGS

The 1958 presentation of awards will be held in London on Tuesday, 11th November, at 7 p.m.

CORRECTION OF MEMBERSHIP REGISTER

Mrs. Vera Hinton, F.G.A. was elected to Fellowship on 6th February, 1958, and not as an ordinary member (Vol. VI, No. 6, p. 290

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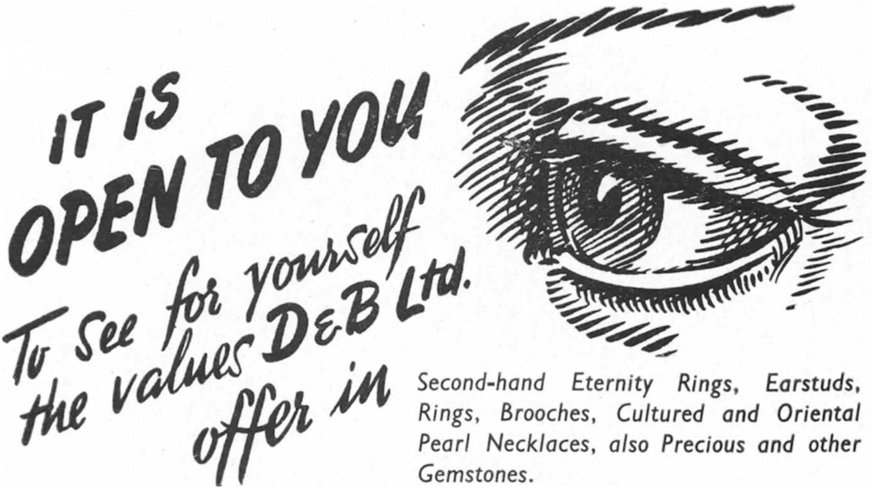

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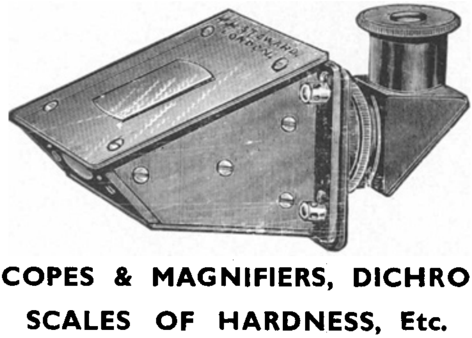

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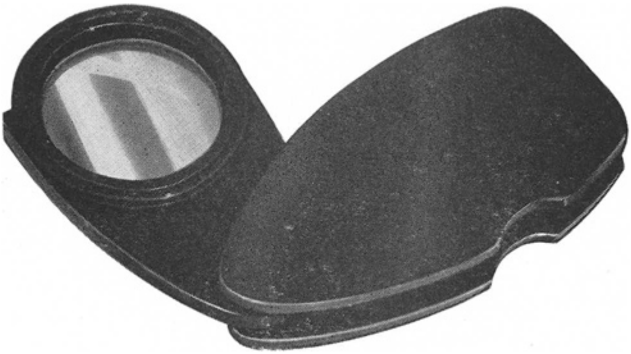

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