PRECIOUS STONES

BY

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WITH A CHAPTER ON
ARTIFICIAL STONES

BY

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PREFACE

The author has to acknowledge his indebtedness to R. C. Munro Ferguson, Esq., M.P., for permission to figure some of the very fine specimens of Precious Stones contained in the Raith Collection; to Dr. J. B. Mears, of Edinburgh, for his careful drawings and photographs of these specimens; to Mr. R. Dykes, of the Marine Biological Laboratory, Lowestoft, and lately assistant to Sir J. Murray, K.C.B., for his chapter on the artificial production of Precious Stones; and to the life-teaching of his late father, J. G. Goodchild, of H.M. Geological Survey. Among the numerous larger works on this subject the reader is especially referred to the splendid book by Dr. Max Bauer, translated by Mr. L. J. Spencer, of the British Museum.

The different gem stones are here considered in a mineralogical sequence, and the numbers preceding the names are the species numbers of Dana's System.

WILBERT GOODCHILD.

THRELKELD,
October, 1907.

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PRECIOUS STONES.

CHAPTER I.

INTRODUCTORY AND HISTORICAL.

From the earliest times gems and precious stones have been prized on account of their beauty and for the purposes of personal adornment; this is amply shown by the numerous references to them by the ancient authors; Pliny, in Books XXXVI. and XXXVII. of the Natural History, quotes from many of these works, all of which, except that of Theophrastus, are now lost. A considerable number of these writers were Greeks, and several of them would appear to have lived in or visited more Eastern lands, where very probably their interest in the precious stones was largely brought into being. King, in his work on "The Natural History of Precious Stones," calls attention to the fact that Socatus, one of the authors quoted by Pliny, speaks of having seen a certain wonderful gem in the possession of *the King*, which according to Greek usage would mean the king of Persia; this gives us a definite conception of the antiquity of this love of gems. Another author quoted by Pliny is spoken of as Zachalias the Babylonian—again pointing to the connection between the study of this subject and the ancient civilisation of the East. This relation may be accounted for by the fact that many of the earliest known localities for gems were in the East, or on the other hand it may be that the people of the lands to the north-west of India first showed a marked degree of civilisation and hence first observed these wonders of Nature, and sought for and found new localities where they occurred.

In these early times gems were prized not only for ornament but, possibly to an even greater extent, for supposed magical and medicinal virtues—magic and medicine being then only too closely associated. Under the accurate learning of the best period of Greek civilisation there seems to have been a much larger amount of scientific observation brought to bear on the subject. Pliny in his time showed a still greater exactness, and moreover a marked contempt for the "preposterous lies of the impudent Magi." Solinus, a Roman writer probably of the period of Constantine, improves further on some of Pliny's descriptions of gems.

Later again, the seemingly very deep-rooted belief in the medicinal properties of gems coloured a great part of another work; this was the "Origines" of Isidorus of Seville, written in the seventh century. The book, however, is valuable in containing quotations from writings now lost. Isidorus was a bishop, and one of the next works of which we have record was also the writing of a bishop—Marbodus, bishop of Rennes. Marbodus says his work is a condensation of that of Evax, King of Arabia; King, however (*op. cit.*), is of the opinion that no such book was written by Evax, but that it was a compilation made after the period of truer learning. Both these books show a retrograde step, in going back to the mystical rather than in advancing the scientific knowledge of the subject.

In the twelfth century a "Book on Precious Stones" was written by Mohammed Ben Mansur, of great value on account of it being of a much more exact nature than any of its forerunners, though much of his information would appear to have been derived from the same source. In spite of the forward step which the appearance of this work marks, it was followed by a number of other books which, from the point of view of the present day mineralogist, entirely forsook the subject, as they dealt almost wholly with the supernatural, ascribing to gem stones all sorts of powers against evil spirits, diseases, and the mighty manifestations of Nature. These ideas were still further modified by a growth in the belief that various symbols and inscriptions engraved on the stones were able to enhance their already supernatural powers. King (*op. cit.*) ascribes these new forms of thought to the influence of the Crusades upon the learning of the country, in bringing back magic-lore gleaned from the Arabic philosophers.

No further work of any great value appeared till that of Bœtius de Boot, physician to the Emperor Rudolf II., which was entitled "De Gemmis et Lapidibus," and which was published in 1609. At the same time De Boot, while decrying the magical powers ascribed to gems, goes on to give recipes for the making of various pharmacopœial preparations of precious stones. In 1672, again, we find Robert Boyle, one of the early Fellows of the Royal Society, in his "Essay About the Origin and Virtues of Gems," after making most careful reservations in his preface as to what his opinions were about the virtues of gems, and stating that "not only some of the writers of Natural Magick, but men of note, who should be more cautious and sober, have delivered in their Writings many things concerning *Gems*, which are so unfit to be credited, and some of them perhaps so impossible to be true, that I hope the Believers of them will, among the Votaries to Philosophy, be as great rarities as Gems themselves are among Stones," going on to seriously make the following statement: "And we see, that soft Stone, which is plentifully found near *Naples*, and commonly call'd the *Lapis Lyncurius*, being rubb'd a little and moistened with water, and then expos'd to the Sun in a due season of the year, will, in a very short time, (as Eye-witnesses have assured me,) produce Mushrooms fit to be eaten." The *Lapis Lyncurius* was either Amber, or more probably, as suggested by Sir J. Hill, Hyacinth, a variety of Zircon—not at all a good germinating ground for the spores of mushrooms. And again he says, "because I find no impossibility that at least some costly and less hard (though indeed more valuable) Gems, may have considerable operations upon humane Bodies, some few of which I have had opportunity to be convinc'd of, I will not indiscriminately reject all the Medicinal Virtues that Tradition and the Writers about pretious stones have ascribed to those Noble Minerals." Still, Boyle's book is most fascinating, and shows he was an active champion of the hypothesis of the aqueous origin of most minerals, a cause which Gustav Bischof, nearly two centuries later, again felt the need of impressing on the scientific world in opposition to the Plutonic theory of the origin of all minerals and rocks.

In dealing with the properties anciently ascribed to gems and precious stones, it is necessary to point out that the old conceptions as to what was included in these two classes were very different from those of the present day. By "gem" we now understand a mineral which by its hardness, rarity, lustre or colour is used for the purposes of adornment; a precious stone is also usually a mineral, and possesses these same qualities in a minor degree. Most of the true gem stones are crystallised and are transparent or at least translucent. Formerly, however, besides including all the then known stones that fell under the above heads, many substances were regarded as precious stones which were of a very different origin, and that often for very different reasons than on account of their beauty. Fossils, for instance, were at one time held in high esteem in this relation and were accredited with great use in the preparation of medicinal remedies, and that apparently chiefly on account of their peculiar shapes. Again, we find that when glass was scarce a cup of that material was considered fit to rank with ornaments made from what we still regard as precious stones.

The individual properties ascribed to the various stones will be noticed in the part dealing with each substance, but a few general examples may be given here to illustrate the point. The Diamond, for instance (though not known to the earliest writers), is frequently referred to on account of some of the following reputed properties: taken internally it is a violent poison—it is said to have been administered to Sir T. Overbury (amongst other poisons) when a prisoner in the Tower—and yet Garcias records a case that came under his notice of a woman giving her husband repeated doses of diamond-dust to relieve dysentery, but without effect; the physician Camillo Leonardo in the sixteenth century declares it is a poison of a most violent kind, and Cellini tells how an enemy tried to poison him by employing an apothecary to place powdered Diamond in his salad, but was saved by the apothecary substituting some powdered Beryl. Truth is probably with both sides: an unbroken Diamond can be swallowed by a Kaffir with intent to steal without harm to his system, but sharp fragments of Diamond would be as much an irritant poison as powdered glass in the same quantity. Diamond, again, dispels unfounded fear, and is a protection against insanity; and Boyle (*op. cit.*) instances a quaint belief in the following words: "If it happen that the Mineral Corpuscles, that are wont to impart a certain Virtue to the stony matter of one Gem, should, by some lucky hit, be so united with that of another sort of Gems (of which case I formerly gave an Instance in green Diamonds,) though the quantity of this unusual Ingredient may be but very small, yet, if it's efficacy be great, it may innoble the Stone with a notable degree of some such Virtue as is supposed not to belong to that *Species*, but to an other."

CHAPTER II.

MODES OF ORIGIN.

THE origin of each gem will be dealt with in its proper place, but here again a few general points may be noticed. It is well worth the reader's while to study such a book as that of Robert Boyle's above referred to, to gain an insight into the earnest endeavours these old scientists made to discover the how, why, and wherefore of Nature's working. Aristotle in the third book of Meteors states his belief that the infusible stones were made by a "dry exhalation"; another theory was that they were formed of a mixture of earth and water congealed by cold; later again the almost universal belief was that they originated from the actual fusion by heat of various earthy matters. Boyle, by careful "examens" of different chemical substances, as alum, salt, saltpetre, etc., in the process of crystallisation, came to the conclusion that all gems originated from crystallisation from a watery solution; he came to the conclusion that for the particles, of which the mineral was composed, to be able to move into their proper places so as to unerringly build up a crystal of a definite geometrical form, these particles must have existed in a fluid state of some sort. Crystals are formed either by sublimation, solidification from a molten mass, or separation from a solution, and it is quite possible one of the commonest ways of formation of the crystals of mineral substances is by separation from a solution at a great temperature and under enormous pressure. Suppose we dissolve in cold water as much Glauber's salts (sodium sulphate) as possible and then heat the solution to nearly the boiling point, on adding more of the salt we shall find it dissolve readily, and conversely on cooling it will be again deposited in a visible form as crystals. In such a case the temperature to which we can raise the solution is very nearly fixed by the pressure of the atmosphere; if, however, we heated the solution in a strong metal vessel capable of withstanding a pressure of several hundred pounds to the square inch, we should find that crystals of the Glauber's salts which remained undissolved at the ordinary boiling point were dissolved. Thus we can reason that given sufficient heat and sufficient pressure and sufficient *time*, many substances, which in the chemical laboratory seem insoluble, may be readily dissolved. Conversely on the lowering of the temperature and the relief of the pressure, it is possible to have such mineral substances deposited from solution; in other words, they may appear as crystals. It is more than probable that some gems are actually deposited as crystals from a molten magma, but it is even more certain that some are formed on the cooling of solutions at high temperatures.

While most precious stones are crystalline, some few, as the Opal, are probably not, but the distinction is now regarded as a somewhat arbitrary one; whether crystalline or colloid, Opal is probably deposited by water charged with silica slowly percolating through fissures in rocks.

In dealing with the origin of the various gems, the classification proposed by J. G. Goodchild[1] will be followed in the

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[1] "Proc. Royal Physical Soc.," vol. xiv., p. 183.

main, for though it was put forward chiefly in connection with certain Scottish minerals, it covers most, if not all, of the minerals with which we have to deal, since the majority fall under comparatively few heads which will be dealt with fully as being more important to our purpose:—

I. Epigene minerals.

  A_1.—Those whose first stages consist in their being dissolved at the surface, and then re-deposited elsewhere outside the lithosphere.

    (*a*) Those deposited on the land.
    (*b*) ,, ,, in fresh water.
    (*c*) ,, ,, in closed bodies of water.
    (*d*) ,, ,, at the bottom of the sea.

  A_2.—Those whose materials arise through solution at the surface, and subsequent re-deposition within the lithosphere.

  A_3.—Those due to subterranean percolation of waters from the surface.

    (*a*) Those which are altered *in situ*.
    (*b*) Those whose materials have been dissolved within the lithosphere, and subsequently re-deposited at lower levels.

II. Hypogene minerals. Mostly of hydro-thermal origin, and usually connected with some manifestation of elevatory movement.

  B_1.—Original minerals of eruptive rocks.

    (*a*) Silicates.
    (*b*) Metals and their compounds.
    (*c*) Other minerals.

  B_2.—Original contents of mineral veins.

B_3.—Minerals arising from solfataric action.

B_4.—Those deposited at the surface by thermal springs.

B_5.—Those arising through thermo-metamorphism.

B_6.—Minerals arising through dynamic metamorphism.

B_7.—Combinations of the effects of B_5 with those of B_6.

Under A_1 we are only immediately concerned with some forms of Gypsum, which come under (*c*). During past geological times there were in some areas great closed lakes similar to the Dead Sea at the present time; the rivers flowing into these brought down many salts in more or less dilute solution; now it is at once obvious that if a lake persists with no outlet, the evaporation from its surface must be sufficient to account for all the water brought to the lake by the rivers flowing into it (with the exception of a small quantity which may intrude into the surrounding rocks). Thus, as the water evaporates the solution of the various salts is concentrated, and some of the salts finally deposited. The Gypsum probably results from the double decomposition of magnesium sulphate and calcium hydrogen carbonate, both contained in the water. It may also arise by the concentration of estuarine or brackish water in shallow lagoons. Once it is disseminated in scales throughout the mud at the bottom of the lake, we can more easily account for the subsequent segregation into masses which has occurred in most known gypsum-beds; such segregation would come under the head A_3 (*b*).

The next group we are concerned with is A_3 (*a*) dealing with those minerals which have been produced by alteration of pre-existing minerals *in situ:* take Serpentine as an example; it is a silicate of magnesium (often with some iron replacing part of the magnesium) with some water, which water is only driven off at a red heat, and is, therefore, in chemical combination. Now, there is in nature a very large number of ferro-magnesian silicates, and several of these, when acted on by downward percolating water (probably containing small quantities of alkaline carbonates in solution, and certainly acting over long periods of time), are hydrated, and one of the substances that may be so formed is Serpentine.

The next group is much more important, as it includes some forms of Calcite, all the true Agates, and the minerals Prehnite, Opal, Dioptase, Turquois, and many of the forms of Quartz and Chalcedony.

Consider these same waters referred to above, charged with traces of alkaline carbonates, and percolating downward through, say, a mass of ancient lava. First we may ask, "Whence came the carbonate in solution?" Rain falling on the earth contains a certain (small) amount of carbon dioxide or carbonic acid: as the water percolates through the layers of the soil it becomes further charged with the humus acids—allied to carbonic acid, and generated largely by the action of bacteria upon the organic matter which is everywhere present on the surface. This weak acid solution in the course of time acts on some of the constituents of the lava, and slowly dissolves, for instance, one of the complex silicates containing sodium. Thus a weak solution of sodium carbonate is formed. Such a solution would probably have no perceptible action on a piece of lava in a laboratory, because we, relatively speaking, neglect the all-important factor, time. But in Nature's laboratory it is quite different, and the rock-forming minerals of the lava are slowly decomposed, a small portion of the material being carried deeper into the rock. Now, a lava frequently contains steam holes, or vapour cavities, and if the solution meets one such in its downward path, it is carried into the cavity by osmosis. Usually the first solution to enter is one derived from the attack of the water on one of the ferro-magnesian minerals, and once it is in the cavity a thin film of a mineral (in most cases one allied to Serpentine) is deposited on the wall of the cavity, and forms what is called the "priming." Dr. Heddle showed this priming to consist in most cases of Celadonite. The thickness of this layer may vary from a mere film to one entirely filling the cavity. If the Celadonite continued to be deposited along with silica in the form of Chalcedony, it often took the form of moss-like growths, surrounded by the clear Chalcedony, giving rise thus to a Moss Agate. If the Celadonite and Chalcedony were intimately mixed Prase or Heliotrope would be formed. Later silica in solution was carried into the cavity by osmosis, and deposited next inside the priming, or only separated from the Celadonite by a thin layer, to be described immediately. The deposition of the silica took the form of Chalcedony, and was very probably brought about by the escape of the solvent. Often the decomposition of the ferro-magnesian silicates was closely followed by the disintegration of the felspars of the rock, and the resulting products carried into the cavity and deposited immediately within the Celadonite, as a layer of one of the Zeolites. Rarely the entire cavity might be filled with Zeolite. All three of these minerals form coatings of practically uniform thickness.

In other words, the roof received as much deposition as the floor. This points to a considerable degree of surface tension between the solution of silica and the pre-formed portion of the Agate; but if the layer of clear Chalcedony became thick, gravity in some cases overcame the surface tension, and the newly deposited jelly-like silica sagged somewhat, and as further layers were added the sagging would become more marked, until a diminutive stalactite was formed. The presence of such a stalactite increased the surface tension at that point, and caused a greater relative deposition of new silica. In most cases small growths of zeolitic minerals occurred on the "skin," often in the form of minute sheaves of crystals; thus at such points the surface area was much increased, and hence also the absolute surface tension, leading to an extra deposit of silica there in layers concentric to these little sheaves. In this manner were formed the "eyes" so commonly seen in Agates. Where the eyes were close together the bands took on the form of salient and re-entering angles, giving on cross-section a plan somewhat similar to the plan of a fort; hence such Agates are called Fortification Agates.

Should much zeolitic matter be deposited with the Chalcedony the Agate has an opaque chalky appearance and is then known as Chalcedony Cachalong. Often too the silica is in the hydrous colloid form, Opal; or, again, the last formed layers (in the centre) may be anhydrous and they then take the form of Quartz, Amethyst or Cairngorm.

Now Opal in its solution seems to have a much weaker surface tension, and so, instead of finding it evenly coating the inside of the cavity we see that it is deposited in horizontal layers; when the layers are parallel Onyx is formed, but the term refers to the parallelism of the bands and not to their composition, hence Onyx may consist of Chalcedony. Opal containing finely divided zeolitic material is true Cachalong.

That all these layers remained in the form of a jelly until (in most cases, at any rate) the cavity was entirely filled, is clearly shown in many Agates by what Dr. Heddle called the "tube of escape." The contents being denser, the osmotic pressure was greater; possibly also heat was liberated on the crystallisation of some of the silica; at any rate, the weakest part of the skin gave way and a minute pore was formed through which some of the silica jelly was forced, the gelatinous layers of silica near the opening being at the same time bent outwards.

All such true Agates being formed in closed cavities assume the shape of these spaces, which, since they are often steam cavities in lavas, are in many cases lenticular, similar in form to the bubbles in inferior glass. Thus one of the means of recognising an Agate before it is cut into is its shape.

When ferric oxide is deposited in the Chalcedony in minute particles it imparts a translucent blood-red or flesh colour to the Agate, which is then called Carnelian.

Some colloid substances are liable to a molecular change causing them to pass into a crystalline form (*cf.* Roman glass). Opal is so liable, and the change is accompanied by decrease in volume, hence cracks are formed; these cracks are sometimes penetrated by solutions of hydrous oxide of manganese, which is deposited in dendritic forms: such Agates are called Mochas.

Vein Agates are formed in fissures or spaces in communication with the surface; in these cases surface tension still has an important bearing on the formation, but osmosis is probably not a factor. Frequently, included material is so abundant as to cause opacity; in such cases the variety of Chalcedony is known as Jasper.

From the point of view of genesis most crystals of Dioptase probably come in this class, being the result of the decomposition of copper ores by downward percolating water and subsequent deposition of the copper as a hydrous silicate at a lower level.

Turquois is another mineral whose origin is similar, and in some cases Gypsum falls under this head.

In Class II., Hypogene minerals, are many of the gems and precious stones. A consideration of the origin of many of these minerals carries us into geologically debatable ground. Many have been the hypotheses and theories advanced to explain the formation of such compounds in Nature's laboratory. As far back as 1672 Robert Boyle (*op. cit.*) stoutly maintained that the gems were deposited from a fluid—in most cases he seems to have had a watery solution in mind; one of his passages, on account of its quaintness and its apt expression of the point in question, may be quoted: "But unless a Concreting stone, or other like Body be either surrounded with, or in good part contiguous to a Fluid, 'tis not easie to conceive how it should acquire a Curious Angular and determinate shape. For Concrescent Bodies, as I may so speak, if they have not room enough in an Ambient Fluid for the most congruous ranging of their parts, cannot cast themselves into fine and Regular shapes, such as I shall presently show that divers Gems seem to affect; but the Matter they consist of must conform to the Figures of the Cavity that contain it, and which in this case has not so much the Nature of a Womb, as of a Mold. And so we see that Salt-Petre, and divers other Salts, if the Water, they were dissolv'd in, be much too far boyl'd away before they are suffer'd to shoot, will, if the Liquor fill the Glass, sometimes coagulate into a Mass, fashion'd like the inside of the containing Vessel, or if a pretty quantity of Liquor remain after the coagulation, that part of the nitrous Mass, that was reduc'd to be concreted next the Glass, will have the shape of the Internal surface of it, whatever that be; but those Christals that are contiguous to the remaining Liquor, having a Fluid Ambient to shoot in, will have those parts of their Bodies, that are contiguous to the Liquor, curiously form'd into such Prismatical shapes as are proper to Nitre." It may be remarked in passing that when Boyle speaks expressly of "*determinate*" shapes and the prismatical shapes proper to nitre, it seems as if he had recognised the fact that a given compound crystallises in one definite shape, although this has been denied.

As previously pointed out, Bischof in 1854 placed before geologists and physicists a splendid series of observations from which he deduced the very important influence of water in the formation of many compounds commonly supposed to result from the action of dry heat.

The view suggested by J. G. Goodchild in giving the present classification, was one that had for some years previously been taught by him; for a full explanation of it the reader must be referred to the paper mentioned above; in outline it is as follows: If a large intrusive sheet of rock be followed over a considerable area of country, its character to the eye is seen to change but little, and on chemical analysis its composition is found to be very fairly uniform; also it is seen that the older rocks into which it is intrusive are not pushed aside by the mass, but rather replaced by it—there is no material increase of bulk; in other words, no amount of new matter corresponding to the bulk of the intrusive mass can have been introduced unless an equal bulk had been removed. This would manifestly be unlikely, and at once suggests that the intrusive mass may be the result of some alteration of the older rock masses replaced by it. The difficulty that at once confronts one is that the composition is so uniform even in passing through considerable masses of rocks of entirely different composition; but an *average* analysis of the rocks throughout the extent of the intrusion reveals the fact that the composition of the intrusive sheet chiefly differs from that of the surrounding rocks in a greater proportion of alkali. The writer above referred to suggested the possibility that such alkali might be slowly carried into the rocks by osmosis from the area of great terrestrial activity along the seaward margin of the land. Once such alkaline water is introduced at points where activity is great and temperature high, rocks may be liquefied at a very much lower temperature than that of ordinary dry fusion, so the depth and temperature demanded need not necessarily be very great. Most rock-forming minerals have a fairly definite melting point, but of course different minerals melt at different temperatures; so it is quite possible that conditions might obtain which would suffice to introduce into a rock that was on the whole in a solid state, certain minerals in a state from which they could crystallise. In this way a shale may be converted into Lydian Stone, and the components of an impure limestone or other sedimentary rock may be rearranged so that Zircon or Sphene may be formed, amongst many other minerals.

Under B_2, practically the only minerals which concern us are Fluor Spar and Quartz; in a mineral vein both these may result from the cooling of heated waters rising up through the great fault-fissures. It may be noted that the sequence of deposition of these minerals is usually constant in any given vein, and that such sequence can in most cases be very easily determined from an examination of the vein.

The group B_5 includes the great majority of the minerals used as gem stones. Their origin appears to be very similar to that of the first group of Hypogene minerals spoken of. They may be regarded as falling into two sub-groups; firstly, those whose whole constituents existed in the rock before its change; and secondly, those whose formation demanded the introduction of some fresh elements from without the rock. In both cases the molecular rearrangement would appear to have been brought about by the slow action of weakly alkaline water under considerable heat and pressure. In the first sub-group a calcareous rock containing the usual numerous impurities may, by molecular or atomic reconstruction, have formed in it such minerals as Idocrase, Sphene, Spinel and several of the Garnets, besides many other minerals which concern us less. A rock of a clayey nature provides the materials for the formation of Iolite, Andalusite, some of the Garnets, and other compounds. One point of great interest is that Graphite or other forms of carbon diffused in a rock may by the action of heated water be converted into (possibly) a metallic carbide from which a pure form of carbon may be deposited in visible quantity. Anthracite probably thus formed may be found in many agglomerates, and it was suggested by J. G. Goodchild that Diamond may arise in this way; certainly Diamonds are found in a similar rock (agglomerate) in the great mines of South Africa.

Rocks of eruptive origin have developed in them minerals bearing naturally a relation in composition to that of the parent rock, so that one of basic or sub-basic character may have Epidote and Garnets formed in it.

Of the second sub-group Tourmaline is a good example, though this mineral usually shows evidence of dynamic action as well. Topaz, Beryl, Euclase, Phenakite and Chrysoberyl very probably have some of their rare constituents brought to the rock in this way. Topaz and Beryl often occur in the druses of plutonic rocks (as granite) which seem to have been formed by the liberation of aqueous vapour at the outer parts of the granite mass at a later stage in its consolidation; these cavities often have several minerals deposited in them in a regular succession, Quartz (often as Cairngorm) being among the earlier, Topaz and Beryl among the later. In such druses, where the crystals only form a lining, the crystal forms are idiomorphic, but where the crystals have grown so as to touch, they are allotriomorphic, and in some cases such growth is associated with absorption of the substance of the crystal to some extent; in these instances the absorption is found to occur almost entirely along the axis of greatest elongation.

Tourmaline presents a good picture of the changes that occur in the formation of itself and other minerals which owe their origin to the causes tabulated under B_5 and B_6. We find it developed as a secondary mineral in highly-silicated rocks which have been subjected to dynamic changes; the beginning of its formation only commenced after many other changes had occurred in the rock, since its crystals are attached to crystals of pre-formed minerals, but its growth was completed before the cessation of the movements which caused the metamorphosis; the last movements fractured the Tourmaline crystals, chiefly transversely to their axis of greater elongation, and bent them, and then the fissures so formed were filled with the last of the rock-forming minerals to consolidate, since Quartz, Felspar and Mica are found in these interstices. The absorption of the ends of the crystals seems to have occurred at the time of the bending; it is comparatively rarely one finds well terminated crystals, though specimens showing the prism zones well developed and perfect are common.

CHAPTER III.

THE PHYSICAL PROPERTIES OF GEM STONES.

I. The most important group of physical properties we have to deal with is that dependent on light. When light acts on a gem it may—

A. Be reflected back again.
B. Be transmitted.
C. Produce phosphorescence.

A. When light is reflected from a mineral two phenomena may be observed—

a. Colour.
b. Lustre.

a. White light falling on a mineral and suffering reflection may reveal a certain colour of the stone. This is due to certain of the components of the white light being held back or absorbed by the substance, while others of the coloured rays are returned to the eye and there produce a sensation of colour. Should a stone reflect all the rays of white light in the same proportion as it receives them it will appear white; if all or nearly all the rays are stopped it appears black; if all but the green rays are stopped we should say the stone was green, and so on. It is very unsafe to place much reliance on colour in the identification of precious stones, as in many cases one mineral may occur in several different colours, and on the other hand stones of very various kinds have unfortunately become known by the same name when they are of one colour. For example, a red Corundum is Ruby, while a blue crystal of the same mineral is a Sapphire, but a red Spinel may also be sold as a Ruby; an expert eye can usually distinguish a difference in such a case, but it is not absolutely reliable.

b. Lustre is of several different kinds, usually described as—

1. Metallic.
2. Adamantine.
3. Vitreous.
4. Greasy.
5. Resinous.
6. Silky.
7. Pearly.

The lustre may be of the varying degrees of splendent, shining, glistening or glimmering.

By far the most important in the crystallised gem stones is the adamantine lustre, and that we wish to find in the splendent degree—in other words, the ideal is to have the stones of as great a brilliance of lustre as possible, and hence stones which do not reach this standard are thought less of. A high lustre is almost an essential of a true gem stone at present, though there are signs of a coming appreciation of the more modest appearance of some of the less splendent minerals.

B. When the light is transmitted there are three conditions to be observed :—

a. Diaphaneity.
b. Refraction.
c. Polarisation.

a. Diaphaneity. If light passes through the mineral so that objects can be seen through it, the mineral is said to be transparent; a mineral of a lesser degree of diaphaneity is sub-transparent. If light is transmitted, but in such a manner that we cannot see through the substance, the body is said to be translucent; or sub-translucent if only a small amount of light passes. If no light goes through the substance is opaque.

b. Refraction is of the highest importance in the study of gem stones; many of the peculiarities of gems are due to this phenomenon.

1. Single refraction. All transparent minerals which are crystallised in the cubic (or isometric) system, and all transparent amorphous substances, are isotropic. If a ray of light *A O* (Fig. 1) impinges on a piece of glass having parallel surfaces *F O*, *D G*, at an angle *A O B* with the normal *O B*, it is found that the ray does not pass through the glass in a straight line *A O E*, but is bent or deflected into the path *O D*, and on emerging into the air again at *D* it proceeds in a direction *D J* parallel to its original direction. The angle *A O B* is called the angle of incidence, and the angle *D O C* the angle of refraction. The lines *B M* and *C N* are proportional to the sines of these angles

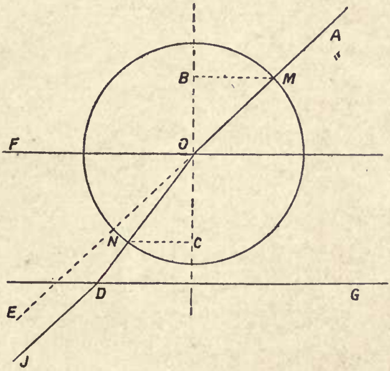

FIG. 1.—Diagram of Refraction.

respectively and the ratio $\frac{B\,M}{C\,N}$ is the index of refraction when the incident ray is passing through air. All substances which transmit light have a definite index of refraction.

All the components of white light are not equally refracted by a given substance, the rays at the violet end of the spectrum being most bent and those at the red end being least bent. This is not well seen in the case of a beam of white light passing through a parallel-sided piece of glass because the various component rays become parallel again; but if the beam pass through a prism the components are further separated on passing again into the air (Fig. 2). This separation is known as dispersion; the power of dispersion varies in different substances, but is high in many of the gem stones, particularly in Diamond; to this property Diamond owes much of its beauty, as the light being much dispersed in the stone emerges again in marked rays of coloured light.

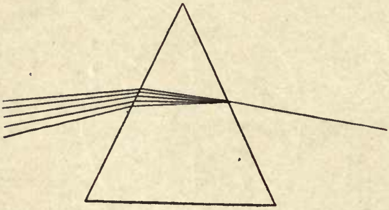

Fig. 2.—Diagram of Dispersion.

Since all colours are not equally bent in one given substance it is necessary to refer the index of refraction to light of one particular colour. The middle part of the spectrum is usually taken for this purpose; the difference in index for different rays is not great, for even in Diamond, which has such a great dispersive power, the index for the red rays is 2·407, while for the violet rays it is 2·465; for the middle of the spectrum it may be taken as 2·44.

Since the sine of the angle of refraction increases with the sine of the angle of incidence, the former will have its maximum value when the latter is unity; thus if r be the angle of refraction, this angle will be at its greatest when $\sin r = \frac{1}{n}$, where n is the index of refraction; the angle having the value given by this equation is called the critical angle. Supposing light were proceeding from within the optically denser medium and impinged on the surface at this critical angle, the ray on passing into the rarer medium would just skim the surface; but if the angle in the denser body were greater than the critical angle, no light would pass out of the denser medium, but all would be reflected again within it. Such a phenomenon is known as total internal reflection. Applying this principle to a cut gem stone it is obvious that light impinging on one of the facets from air at any angle may be at least partly refracted and pass within the stone, but that on meeting the surface of a facet from within it may be wholly turned back. In Fig. 3 this is shown in the case of the Diamond, where a ray is shown undergoing first refraction, then totai lnternal reflection three times, and finally refraction a second time. When the cutting of precious stones is described, it will be found that in the Diamond at least there are definite proportions at which the cutter normally aims; these proportions ensure the facets being at

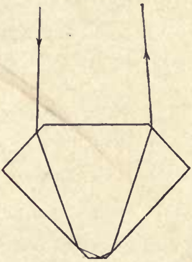

FIG. 3. — Refraction and Internal Reflection.

such an angle as will give the greatest amount of light back again on the exposed aspect of the gem, so that its brilliance will be as great as possible. Another effect of this repeated reflection is to cause the ray to pass over a much longer path in the stone, and thus the dispersion produced is greater, and therefore the prismatic colour effect is more marked.

For the accurate measurement of refraction an instrument called a refractometer is used. Its action depends on the fact that the refractive index can be calculated when the angle of total reflection is known; in the improved form devised by G. F. H. Smith (and described by him in the "Mineralogical Magazine," vol. xiv. p. 83), the instrument consists of a hemisphere of optically dense glass, so mounted that its plane surface makes an angle of 26 degrees with the axis of the instrument; on the opposite aspect of the mount carrying the hemisphere is a piece of ground glass; arrangement is made for the adjustment of this portion of the instrument in relation to the axis of the tube; a correcting convex lens is placed close to the hemisphere and in the tube; at the other end of the tube is a positive eye-piece capable of sliding adjustment, and provided with a totally reflecting glass prism to allow of the instrument being held in a convenient position. A scale is provided by means of which the index can be read to two places of decimals at least. In using the instrument the gem to be observed is placed on the plane surface of the hemisphere and moistened with a drop of a liquid of higher refractive index than itself; on looking through the eyepiece a shadow is seen crossing the scale in the form of a circular arc. By using a hemicylindrical glass and a cylindrical lens the line of separation between light and dark appears as a straight line. The range is from 1·40 to 1·76 in value of *n*.

2. Double refraction. All crystals except those belonging to the cubic system show double refraction; that is to say, a ray of monochromatic light passing through such a crystal is not only deviated from its direction without the crystal, but is turned in two directions, part of it going in one path and part in another; the angle between these two paths is very small, never more than a few degrees at most, and in some cases is so small that the two rays would seem to be one except when determined by special apparatus.

This double refraction can be readily shown if we take a piece of Calcite of the clear variety known as Iceland Spar or Doubly Refracting Spar, of the form it naturally assumes when broken, and view through it a mark, such as a cross, on a piece of paper. Two crosses appear, both somewhat removed from the position we see the original mark in, when nothing is interposed, but one more displaced than the other. On rotating the Iceland Spar, one cross appears to move round the other. Similarly, if we view an object through a cut specimen of one of the doubly refracting gems such as Peridot, we shall see two images of the object through each of the facets on the part of the gem away from the eye. On rotating a piece of Iceland Spar as above, we should also notice that in certain positions the two images were further apart than in others; now if the mineral were cut in a particular direction and the surfaces polished, on looking at the cross through it we should only see one image; in other words, it is singly refracting in that direction. Such directions are known as optic axes;

all minerals crystallising in the hexagonal and tetragonal systems have one such axis, and it coincides with the principal axis of the crystal. Minerals of the remaining crystallographic systems (that is, the orthorhombic, the monosymmetric or monoclinic, and the triclinic) have two such axes; all crystals with double refraction are anisotropic.

The property of double refraction can be made use of in the identification of certain gem stones. If on looking through a cut gem we see two images of an object through one pair of facets, we know that the gem is a doubly-refracting one; but if we cannot be sure of seeing two, we cannot say at once that it is singly refracting, as there are some possible fallacies; firstly, we may be looking along the optical axis of a uniaxial crystal, or along one of the axes of a biaxial crystal, in either of which cases only one image would appear; secondly, the separation of the two images may be too slight to be observed by the unaided eye.

c. Now, if a ray of white light be reflected from the surface of glass at a certain angle, a particular set of the light undulations are suppressed and the remaining undulations can no longer be reflected in all directions; if these residual vibrations be received on another plate of glass inclined to the rays at the same angle, but with the plane of incidence at right angles to the plane of incidence on the first piece of glass, no light is reflected from the second glass. If now between the two pieces of glass a crystal belonging to the cubic system, or an amorphous transparent body, be placed, there is still no light reflected to the eye. Should, however, an anisotropic body be interposed, light will be transmitted to the eye again, unless perchance the optic axis coincides with the direction of the ray of light between the two sheets of glass. Such an instrument is a simple form of the polariscope. More frequently two prisms of Iceland Spar cut and mounted in a particular way are used to polarise and analyse the light; such prisms are called "Nicol's prisms"; the prisms are mounted so as to be capable of complete rotation with regard to one another, and there are two positions in the complete revolution of maximum extinction of light; when the prisms are in one of these two positions, they are said to be "crossed." Now a singly-refracting body placed between crossed Nicol's prisms allows no light to pass whatever the position of the body, but in the examination of a gem we must use two or even three positions to make sure we are not dealing with a doubly refracting substance placed with the optic axis in the axis of the instrument. In examining a gem it must be first placed resting in the carrier on its small back facet, so as to give the light every opportunity of being transmitted through the stone. If there is a possibility that total internal reflection is preventing the light reaching the eye, we may overcome the possible fallacy by immersing the gem in a liquid of similar refractive index; for this purpose methylene iodide or mono-bromo-naphthalene may be used. When a doubly-refracting stone is placed in the right position, we shall find on rotating it that there are four positions in the 360° in which there is maximum lightness, due to the light being so altered in its passage through the gem that it can pass through the analyser.

One other possible fallacy remains to be mentioned. Some singly-refracting substances show what is known as anomalous double refraction; this is due to strains set up in the substance. They can be distinguished under the polariscope by the feeble change from light to dark as they are rotated and by the light not being uniform over the whole field of view.

Another important phenomenon arising from double refraction remains to be considered. In an anisotropic substance the vibrations composing the one ray are at right angles to those composing the other ray. Now, a different absorption of light occurs in these two planes, and as a consequence images of different colours are seen; this is known as pleochroism. For the observation of these colours an instrument known as a dichroscope is used ; it consists of a cleaved piece of Iceland Spar mounted in a tube having a lens at one end and a square aperture at the other. The lens can be adjusted to give focussed images of the aperture, and at the end where the aperture is a carrier to hold the gem is fitted so that it can be rotated around the axis of the tube. A singly-refracting gem placed over the square aperture gives two images of exactly the same colour; but a coloured doubly-refracting stone gives two images of distinctly different colours. Care must be taken to move the gem so as to ensure viewing in other than an optic axis.

C. Phosphorescence is seen in some minerals after exposure to light. For example, a Diamond that has been exposed to sunlight and then taken into a dark room gives off a soft light. The phenomenon is not only produced by the action of light, for some minerals show it on being rubbed (*e.g.*, Diamond and Agate), while others show it on being heated (*e.g.*, Topaz). Fluor Spar, Aragonite, and Kunzite also phosphoresce strongly.

Some other phenomena in relation to light remain to be noticed. Some minerals, especially Labradorite, when viewed in certain directions are seen to give a brilliant colour effect. This is in no way due to any material pigment, but wholly to the minute structure of the stone causing an optical colour effect, as is caused in the feathers of many birds by their structure. This effect is known as change of colour. Iridescence is caused in a somewhat similar way by interference of light in minute air-filled cracks in the mineral. It is often seen from natural flaws in Quartz crystals, and is sometimes intentionally produced by suddenly cooling a heated piece of this mineral. The colour of Opal is sometimes ascribed to this cause, and sometimes referred to the bending and dispersion of the light rays. Minute crystalline structure may also produce the quiet soft change of light seen in the Adularia or Moonstone so well. The same effect occurs even more markedly in some specimens of Chrysoberyl, causing a streak of light to appear on turning the stone, which is then, from its appearance, called Cat's Eye. Other minerals showing this change are known under the same name; for example, some specimens of Quartz, though in this case it is due rather to a fibrous structure than to a minute plate-like arrangement. The appearance in this case is called chatoyancy.

Asterism, so often seen in crystals of Sapphire cut at right angles to the vertical axis of the crystal, is due either to minute canals crossing in one plane at angles of 120°, or to an optical effect from twin-plates in the crystal. Fluorescence is a change of colour in a mineral, as seen when viewed first by reflected and then by transmitted light.

Fluor Spar (from which name the term is derived) shows it well, as does also Amber.

Absorption bands in the spectrum are only seen in two minerals; in both cases their discovery was due to Professor Church. Zircon shows some black bands when examined in the spectrum of white light, due to the presence of traces of uranium. Almandine also shows some black bands, in this case in the green portion of the spectrum.

The effect of Röntgen rays on gems is now of much importance, especially in the case of the Diamond, for this is very transparent to these rays, while many of its would-be imitators, as glass, Quartz, white Topaz, etc., are opaque, and these cast shadows. So also the red and blue shades of Corundum (Ruby and Sapphire) are partly transparent, while their imitators, Balas Ruby (Spinel of rose red colour) and blue Tourmaline, are opaque. Exposure to Röntgen rays or to the emanations of radium may cause some minerals to phosphoresce (*e.g.* Kunzite); and Crookes has shown that some minerals phosphoresce strongly when exposed in a high tension electric current in a very rarefied atmosphere. Thus Ruby shows a strong red light, Sapphire a blue, and Diamond a bright green light.

Subjoined is a table of the refractive index of the principal gems:—

Diamond	2·44	Orthoclase	1·53—1·52
Fluor Spar	1·44	Diopside	1·70—1·67
Quartz	1·55—1·54	Beryl	1·58—1·57
Opal	1·48	Cordierite	1·55—1·56
Corundum	1·77—1·76	Pyrope	1·79
Spinel	1·72	Almandine	1·77
Chrysoberyl	1·76—1·75	Hessonite	1·74
Calcite	1·66—1·49	Olivine	1·70—1·66

Phenakite	1·67—1·65	Epidote	1·76—1·73
Dioptase	1·72—1·67	Axinite	1·68—1·67
Idocrase	1·72—1·71	Tourmaline	1·64—1·62
Zircon	1·97—1·92	Sphene	1·90 (mean)
Topaz	1·63—1·62	Apatite	1·66 (maximum)
Andalusite	1·64—1·63	Gypsum	1·53 (mean)
Cyanite	1·72 (mean)	Amber	1·5
Euclase	1·67—1·65		

II. Physical Properties Dependent on Heat.

The forms of radiant energy, heat and light, are so closely related that we might expect their manifestations in relation to the precious stones to be much alike. This is so, for heat rays may be reflected, refracted, or absorbed, as may light rays. Effects akin to polarisation may be observed too, but none of these effects are of the same importance in the general consideration of gem stones as are the results of the action of light. A few facts may, however, be briefly stated as of general interest.

Heat easily passes through Fluor Spar, hence it is said to be diathermanous, while Tourmaline, Gypsum and Amber are almost opaque to heat rays.

The conductivity of heat is found to vary in different minerals and in different directions in relation to the crystal axes; the coefficient of expansion is different in these several directions in many cases, and this brings about changes in the optical characters under these conditions. On the whole the precious stones are good conductors of heat as mineral substances go, and hence it is stated in Mr. H. Spencer's translation of Max Bauer's "Precious Stones," that this may sometimes be used as a means of distinguishing between a true and a false gem;

when a precious stone is breathed on its good conductivity causes the breath to condense on its surface quickly and to quickly evaporate again, whereas on a glass imitation both actions occur more slowly.

Fusibility. Most gem stones fuse with difficulty, if at all, before the blowpipe; red Garnet, however, is moderately fusible, and where thin splinters of the rough stones can be obtained this property may be made use of in identification.

III. Electrical and Magnetic Properties.

A surface charge of high potential electricity can be imparted to some precious stones in a much greater degree than others. When produced by rubbing with a dry cloth the charge is positive in cut gems, except in the case of Amber, which becomes negatively electrified. The presence of such a charge can be demonstrated by the electroscope or other similar instrument. Most minerals soon lose their charge, even in dry air, but Topaz, Sapphire and Diamond retain their charge for longer periods, chiefly in the case of Topaz and least with the Diamond. Electricity developed in uncut gems other than the Diamond is negative; Calcite, Topaz, Fluor Spar and Quartz show electric phenomena on pressure, especially Calcite.

When some precious stones are heated, electricity is developed on them; this is known as pyroelectricity. Axinite, Tourmaline and Topaz show it well; a crystal of Tourmaline on heating to about 150° C. becomes positively electrified at one termination and negatively at the other; if now it be suspended by a non-conducting thread it will act as a magnet; on cooling, the charges on the poles reverse, positive becoming negative. If a crystal with such a charge be dusted with a fine mixture of sulphur and red lead, the yellow sulphur will be attracted to the portions charged with positive electricity, while the red lead goes to the negatively charged portions.

The pyroelectric behaviour of Tourmaline and Topaz may be made use of to distinguish these minerals from others of similar colour.

Though some minerals show magnetic properties, only one is of any importance in the present case: this is Iserine, one of the titaniferous iron ores, which has been used as an ornamental stone.

IV. Specific Gravity.

The specific gravity of a substance is the ratio of the weight of a given volume of that substance to the weight of an equal volume of a standard substance. Water is always taken as the standard in dealing with minerals. Specific gravity is of the greatest importance in dealing with precious stones, as it affords a means of identifying many of them when cut and polished, without in any way damaging the stone.

There are many methods of determining the specific gravity of a substance; three will be briefly described here applicable to the cases (*a*) where there are many small fragments of the mineral available; (*b*) where it is desired to deal with a small cut stone, and (*c*) where a relatively large specimen can be used. Of course the use of the various methods is not thus restricted; they are merely cited as examples.

(a) *Method by Specific Gravity Bottle.*

When a solid is entirely immersed in water it is obvious that it displaces a volume of water equal to its own volume. Thus if $W =$ weight of the substance in air

and $w =$ weight of the water displaced,

then $Sp.\ gr. = \frac{W}{w}$.

A small flask of very thin glass, provided with an accurately-fitting glass stopper (through which a small hole is drilled), is filled with water; the stopper is then inserted so as to force a little water out through the narrow aperture in the stopper; the bottle is carefully dried outside. The substance to be examined, preferably in small fragments, is accurately weighed and the weight noted; let the weight be W. Now weigh the bottle, full of water, and the substance together in the balance, and let the combined weight be x. Now remove the stopper and carefully place the mineral in the bottle, taking care that the fragments do not carry air-bubbles with them; replace the stopper and again dry and weigh the bottle; let this weight be y. Now $x - y$ is equal to the weight of the water displaced, or, in other words, to the weight of a volume of water equal to the volume of the mineral. Hence $\frac{W}{x - y}$ is equal to the specific gravity of the substance. In all accurate determinations a temperature of 4° C. should be maintained to ensure the water remaining at the maximum density.

(b) *Method by Dense Solutions.*

A small number of liquids may be obtained which have a density equal to or greater than most of the precious stones. Sonstedt's solution is a saturated watery solution of the double iodide of mercury and potassium of sp. gr. 2·77; it mixes with water without any marked change in the volume, and hence may have its specific gravity lowered in proportion to the quantity of water added. The borotungstate of cadmium has also been used. More recently, however, methylene iodide has been used; this is a carbon compound of the formula CH_2I_2, and has a density of nearly 3·33 at 15° C.; owing to its high coefficient of expansion it is important to use it at a definite known temperature; it has the advantages of mixing freely with benzine (sp. gr. ·88); of being light-coloured, so that the mineral under test can be easily seen; and mobile, so that the test specimen can move freely. By means of benzine or methylene iodide or a mixture of the two, any density between ·88 and 3·33 can be obtained. Further, by saturating methylene iodide with iodine and iodoform its density can be raised as high as 3·6. The principal gem stones with a higher specific gravity than 3·6 are Corundum, Spinel, Chrysoberyl, the Garnets, Zircon and Cyanite. The most convenient way of using these solutions is to have them in four wide-mouthed stoppered bottles of glass. No. 1 contains the saturated solution of iodine and iodoform in methylene iodide, and has a sp. gr. of 3·6; No. 2 contains pure methylene iodide, sp. gr. 3·3; No. 3 a dilution of methylene iodide with benzine to sp. gr. 3·0; and No. 4 a similar, but further, dilution to sp. gr. 2·65. The specific gravity of these solutions must be tested from time to time by some such convenient means as the use of specific gravity beads, which are hollow glass beads so weighted that they neither float nor sink in a liquid of a certain density, the numerical equivalent of which is marked on the bead. Thus, when a mineral is placed in, say, No. 1 bottle, and is found to sink, we know it is of a density greater than 3·6. A mineral of a sp. gr. of 2·8 would float in solution No. 3, but would sink in solution No. 4. Thus we may divide all the specimens tested into five groups, and thus greatly aid their identification. If it is desired to accurately determine the specific gravity of a specimen we may select a solution in which it floats, and then dilute with benzine till it neither floats nor sinks. It is then of the same density as the solution, and this is determined by the specific gravity bottle described in method (a), then weighing the same bottle full of water at 4° C., again emptying and drying the bottle, and finally weighing it full of the solution in question. Then (weight of bottle with solution less weight of bottle) divided by (weight of bottle with water less weight of bottle), is equal to the specific gravity of the solution, and therefore of the gem to be determined. In removing a gem from one bottle of solution to another care must be taken to dry it, or else the solutions will become mixed and altered in density. The bottles containing the four solutions must be kept in the dark also, to prevent decomposition with separation of iodine, which would not only cause a dark colour to appear, but would also alter the density. Such solutions may also be used to separate particles of various minerals for analysis.

Still more recently thallium-silver nitrate, $Ag\ Tl\ (NO_3)_2$, a solid salt, has been used; with the addition of a little water it remains fluid at as low a temperature as 50° C. The pure salt melts at 75° C., and forms a transparent liquid of specific gravity of 4·8; a very small quantity of water considerably lowers the density of the resulting liquid; in using this method care must be taken to allow for temperature—in other words, the density of the solution must be determined at the same temperature as the solution was at when the stone was being tested in it.

(c) *Method with the Hydrostatic Balance.*

In this method any delicate balance may be used, but there are many special forms made for the purpose which are very convenient in use. The method is more adapted to the examination of larger specimens. If the scale pans come close down to the platform of the balance one pan must be removed and a long fine hair or strand of silk attached in its place; the remaining pan is now exactly counterpoised by attaching a suitable weight at the end of the beam where the detached pan was. A small beaker partly full of water is arranged so that a gem attached to the end of the hair will be under the surface of the water when the instrument is in a balanced position; this beaker can then be removed from its support and the gem attached to the end of the silk or hair by slinging it in a small neat loop. The exact weight of the gem in air is then ascertained; the beaker is now replaced, allowing the stone to be completely immersed in water but having as little of the hair as possible in water. The weight in water is now determined. The difference between the weight in air and the weight in water is the weight of a volume of water equal to the volume of the stone, therefore the weight of the stone in air divided by this difference is the specific gravity of the stone.

A very full and exact account of these and other methods of determining specific gravity will be found in Max Bauer's work above mentioned. In the following list of the specific gravities of precious stones the minerals are arranged on the basis of composition that will be followed in the systematic description.

Diamond	3·50—3·52	Garnet: Topazolite	3·65—3·85
Fluor Spar	3·02—3·20	Demantoid	3·83
Quartz	2·5—2·8	Uvarovite	3·42
Opal	2·19—2·20	Olivine	3·33—3·44
Corundum	3·93—4·08	Phenakite	2·95
Spinel	3·60—3·63	Dioptase	3·27—3·35
Chrysoberyl	3·68—3·75	Idocrase	3·35—3·45
Calcite	2·69—2·75	Zircon	4·6—4·7
Malachite	3·71—4·01	Topaz	3·4—3·6
Orthoclose	2·53—2·59	Andalusite	3·10—3·19
Microcline	2·44	Cyanite	3·58—3·68
Albite	2·54—2·64	Euclase	3·05
Oligoclase	2·63—2·74	Epidote	3·35—3·5
Labradorite	2·67—2·76	Axinite	3·29—3·30
Pyroxene	3·2—3·4	Prehnite	2·92—3·01
Spodumene	3·15—3·20	Tourmaline	3·02—3·10
Jadeite	3·3	Staurolite	3·73—3·74
Amphibole	3·0	Serpentine	2·47—2·60
Crocidolite	3·2—3·3	Sphene	3·35—3·45
Beryl	2·67—2·75	Apatite	3·16—3·22
Cordierite	2·60—2·72	Turquois	2·62—3·0
Lapis Lazuli	2·38—2·45	Gypsum	2·28—2·33
Garnet: Grossular	3·44—3·62	Amber	1·08
Pyrope	3·70—3·78	Jet	1·02
Almandine	3·95—4·29		

V. Properties Dependent on the State of Aggregation.

Of the many properties of minerals in general, falling under this head, only two specially concern us in the study of precious stones—fracture and brittleness. Fracture can be seen in most rough precious stones; it must be distinguished from cleavage (*q.v.*); fractured surfaces, though they approach geometrical planes in some cases, are never true planes. When the fracture is flat or nearly flat it is said to be "even"; this is seen in some Jaspers. Should it be rougher and covered with minute points it is "uneven," as in Lapis Lazuli; when still more rough it is "hackly." When the broken surface shows the smooth curves so well seen in a broken piece of thick glass, the fracture is "conchoidal" (*i.e.* shell-like), this is well seen in Quartz and many of the gem stones. Where a gem stone has been damaged, as by a blow, but without separation of the fragments, a crack may often be seen reflecting beautiful prismatic colours (*c.f.* refraction). This is occasionally made use of in stones that have no intrinsic beauty of colour as in Quartz; but in a highly refracting gem any flaw of the sort, especially if situated at the back part of the cut stone, greatly detracts from the brilliance, so that when a flaw develops before the stone is cut, the size of the finished stone and the direction of the cuts are arranged to eradicate such blemishes. This was exemplified in the case of the Koh-i-noor, which as exhibited at the Crystal Palace weighed 186$\frac{1}{16}$ carats, but which was afterwards re-cut by Messrs. Garrard, when it weighed 102$\frac{1}{4}$ carats.

Brittleness depends very largely on the grosser structure of the stone; where this is minutely fibrous, as in Crocidolite or Malachite, there may be considerable tenacity, though the hardness of these two minerals is very different; at the same time the brittleness depends partly on the hardness, and also on the presence or absence of a cleavage.

VI. Hardness.

All the true gems are essentially hard. A mineral does not fulfil the commonly accepted idea of a gem unless it is hard; but the degree of hardness varies considerably. An arbitrary scale devised by Mohs is used to express the relative hardness of different minerals. Ten different minerals of dissimilar hardness are chosen; these are (No. 1 being the softest)—

1. Talc.
2. Gypsum.
3. Calcite.
4. Fluor Spar.
5. Apatite.
6. Orthoclase Felspar.
7. Quartz.
8. Topaz.
9. Sapphire.
10. Diamond.

If we were dealing with an uncut gem on which a scratch would not be of great importance we might first apply a sharp corner of it to the test stones, beginning with the softest until we come to one it will not scratch; if on reversing the positions the test stone does not scratch the stone under examination, we know that the two are of equal hardness; should it scratch the examined stone we know the latter has a hardness between the test stone that will scratch it and the test stone next in the series below. By approximation we may fix the hardness at, say, 7·25 or 7·5 when the examined stone just scratches Quartz and is easily scratched by Topaz. In the case of cut gems we usually have to be content with finding what is the highest member of the series of test stones it will scratch; in some cases we may be able to try to scratch the cut gem on the girdle or part by which its mount clasps it. Many minerals show a different degree of hardness on different crystal faces or in different directions; thus Cyanite shows a variation of hardness in different directions between 5 and 7 on Mohs' scale. We must be careful to distinguish between a scratch on a test stone and a streak of broken-down fragments of the tested specimen; if it be a true scratch the mark will of course remain on brushing with a soft camel-hair brush. It is necessary to examine the mark with a lens in cases of doubt. In testing, no more force should be used than is just sufficient to produce the scratch, and no more scratch should be made than is necessary. Where the test stones are of a cleavable mineral, clean cleavage planes (*c.f.* Cleavage) will be found the most suitable for trying the hardness on. A steel point is as good an instrument as one can have for a single test; good carbon steel tempered to a pale straw colour will just scratch quartz under favourable conditions; more often the steel can be scratched by quartz. Thus a steel point may be taken as of No. 7 hardness; what is called "gem-hardness," that of the true gem stones, is greater than 7. It should be noted that the newer "high speed" steel is a great deal harder than ordinary carbon steel. As glass is easily scratched by steel, such a steel point will readily serve to distinguish glass imitations of precious stones in most cases.

A tabular statement of the hardness of precious stones is given below. It should be noted that under certain species are included in some cases several varieties, and this accounts for much of the variation. For example, Quartz in its crystalline forms of Rock Crystal, Amethyst, etc., has the standard hardness of 7·0, but the cryptocrystalline varieties Agate and Chalcedony have a hardness of only 6·5 in some cases.

Diamond	10·0	Garnet: Topazolite	7·0
Fluor Spar	4·0	Demantoid	7·0
Quartz	6·5—7·0	Uvarovite	7·5—8·0
Opal	5·5—6·5	Olivine	6·5—7·0
Corundum	9·0	Phenakite	7·5—8·0
Spinel	7·5—8·0	Dioptase	5·0
Chrysoberyl	8·5	Idocrase	6·5
Calcite	3·0	Zircon	7·5
Malachite	3·5—4·0	Topaz	8·0
Orthoclase	6·0	Andalusite	7·5
Microcline	6·0	Cyanite	5—6
Albite	6·0--6·5	Euclase	7·5
Oligoclase	6·0	Epidote	6—7
Labradorite	6·0	Axinite	6·5—7·0
Pyroxene	5—6	Prehnite	6—7
Spodumene	6·5—7·0	Tourmaline	7·0—7·5
Jadeite	6·5—7·0	Staurolite	7·0—7·5
Amphibole	5·5—6·0	Serpentine	3·0
Crocidolite	4·0—4·5	Sphene	5·0—5·5
Beryl	7·5—8·0	Apatite	5·0
Cordierite	7·0—7·5	Turquois	6·0
Lapis Lazuli	5·0—5 5	Gypsum	2·0
Garnet: Grossular	6·5—7·0	Amber	2·0—2·5
Pyrope	6·5—7·5	Jet	2·0—2·5
Almandine	7·0—7·5		

VII. CLEAVAGE.

Minerals which occur in crystalline masses or in actual crystals (*vide infra*) have a very definite internal arrangement of the molecules composing them, causing the mineral to have different properties in different directions, whereas an amorphous substance is similar in all directions. One of the phenomena noticed in crystalline bodies is that the coherence in certain planes is weaker than in other planes. There may be one or several such planes of weaker cohesion, and this leads to the substance dividing along such planes with more or less facility; such a plane is known as a cleavage plane, and as it always bears a definite relation to the crystalline form of the mineral, it is of great use in identification when the crystal faces are destroyed, or when the form of the crystal is very complex. From the point of view of the gem cutter, these "cleavages" are of great assistance when bringing the rough gem into approximately the shape the finished stone is to assume. This is particularly so in the case of the Diamond, for it has four such cleavage planes which tend to divide the mineral into the form of the regular octahedron, from which form the commonest type of cut Diamond, the "brilliant," is readily derived. Adularia, a variety of Orthoclase Felspar, and Topaz are two other precious stones which show cleavage well. Calcite has a very perfect cleavage in three directions, tending to divide it into rhombs, a fact of great help in making some of the instruments used in the optical examination of precious stones, such as the polariscope and dichroscope.

A cleavage plane may be distinguished from an even fracture, for the former being a true plane, another such plane exactly parallel to it can be easily produced.

It must be borne in mind that a gem which possesses a distinct cleavage is more liable, other things being equal, to be broken or damaged by sudden changes of temperature.

VIII. Crystalline Form.

The greater number of bodies of definite chemical composition, including minerals and therefore gems, occur in "crystals" or are "crystalline." This leads us to the conclusion that the minute groups of chemical atoms are arranged in some definite way. Each substance that crystallises has its own definite geometrical form; this might not appear to be so at first sight, for if we took a group of crystals of Fluor Spar, for instance, gathered together from many different localities, the specimens would seem at first anything but similar, yet if we come to measure the angles between the different planes or "faces," we should find that a good many possessed planes exactly at right angles to one another; if the six possible faces of this kind were all equally developed, we should see the specimen was in the form of a perfect cube—all the six faces together belonging to the "form" of the cube; but they might not be equally developed and the resulting figure might be a parallelepiped, or rectangular solid figure (with opposite sides equal necessarily) having adjacent faces of different sizes. Still such faces would be parallel to the faces of a perfect cube and, therefore, would be, crystallographically, identical. Again, amongst the Fluor Spar crystals we might find many that showed the solid angles of the cube truncated by a plane having the form of an equilateral triangle. Since parallel planes are identical in a crystal, we might imagine these triangular faces moved inwards towards the centre of the crystal until they were, all eight of them (one at each corner of the cube), equally distant from that centre; there would then obviously be no face of the cube left, but a symmetrical eight-faced solid figure; such a form would be a regular octahedron. If we could bore through such an octahedron from one of its corners to the diametrically opposite corner in the case of each of the three pairs of such corners, all the bore holes would pass through one point at the centre. On measuring the length of the holes they would be found all equal, and each one would be at right angles to the other two holes. Imaginary lines might be drawn down the centre of each hole; we should then have three lines of equal length, passing through a common point, and inclined to one another at 90°. Such imaginary lines would represent the "axes" of the crystal of Fluor Spar. It would be noticed that each of the faces of the octahedron met the three lines at points equally distant from the centre of the crystal; the lengths thus cut off would be the "intercepts" on the axes. If other faces of the crystal were examined and the angles they made with one another measured, and from these angles the points where these faces would cut the axes were calculated, it would be found that the intercepts could be expressed in whole numbers; for instance, a face might cut one axis at a unit distance from the centre, and each of the other two at twice this distance: the relation is always a simple one.

An examination of all the known crystallised bodies reveals the fact that their crystals can be placed in one of six classes, known as the six "crystallographic systems." They are known as the cubic, hexagonal, tetragonal, rhombic, monosymmetric or monoclinic, and the triclinic. We may think of them all with regard to the relation of their axes.

The system to which the above example belongs is the cubic; in it there are three axes, all at right angles, and all of equal length.

The hexagonal system has three equal axes inclined to one another at 120°, intersecting in a point through which passes a fourth axis of length different from the others.

The tetragonal system has two axes of equal length at right angles to one another and a third unequal axis at right angles to the other two.

The rhombic system has three unequal axes all at right angles.

The monosymmetric system has three axes of unequal length, two of them at right angles and the third inclined to the plane containing the other two at an angle other than 90°.

The triclinic system has three unequal axes, all inclined to one another at angles other than right angles.

The easiest way perhaps to get a clear conception of the simplest forms of each system is to use several pieces of fine steel wire; old knitting needles answer very well. These may be cut to the lengths corresponding to the system to be represented; for instance, for the rhombic system we might have one piece 3 inches long, one piece 2½ inches and another 1½ inches in length. These can now be run through an indiarubber ball of about 1 inch diameter, taking care to keep them as near the centre of the ball as possible and at right angles to one another. If the ball be now covered over with moist pipeclay moulded into an eight-faced solid figure whose corners coincide with the tips of the wires, a rhombic pyramid will be produced. If a set of the pyramids belonging to the six systems of crystals be made in this way, a general conception of their form is obtained.

It must be borne in mind that the external form of a crystal is by no means its most important phenomenon, for with this external form is associated a definite internal structure on which depend so many of the properties already mentioned.

In relation to precious stones, crystallography is chiefly of importance in the case of uncut gems, or in the cutting of a stone; but a knowledge of the properties dependent on the internal structure aids very greatly in the identification of a cut specimen (*cf.* Physical Properties Dependent on Light).

When a mineral only shows the internal structure without any definite external crystal forms it is said to be "crystalline." When the external form is developed the internal arrangement of the molecules is always present, and the mineral is then said to be "crystallised."

Crystals deposited from an ordinary aqueous solution are usually found to have started their growth from some preexisting solid body; the point from which this growth commences is known as the point of attachment. Many of the beautiful groups of Rock Crystal from the Alps show this very clearly. Such crystals are necessarily imperfect in outline at this point.

When crystals are deposited during the cooling of rocks undergoing hydro-thermal metamorphism, two modes of occurrence are to be noticed. If the mineral in question is one which for some reason or another crystallises out before the majority of its associated minerals, its crystals are very likely to be perfectly developed all round—they have the characteristic external shape of the crystals of that mineral; they are then said to be "idiomorphic." Crystals which during their deposition are, so to speak, crowded against other crystals, may mutually compress one another so that in a large part their external form is not the characteristic one; in such a case they are "allotriomorphic."

CHAPTER IV.

THE CUTTING OF GEMS.

It is somewhat doubtful at what period the true cutting of gems was first practised. There is no doubt that from very early times precious stones were polished, often into curved forms, often simply on the natural crystal faces, to remove the cloudy films present. If we regard cutting as the production on the gem of surfaces, usually plane, with the removal of a considerable amount of the material, we may regard the art as dating before 1475, by which time Louis de Berquem performed the operation. Charles the Bold sent him three Diamonds to cut. The first one to be actually cut was a large pyramidal stone, about ⅝ inch on the edge. It was cut into a regular pyramid, whose apex was modified by a four-rayed star, each ray being of two triangular facets. It was set with three large Balas Rubies and four pearls, as a pendant. It was taken as plunder from the tent of Charles at Granson (1475) by a common soldier, who threw it away once, but afterwards recovered it, and sold it to a priest, who afterwards sold it for ten times what he gave for it to the authorities of his district; thence it passed to the Bernese Government, who sold it, with other jewels, to Jacob Fugger for 47,000 florins. Fugger's great-nephew made an accurate full-size drawing of the pendant, which is reproduced in the Bib.

Imperialis of Lambeccius. The jewel was afterwards sold to Henry VIII., and passed to Mary, who made a present of it to Philip. It is possible it is still amongst the Spanish jewels in a re-cut state. Fugger's drawing is reproduced in King's "Precious Stones," with many interesting facts about the jewel.

Numerous jewels of the sixteenth century show the original style of cutting introduced by de Berquem. Kentwaur, in 1562, mentions two types of cutting, the "point" and the "table." The former was simply the natural octahedron, with the faces reduced to a perfectly regular form, and polished; but the latter had one apex ground down till the flat surface produced was equal in width to the two adjacent sloping facets added together, and the opposite apex was likewise ground down to a plane, but of smaller extent, and all the surfaces polished (Fig. 4). In the case of a thin stone, the portion below the setting consisted of a large plane, while the upper portion was cut as the above table.

The "rose" (p. 55) was produced in the middle of the seventeenth century, and by 1665 the famous Mogul was cut into a high-crowned rose of 280 carats by the Venetian jeweller Borghis. The "brilliant" cut was discovered by another Venetian, Peruzzi, towards the end of the seventeenth century, from experiments on coloured stones. This was similar in general form to the older table-cut stone, but was worked in a more elaborate fashion, having thirty-two facets above and twenty-four below the "girdle," besides the "table" and "collet," or fifty-eight facets in all.

Louis de Berquem's essential discovery was the fact that one Diamond will abrade another when the two are

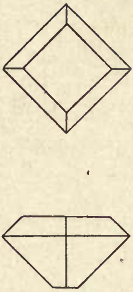

Fig. 4.—The Table.

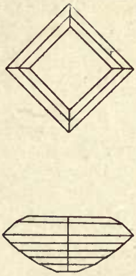

Fig. 5.—Step-cut.

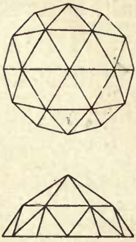

Fig. 6.—The Rose.

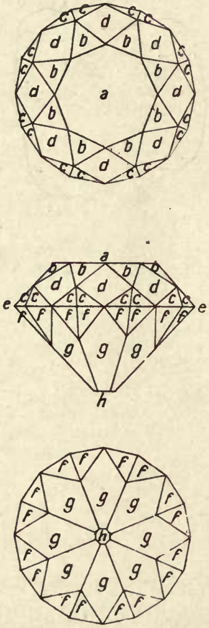

Fig. 7.—Brilliant-cut.

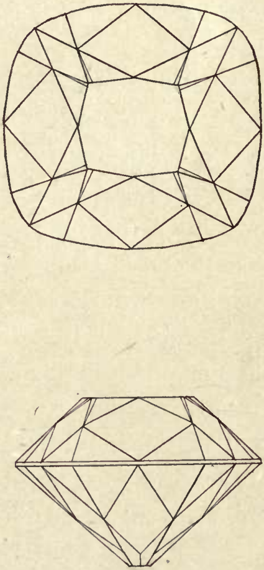

Fig. 8.—The Pitt or Regent Diamond.

rubbed together. To Peruzzi would seem to belong the honour of discovering the principle of modifying the back of the stone so as to bring out the full brilliance of the specimen. As pointed out when dealing with light, this brilliance depends jointly on refraction and repeated internal reflection.

By far the most important type of cutting is that called the brilliant. In this form the greatest circumference of the stone is called the "girdle"; the portion lying above the girdle is the "crown," and that below is the "culasse." The crown terminates in a large plane called the table (*a*, Fig. 7). Meeting the table in an edge are eight triangular facets called the "star facets" (*b*, Fig. 7); meeting the girdle in an edge are sixteen upper "skill facets" (*c*, Fig. 7); and between the star facets and the upper skill facets are eight lozenge-shaped facets known as "bezils" (*d*, Fig. 7). Below the girdle, that is on the culasse, are sixteen triangular facets meeting the girdle in an edge. These are the lower "skill facets" (*f*, Fig. 7); and running from them to the lowest portion of the stone are eight facets, with five sides each, called the "pavilions" (*g*, Fig. 7). The lowest portion of the stone is a small plane called the "collet" (*h*, Fig. 7). Sometimes the upper and lower skill facets are collectively referred to as "cross facets." There are thus thirty-three planes in the crown, and twenty-five in the culasse. The table and collet are both parallel to the plane of the girdle.

There is a general proportion in the finished stone which has become by the experience of generations of cutters to be regarded as a standard, because a stone so proportioned is found to give the greatest brilliancy. Thus if the diameter of the collet be taken as unity, the girdle should be nine units in diameter, and the table five; also the vertical distance from table to girdle should be one-half the vertical distance of the collet from the girdle. These proportions give the outline shown in Fig. 7, and as will be seen from Fig. 3, the angles thus formed are eminently adapted to repeatedly reflect the light within the stone. The exact finished form of the stone is by no means fixed, but is modified by the cutter to suit the rough gem he is dealing with, so as to sacrifice as little material as is consistent with giving a good result. In the case of colourless and transparent stones the proportions given above are adhered to more or less closely; but the plan of the stone may be considerably modified. Thus it may be generally circular, as in Fig. 7, or square or oblong, as in the Pitt or Regent Diamond (Fig. 8), or triangular, etc. Again, a coloured stone is usually cut in a rather more shallow form; the deeper the colour, usually, the thinner the stone. If the stone were of the proportion of a colourless gem the tint might be so deep as to lose a great deal of its beauty.

The presence of a flaw or other imperfection may considerably modify the form given to the finished stone; as a rule the English cutters prefer to have the gem perfect technically even at the sacrifice of a good deal of weight, and hence flaws are either removed altogether, or at least the stone is so cut that the flaw comes in the girdle, where it is not so conspicuous. The slightest imperfection in the region of the collet has a very great influence on the appearance of the gem, as it is reflected again and again, and thus seemingly magnified. The triple-cut brilliant form is only given to larger stones of good quality, smaller stones being cut in some of the many modifications of the brilliant pattern, such as the double brilliant, or even more simple forms. An English-cut stone can often be distinguished by the greater accuracy given to the angles of the facets, so that the resulting gem is exactly symmetrical.

Among the many other forms into which gems are cut, a few may be mentioned: for transparent stones, besides the brilliant-cut there is the "step-cut"; in this the facets are elongated, the longer edges being parallel so as to form a series of steps. The crown may have two or three steps and the culasse five or six or more; table and collet are formed as in the brilliant. A step-cut stone may be square or six sided, etc., just as a brilliant; this form is shown in the square type in Fig. 5. Two older forms of cut have already been referred to: the "point," in which the octahedral crystal faces, or the octahedral cleavage planes were simply rendered symmetrical in outline and polished, and the "table-cut," in which a table and collet were formed (Fig. 4). Another type is the "rose." In this the gem is worked into a series of, usually, triangular facets, arranged in two series, an upper series forming the crown or star, and a lower series, that called the teeth; the under surface is a simple plane (Fig. 6). More rarely stones are cut into a general pear shape, worked all over with small triangular facets, "briolette;" or into a "rosette," which has the form of two rose-cut stones joined together by their large plane surfaces; occasionally a very thin stone is cut as a "half-brilliant," which is similar to the crown only of an ordinary brilliant, the lower part of the stone consisting of a large plane, as in the rose.

Garnets are frequently cut "*en cabochon.*" In this form the upper surface is a low dome, convex towards the eye; the under surface is flat, or, in the case of very intensely coloured stones, concave, so that the stone in section would show a parallel curved outline; or the concavity may be such as to leave the stone thicker at the centre and thinner at the edges. Rarely, the upper convex surface is worked in small facets around its margin. Turquois is often cut *en cabochon;* Chrysoprase may be cut so, too, but more often it is given a lower curve, "*Goutte de suif*" being the name then used.

Many of the coloured gems as Topaz, Sapphire, Ruby, Emerald, Garnet, Peridot, Amethyst, Cairngorm, etc., are frequently step-cut, though they may be formed into brilliants, and are, in many cases, so cut. The Chrysoberyl is usually cut as a brilliant; colourless Corundum is usually step-cut; most of the opaque gems are cut either *en cabochon* or as the "tallow-drops" above referred to; very often the margin in Chrysoprase is worked with one or two rows of small triangular facets. Cat's-eye is usually cut *en cabochon,* and the finished stone must be so arranged as to have a definite relation to the internal structure of the gem, to show its full beauty. Moonstone and Labradorite must also have a definite relation to the crystal structure to bring out the best effect.

In the actual cutting of precious stones in general, a careful study of the rough stone has first to be made to determine in what direction it can best be cut so as to leave as large a finished gem as possible, free from imperfections; this having been decided on, these imperfections are removed and the stone brought to approximately the desired shape by methods varying with the mineral in hand. In the case of the Diamond, unless the rough stone is of the octahedral form already, cleavage is first made use of as far as possible. In cleaving a Diamond the stone is cemented firmly to the end of a support in such a position that when the support is fixed on the bench so as to be vertical, the cleavage plane to be attacked will also be vertical. The support is then put in position, and means taken for ensuring the collection of any fragments. A steel blade is now placed in the cleavage plane at the desired point and a sharp tap delivered on the blade by a rod held in the right hand; by repeating this process a cleavage octahedron free from flaws is produced. The cement used is a solution of shellac in turpentine, thickened with very fine brick-dust. Often before applying the cleaving blade a fine groove is cut in the "trace" of the cleavage plane by means of another Diamond. The art of cleaving Diamond is said to have been known in the East from ancient times; it seems to have been discovered independently by Wollaston, although De Boot (1609), speaking of the Diamond, says he knew a physician who could, "without the aid of any instrument or material, other than those furnished by the human body, divide it into fine scales like a piece of talc." However, Dr. Wollaston turned his discovery to good advantage by buying up mis-shapen Diamonds that the jewellers had considered not worth the enormous labour of grinding into shape, and, by cleaving them, he reduced them to a form easily worked on.

After the cleaving has been effected by one workman, the stone is handed to another, who is known as a bruter. The operation he performs is the *brutage*, or bruting. This operation is the outcome of de Berquem's discovery that when one Diamond is rubbed on another each is abraded; it is made use of to still more nearly approximate the stone to its desired form. The stone is cemented to the end of a wooden holder about a foot long, and two stones are wrought simultaneously by grasping the two holders and rubbing the stones together in the desired direction over a wooden trough, into which the fragments and dust fall, and in which they are separated into larger and smaller particles by a fine sieve. In bruting, care must be taken not to overheat the stone by the friction, or a scaly appearance may be produced in the interior of the gem. When the bruting is completed the surfaces have somewhat the aspect of ground glass. The table and collet are the most important faces to be dealt with at this stage, and entail the greatest amount of work, as there is no cleavage that can assist in roughing out these planes; working in a plane normal to an axis of the octahedron five-ninths of the upper pyramid must be removed to produce the finished table, and at the other end of the same axis one-ninth of the lower pyramid for the collet.

In Amsterdam the Diamonds are sometimes slit by a disc of thin metal revolving at high speed, and dressed on its edge by diamond-dust and olive oil. This method allows of a slice being taken off in any direction desired, but the process is extremely slow, taking many days to accomplish; and it is stated that the resulting finished stone is inferior in quality to one that has been cleaved.

Sometimes the larger planes are roughed out by working the stone in a high-speed lathe.

When the bruting is completed, there yet remains much work to be done, for the smaller facets have to be wrought and the whole gem polished; this is done by the polisher. But first it must be mounted on a suitable holder by the solderer; small brass cups, known as "dops," of one or two inches in diameter, and having a short stalk attached, are heated in a Bunsen flame and filled with a solder composed of one part of tin to two parts of lead, similar to the solder plumbers use for wiped joints in lead pipes. This alloy melts at about 441° F. or 227° C., and has the property of being plastic at considerably below its melting point. When the solder has attained the plastic state by sufficient heating, and has been worked up into a cone projecting from the hollow of the cup, the stone is embedded in the metal at the apex of the cone in such a way that only the part of the gem to be immediately worked on is exposed; on cooling down the solder contracts considerably and grips the stone very firmly. Soldering, like other operations in gem cutting, requires great dexterity and experience, as the stone must be fixed at the correct angle, so that its position can be known by the position of the holder, and further, in the case of the Diamond (or other cleavable gems), the alternate contraction and expansion from heating and cooling may cause flaws if the operation is not done very skilfully.

In some cases a split clamp, tightened by a thumb-screw, is used to hold the stones, instead of their being soldered into the dops.

The dop, or its substitute, is now mounted in a clamp which in its simple form consists of a bar rather less than a foot in length, having a slot at one end; the parts of the clamp on either side of the slot can be brought together by a bolt and nut so that the peg of the dop may be firmly held there; the other end of the clamp is formed into two vertical legs or supports of such a height that when resting on the table, with the bar of the clamp horizontal and the dop fixed, the gem mounted on the dop is about an inch above the table. The clamps are made of iron, and when in use are further weighted, as the need occurs, with lead weights. In the case of the Diamond, grinding and polishing occur simultaneously, and are performed on a rapidly rotating disc of iron called a "skief" or "lap." This lap is a wheel of about twelve inches diameter and one inch thick, mounted on a steel shaft running on pivot bearings; the wheel is of porous cast-iron, and it is mounted so as to rotate in a horizontal plane an inch or so above the level of the bench. The rate of rotation is always high, and the harder the stone under treatment the greater the speed necessary to obtain a cutting effect. When the speed is high enough, a gem may be abraded by a substance of its own degree of hardness, or even one of a lower degree, though, of course, the harder the abrading agent in comparison to the gem, the more rapid the progress with the work. The usual speed may be taken as 2,000 to 3,000 revolutions per minute, which gives a peripheral cutting velocity of, roughly, 100 to 150 feet per second, or say 75 to 100 miles per hour. Power is applied by steam, gas, water, or from an electromotor, and the spindle is driven by a small pulley running below the bench. The abrading material in the case of Diamond is always the powder of the same mineral, as no harder substance is available; this is naturally expensive, hence the precaution taken to save all dust from the process of bruting. In the cleaving, too, such fragments as are too small to be cut for gem use are saved, and are later crushed in a steel mortar furnished with a well-fitting cylindrical pestle of steel, the dust being used in the same way as that from bruting. The impure variety of Diamond, called Bort, is also extensively used and also the finely granular opaque variety, Carbonado. Bort is harder than the pure crystallised variety, and Carbonado is as hard or harder, and is also less brittle than the pure Diamond.

The abrasive agent is mixed with a little olive oil in a capsule and a small quantity of the mixture applied to the upper surface of the lap or skief. The clamp with the dop in position is then lowered so that the gem rests on the lap. The position must, of course, be accurately adjusted to grind the stone in the desired plane; usually one operator manipulates four dops, placed equally distant round the lap so as to distribute the pressure evenly. As before mentioned, the clamps are weighted with lead weights to give sufficient pressure, without which the work would progress much more slowly. With a given weight it is obvious that the pressure on a given area will be less with a large facet than with a small, since the same total force is applied over a larger area in the former case than in the latter; hence to maintain an even pressure the weights must be altered. The weights applied vary from 2 to 30 lbs.

As an instance of the importance of having a proper speed, it may be recalled that in the cutting of the Koh-i-noor the work was being done with the wheel at 2,400 revolutions per minute. When the cutters came to one part, however, no progress seemed to be made; greater pressure was applied, with the result that particles of the iron disc, mixed with oil and diamond-powder, became ignited, and then the solder began to melt. At one point after six hours' work no effect seemed to have resulted, but on increasing the speed to 3,000 revolutions per minute the grinding proceeded satisfactorily, though the total time spent in cutting it was 456 hours ; it was found, too, in this case that they were cutting across the angle of meeting of two cleavage planes, or "across the grain" as it is expressed. This is then also a good instance of the importance of grinding in the right direction, for the hardness varies. It is found that the directions of least hardness are in lines between the centres of opposite octahedral faces—that is, the cutting must not take the direction of the crystallographic axis in the Diamond.

The abrading material quickly works its way into the pores of the cast-iron disc, hence the disc does not become worn away so quickly as one might expect.

When one facet has become ground down to its proper shape and size and has received as high a polish as possible, the dop is altered in the holder so as to bring the stone into position for another facet to be ground. When as many of the required planes have been formed as the position of the stone in the solder will allow, the dop is returned to the solderer to have the stone re-set at another angle. Frequently the dops are so hot that they cannot be conveniently handled, so wooden holders are provided; they are of a shape similar to a dumbbell with a hollow down the handle, into which the peg of the dop is placed.

To keep the stone from becoming overheated the dop is from time to time placed in water to cool.

More recently clamps have been used fitted with divided arcs, so that the stone may be placed on the lap at exactly the required angle. In this way much more precise work is possible.

When all the facets have been polished, the stone is cleaned by treatment with a softer material, such as bone ash or tripolite.

The treatment of softer stones is somewhat different. Some of them, as Topaz and, to a lesser degree, Beryl may be partly formed by cleavage, but in most cases the form is given entirely by grinding. For the varieties of Corundum, for Chrysoberyl, Emerald and other hard stones, the lap is made of iron, copper, tin, pewter, or lead; usually the harder the gem, the harder the disc used. The abrasive material is now often Diamond, for though this means a greater cost in material, there may be a greater saving in total cost of the work from the greater rapidity of grinding; the coarser varieties of Corundum known as Emery are also used, and now the artificially prepared compound of carbon and silicon, called carborundum, is extensively employed. Carborundum is made by the treatment of sand and coke in the arc of an electric furnace, and can be produced cheaply in considerable quantity; in commerce it is found in brilliant hexagonal crystals of a rich yellow colour, often merging into the blue known as "electric blue," giving the crystals very much the appearance of the Hæmatite crystals from Elba. Carborundum has the further advantage of being very hard—much harder than the Sapphire—and yet easily reducible to powder on account of its brittleness. The softer abrasives are mixed with water instead of with oil; sometimes powdered Garnet and Topaz are used.

The gem is cemented to the end of a holder of wood or ivory about five or six inches long, and this holder is steadied against a rest fixed near the right-hand side of the lap; the wheel is in some cases rotated by hand, but more often by power, as in Diamond grinding. The stone is first roughly ground to shape and then the facets are ground on; a close watch has to be kept for the appearance of any small cracks in the work, which if not carefully dealt with are apt to extend and spoil the stone.

In grinding the relatively softer gems, the abrading material, as in grinding the Diamond, presses its way into the metal of the lap.

The stone is now handed to another worker to be polished. This process consists of carefully following the previous work and rendering the facets as smooth and bright as possible. The lap used is similar to the grinding lap in type, but is usually of softer material, in the case of softer stones often of wood, covered with leather or paper, on which the polishing material is smeared. When laps of copper, lead, or pewter are used the surface is finely scratched with a piece of sandstone, so as to give minute grooves, arranged similarly to the large grooves on a mill-stone; this has the effect of evenly distributing the polishing material. Several substances are used in polishing: rouge and putty-powder (respectively oxides of iron and tin), rotten stone, fine pumice, tripolite and bole being amongst these. Tripolite is mixed with sulphuric acid for use, the others are mixed with water. All these substances must be in the form of the very finest powder, or the work will not acquire the high polish desired.

When a large portion of rough material has to be removed before grinding can be commenced, it is usually effected by slitting with a metal disc, as described in dealing with the slitting of Diamonds, powdered Diamond mixed with olive oil being used to make the disc cut the harder stones, while for the softer, Emery powder and water may be applied to the somewhat roughened edge. The natives of Ceylon used a fine wire strung on a bow and dressed with the cutting powder to slit precious stones.

In cutting stones *en cabochon* the operator holds the little handle on which the gem is mounted and keeps it constantly moving in position, especially as the work nears completion, so as to give a smoothly-rounded form. The smaller Garnets are fashioned on a fine sandstone disc, dressed with Emery powder and olive oil.

The cutting of Agates, Amethyst, Opal, Topaz, Jasper and other stones which are relatively softer and more plentiful, is largely done at Birkenfeld, on the Nahe, lying to the west of the Rhine, close to the French frontier. Here may yet be seen many of the older methods still in use. The work is carried on in small huts adjacent to streams which provide the power to drive the water-wheels, which in turn drive three or four grindstones of about four feet in diameter; the grindstones are so placed that their axles are only a foot above the floor level, while the lowest part of the stone dips into the stream below, and thus the stone is kept constantly wet. The workmen lie prone on low wooden supports, and hold their work a little above the level of the floor. In spite of the stones being kept moist, a great deal of dust, consisting of sharp, angular mineral fragments, is thrown off, and consequently inhaled, giving rise to great irritation in the lungs, and paving the way for consumption, which, having once been introduced, frequently attacks and carries off the workers in their prime.

Gem stones may be bored by a fine diamond-tipped drill, or by a small steel drill dressed with diamond-dust and olive oil, and made to rotate at a high speed.

In the processes of cutting and polishing, a rough gem will lose 50 per cent. of its weight, or more if a large stone, or 40 per cent., more or less, in small stones; when the rough gem is nearly the form required, as in the case of an octahedral Diamond, the loss may be considerably less.

CHAPTER V.

IMITATION GEMS AND THE ARTIFICIAL PRODUCTION OF PRECIOUS STONES.

THE art of making imitation gem-stones, although brought to a very high standard of perfection to-day, is by no means a thing of yesterday. It is an art that takes us back far into the remote past, almost to the verge of prehistoric times, when man first began to think of personal adornment.

The early Egyptians made imitations—imitations that may have been used as jewels, or simply as copies of rare gems. For what purpose they were made is not known with certainty. In the tombs of upper Egypt we find "pastes" that carry us back to the earlier dynasties, nearly 2,000 B.C. Egypt was even then in a high state of civilisation. Later we find the Greeks, Etruscans, and Romans making them. Pliny mentions the "glass gems from the rings of the multitude"; and again he says, "that so well made were they of lying glass (*mendacio vitri*), that their detection was most difficult." Coming down to our own times, the manufacture of false jewellery has become a thriving industry, that both employs many and pleases many, and sometimes, it is most regrettable to say, deceives many. However, in these days of enlightenment, very little unscrupulous work is done in passing off imitations as genuine, such imitations being usually sold for what they are worth, and nothing more.

One of the most celebrated producers of imitations of engraved gems—in modern times—James Tassie, a native of Pollokshaws, near Glasgow, settled in London towards the end of the eighteenth century, and there copied no less than 1,500 rare engraved gems. He not only made copies, but also original cameo portraits of his contemporaries, some of the best examples of this class of work that we have.

The method of making "paste" copies is comparatively simple. If the gem to be copied is a cameo, a mould of the raised portion is first taken in rotten stone or other fine coherent powder; a piece of glass is then put into the mould and melted. After cooling slowly, the cast in glass has simply to be trimmed, the back ground perfectly flat, and cemented on to a suitable background of real stone. The process is slightly different for copying intaglios, these gems having the subject cut or sunk into the stone; therefore, to produce a copy, an impression has to be taken first. Imitation intaglios or seals are, however, rare.

The glass, or, as it is technically known, "strass" or "paste" (Italian, *pasta*, dough) used in the above work is, generally speaking, some opaque form, maybe translucent, rarely transparent. The white opaque paste is made by adding oxide of tin or bone-ash (phosphate of lime) to the ordinary clear glass used for this class of work. These opaque slags being much like Onyx, Agate, and other varieties of the so-called "Scotch Pebble," great quantities of them are sold as such mounted in brooches and different forms of jewellery.

The artist may have used Vesuvian lava, or perhaps mother-of-pearl shell to work upon, and there are many such cameos to be had. These lava gems, if gems they may be called, range from a dirty cream colour to grey, and almost black. They are easily distinguishable by their colour, opacity, and softness. Of course, neither of these types are imitations, but, on the contrary, may be genuine works of art, though not necessarily of any great value. Many fine examples of cameo exist that have been carved out of such a mineral as Steatite, a variety of Talc, greenish or grey in colour, soft and very soapy to the touch, in fact, the "soap-stone" of tailors.

The Assyrians, Egyptians, and Greeks used Steatite, besides harder and less perishable stones, such as the Onyx and Carnelian. Steatite specimens are much softer than the lava forms.

Paste imitations of cameos may be detected by placing them in hot water. This dissolves the cement, and the front separates from the back. Intaglios are more difficult to detect, owing to the object being in one piece.

For all glass imitations of semi-precious or precious stones, the test of hardness is, perhaps, the best, for the hardest glass used in their production can be easily scratched by an ordinary piece of flint, whereas the glass will make no impression upon the flint. The specific gravity is in nearly all cases, with the exception of the Sapphire, considerably higher than that of the stone imitated. Optical properties, such as "dichroism," or unequal absorption of certain light rays, also afford good tests, glass not being dichroic. Under the microscope imitations are seen to be full of lines and striæ, signs of unequal density and strain. There are also innumerable rounded cavities or bubbles present, unlike the angular rents and vesicles in natural stones. An aluminium pencil drawn across the face of a real stone, such as the Diamond, Sapphire, Ruby or Emerald, will not leave any mark or "streak," but if drawn across a glass surface will do so. This test is only applicable to the above precious stones.

Before dealing with the production of imitation and artificial precious stones, for convenience, another distinction in terms may be made, a distinction between the words "imitation" and "artificial." To many this may appear unnecessary, the two terms being synonymous, but with the advance of scientific research the chemist can now make in the laboratory not "glass imitations," but "real stones artificially," and identical in composition with those found in Nature. Their artificial production is quite modern, carrying us back only a generation or two, but imitation precious stones were known in the middle ages, if not earlier. They were certainly known to the alchemists, for Saint Thomas Aquinas mentions imitation Jacinth, Sapphire, Emerald, Topaz, and Ruby. In the middle of the seventeenth century pastes were not manufactured according to a different formula for each stone, as had formerly been the case, but to one general formula, much the same as that in use at the present day.

One of the chief difficulties in making a suitable glass is to combine hardness with a high index of refraction and dispersive power, for a glass having the latter properties lacks the former, and "vice versâ." The dispersion of thallium glass is about 0·050, and of the Diamond 0·057, so that as regards the greatest charm of the Diamond—its dispersion of light—thallium glass is almost its equal. This is why imitation diamonds of good quality look so well at night. But what this glass has in dispersive powers it lacks in hardness; the facets lose their lustre, become scratched, and owing to chemical alteration, it goes "off colour" and takes on an opacity that renders it in time absolutely worthless. Glass made specially for imitation diamonds must have a high index of refraction and dispersive power, even though it lack hardness; and to obtain such a glass a considerable amount of lead is used in its manufacture. Increase of lead means increase of dispersive power but decrease in hardness. So far as is known, lead seems to be the only suitable element that will impart brilliancy to glass. This property was known to the Romans; but after the fall of Rome, it seems to have been lost and not re-discovered until about the seventeenth century, when it again came into use in England, and English glass was considered the finest. The art of glass-making for all decorative purposes had reached a very high standard of perfection in ancient Rome, so high, in fact, that it is doubtful if we equal it to-day with all our modern methods and improvements.

M. Feil, of Paris, was one of the first men to produce a good quality strass, and as a result imitations are now made so well that their detection is exceedingly difficult without applying suitable scientific tests.

The darkening or opacity taken on by paste with age is due to the sulphiding of the lead. This sulphiding is accelerated in large towns and cities where there is an abundance of sulphurous acid in the air. It is also hastened very considerably by the amount of lead present; some pastes containing over 50 per cent. The following percentage composition of a colourless sample will give some idea of the constituents:—

Powdered silica or Quartz	32 per cent.	
Red oxide of lead . .	50 ,,	
Potassium carbonate .	17 ,,	(replaceable by thallium).
Borax or boron trioxide	1 ,,	
Alumina . . .	trace	
Arsenious oxide . .	trace	(sometimes).

There are many formulæ, all much the same, varying only in the proportions used of the above ingredients. Great care has to be taken in the fusion to prevent frothing; the mixture is fired for some time at such a temperature that caking, or as it is technically called, "fritting," only takes place, after which the temperature is raised until fusion is complete. The contents of the crucible are then slowly cooled, precautions being taken to prevent vibration or any disturbance in the mass likely to introduce air bubbles; for this reason the glass is kept molten for some time after complete fusion. This clear glass is used for imitation diamonds.

Coloured stones, such as Rubies, Amethysts, etc., are imitated by adding to the above glass traces of metallic oxides or other suitable colouring mediums.

The imitation ruby is made by fusing together—

1,000 parts glass.
40 ,, oxide of antimony.

1 part purple of cassius (compound of tin and gold chloride).
1 ,, gold.

For imitation topaz the above formula is used minus the gold, and the fusion is not carried out at such a high temperature. In using gold for colouring purposes, the greatest care has to be taken to avoid clouding due to reduction of the gold to the metallic state. The colour taken on at first is yellowish-green, or maybe, brown, a deep ruby-red being obtained on annealing.

Imitation sapphire .	1,000	parts of	glass
	25	,,	oxide of cobalt.
,, emerald .	1,000	,,	glass,
	8	,,	copper oxide
	0·2	,,	chromium oxide.
,, amethyst .	1,000	,,	glass,
	25	,,	oxide of cobalt
	trace		oxide of manganese.
,, garnet .	1,000	,,	glass,
	trace		of purple of cassius.
,, turquoise .	1,000	,,	opaque white glass.
	trace of copper oxide or oxide of cobalt.		

Although not much used for colouring imitation precious stones, there are many other methods. Various shades of yellow may be obtained by the addition of finely-powdered coal to glass free from lead, and uranium glass is coloured by the use of uranium salts.

Paste has to be cut and polished in the same manner as real stones, only, owing to the inferior hardness, the process is much more simple. Nearly all pastes are cut as brilliants, this method setting the stone off to best advantage. It needs a fairly big stone to work upon, as the brilliant is almost as thick as it is broad. Real Diamonds that are not large enough or contain too many flaws to permit cutting in this way are "rose" or "table" cut; but such a method adopted for paste would be useless. Paste absorbs a considerable amount of light, especially through the "table." But this is not so with the Diamond; almost the whole of the light falling upon it is entirely reflected off again, that which is absorbed being thrown out by the lower facets. It is to this property of strong refractivity and reflection that the Diamond owes its brilliant play of colours, and experts can tell real stones at a glance, by their "fire." If an imitation diamond cut in any form be placed in a good light and turned about in various directions the table will in certain positions appear as a black spot surrounded by a white circle of light. The white circle of light is due to reflection from the small facets between the table and girdle, and the blackness of the table itself is largely due to a great portion of the light falling upon it being absorbed and not thrown out again by the lower facets.

Imitations when examined with a lens are frequently found to be highly fractured round the girdle where clasped by the setting; the fractures being conchoidal or shell-like and characteristic of glass. Real stones rarely show this, at least not round the girdle, but Diamonds are extremely liable to flaws, and I strongly recommend that purchasers of stones smaller than $\frac{1}{8}$ of an inch in diameter, or less than one carat in weight, should examine them carefully with a powerful lens. One stone purchased by me some time ago had no less than four splits in the base or "collet," and one small one half-way across the "table." These flaws detracted but little from the stone's appearance at night, but on comparing the stone with a perfect one, their effect was only too apparent.

First-class imitations command a good price, owing to the cost of their production; the materials, time and skill required for making the rough glass alone, without taking into consideration the expense of cutting and polishing, all tend to keep really fine examples of this class of work from becoming cheap. Very cheap forms of paste are to be purchased, but they will not stand comparison with better qualities.

Although, strictly speaking, pearls do not belong to the mineral kingdom, it may not be out of place in an article of this nature to mention briefly the method of making imitations. They are so perfectly made, besides being not quite so perishable or liable to decay as real pearls, that the latter as a consequence have fallen very considerably in value. They were first imitated by Jacquin at Paris in 1656, and the method in vogue to-day is much the same as that he discovered. It consists in blowing small spheres of opalescent glass coated internally with a preparation known as "Essence d'Orient," made from the scales of such a fish as the Bleak. The sphere is slightly dented, coated externally and internally with parchment size and pearl essence, and then filled in with wax. Pearls imitated in this way are exceedingly beautiful, and have a rich and charming lustre. They may be known by their hardness, which is very much greater than that of real pearls, and by their extreme brittleness, the slightest pressure causing them to crack. Again, their lustre may be described as vitreous or glassy, whereas in genuine pearls the lustre is soft, indeed almost dull.

Coming now to the question of real stones, some methods of "faking" them, by altering or improving their colour, might with advantage be briefly touched upon before proceeding to the more interesting subject of making them artificially.

The colour of some stones may be altered by heat, and the process of "burning" is one that was in use by the ancient Egyptians. Pliny also refers to it in his time, and the method practised then is the same as that in use to-day. It consists in either wrapping the stone up in tinder and setting fire to the tinder, or packing the stone in very fine powder, such as rotten stone or earth, and baking in a clay crucible. Precautions have to be taken not to heat too highly, or the stone may be hopelessly fissured. The yellow Brazilian Topaz assumes a beautiful rose-red colour, and is then known as Burnt Topaz. The colour is discharged from blue Sapphires by burning, and they become clear. Rubies are quite unaffected, and retain their original colour. Carnelians may be intensified in colour and much improved. Stones are coloured also by soaking in chemical solutions. There are many different methods. Perhaps the principal one in use is that for the production of black-and-white Onyx. An ordinary Onyx consists of alternate layers of blue Chalcedony (a crypto-crystalline form of silica) and white opaque Cachalong, another variety of silica. The Chalcedony layers are slightly porous, and if soaked in oil for some time absorb a certain amount; this is blackened by de-hydrating with strong sulphuric acid. Small specimens may be done in half an hour by carefully boiling in pure olive oil and then, after drying, putting them into the acid. If they become too black, their original colour may be restored, or, in other words, the blackness may be removed by warming in pure nitric acid. A solution of sugar may be substituted for oil.

"Off-colour" or yellow Diamonds, known as "straws," have been passed off by unscrupulous dealers as "first water" stones by dyeing them with a magenta varnish, which neutralises the colour. This in time wears off and their true colour shows up. Soaking a suspected stone in absolute alcohol for a moment, and wiping, will soon remove any varnish if there be any to remove.

A method of fraud very little practised, perhaps, because it entails no little skill and the use of real stones, is the production of "doublets" and "triplets."

A Diamond or Sapphire, more often the latter, that, owing to shape or the number of flaws it contained, would be useless for cutting as a brilliant, is cut as half a one, *i.e.*, the upper or table portion. This portion is then ground perfectly flat at the back and cemented by means of a clear transparent cement to the lower or collet half, cut from either Sapphire or paste as the case may be. Such a stone when clasped is difficult to detect, but on being removed from the setting and placed in warm water, the cement is dissolved, and the two portions fall apart much the same as when dealing with imitation cameos.

Coloured stones imitated by the above process have a thin slice of real stone set between the two halves, or the cement used may be coloured. It is to specimens set up in the former method that the term "triplet" is applied.

Coming now to the subject of making real stones artificially, it is one of great interest, not only to scientists and dealers in precious stones, but to the jewel-loving public. It is a subject almost as fascinating and interesting to the experimental chemist of to-day as the search for the mythical "philosopher's stone" was in the days of the early alchemists. Commercially speaking, it is a remarkable fact that in these days of progressive scientific research very little headway has been made in the synthesis of real stones of saleable quality. Certainly, the Diamond, one of the most difficult to produce, has been artificially prepared in the laboratory. The experiments and their results from a scientific point of view are interesting, but at a great outlay for such results, the time and money expended being considerable. The stones, after laborious and tedious extraction from the matrix in which they were formed, could only be well seen with a lens; they were hardly fit to grace the movement of a watch, far less adorn a lady's finger.

Many of the most talented chemists of the world have given the matter their consideration, and the production of a large number of minerals and rocks with a few of the so-called precious stones is now an accomplished fact, although, as already stated, not a commercial success. Our present knowledge of the subject has grown considerably by the investigations of such men as Gustav Rose, Mitscherlich, Credner, Deville, Debray, Kuplmann, Heintz, Manross, Daubree, Senarmont, Hautefeuille, Berthier, Forchammer, Wöhler, Becquerel, Wibel, Moissan, Ebelman, Fraube, Crookes, Noble, Fouqué, Sorby and Levy, and many other noted experimentalists.

One of the chief difficulties to overcome in the synthetical preparation of a mineral is crystallisation. Nearly all minerals crystallise in some form, and more particularly is this so with precious stones, excepting the Opal and Turquoise. Now Nature has one great advantage over our puny experiments in the laboratory: she can take unlimited time and has great stores of energy at her command, enormous pressures and high temperatures working together or independently. In the laboratory, on the other hand, pressure and temperature, although obtainable, are in many cases not sufficiently high, and also not easily controlled. Then, again, as regards time, poor man does not live long enough. Working under conditions such as these Nature need have little fear of being ousted from the Diamond market. Whatever method we may adopt in our experiments, time will not wait, and crystals of fair size and shape are not made in five minutes, so the result is, generally speaking, a few microscopic splinters hardly worth looking at. If sufficient time could be given in many of the experiments carried out, for crystallisation to take place slowly, then one of the chief difficulties would be overcome.

Even presuming we knew definitely how some precious stones were formed in Nature's laboratory, it is doubtful whether we could apply Nature's methods in our laboratories to produce similar results. Many have been the theories put forward to explain the origin of that monarch of precious stones—the Diamond, one in some cases being as feasible as another; but at the present day it is difficult to apply any one of them as correct. To chemists and physicists, from early times, this stone has been the subject of discussion. What does the Diamond consist of? How was it formed? Can it be made artificially? Thanks to the rapid progress in scientific research, all these questions have been answered, perhaps not quite so successfully as we desire, but still in a satisfactory manner.

The composition of the Diamond was early observed by Gassiot and Berzelius; and Lavosier, in 1772, showed that if heated to a high enough temperature (about 800° C. according to Moissan) it burned away, producing by combination with the oxygen of the air that heavy noxious gas, carbon anhydride (carbonic acid), the after-damp or choke-damp of coal pit explosions. Smithson Tennant, in 1779, proved that carbonic acid was the only product of the Diamond's combustion. This was verified by Davy in 1814, who was the first to prove that it consisted almost wholly of pure carbon, the residue after combustion being only 0·2 to 0·05 per cent. of an ash made up of silica and oxide of iron. One of the earliest theories of the Diamond's origin was propounded by Sir Isaac Newton, who stated that it is in all probability "an unctuous substance coagulated." This theory, no doubt, was based upon its high refractive properties, ordinary gum arabic being not at all unlike rough Diamonds. A similar theory put forward by Sir David Brewster was that it owed its origin to the vital processes of plants, and was at one time viscous, like resin.

For a considerable time theory held first place and practical experiments gave no satisfactory results. Theory after theory followed each other in rapid succession from such men as D'Orbigny, Wöhler, Liebig, Berthelot, Bischof, C. C. Von Leonhard, Parrot, Carvill Lewis, Wilson, Göppert and Dana, many agreeing and many disagreeing. Damour and Gannal, of Brazil, considered that the Diamond might be due to the reduction of carbon bi-sulphide (an evil smelling impurity of coal gas). A. Favre, and later the Hon. St. Claire Deville, were led by a study of the minerals associated with the Diamonds of Brazil to consider their formation the result of the reduction of fluorine or chlorine compounds of carbon. Whether this may be the true origin of Brazilian Diamonds or not, it is the writer's opinion that if successful experiments are undertaken in the laboratory it will be in the reduction of such carbon compounds.

Perhaps one of the first experiments on the artificial production of Diamonds to meet with any success was carried out by Despritz in 1853. The method employed by him was to pass the electric spark in vacuo for a month, using a platinum rod as one terminal and a carbon cylinder as the other. The platinum terminal was found to be encrusted with minute octahedral crystals which answered all the tests applicable to the Diamond.

In 1880 J. B. Hannay,[1] of Glasgow, carried out no less than eighty experiments upon the reduction of a carbon compound, only three of which were successful. Iron tubes 20 inches long by 1 inch thick and ½ inch bore were filled about two-thirds full of pure paraffin spirit with a little charcoal, and then sealed off. The sealing of these tubes was the most difficult part of the undertaking. In the earlier experiments screw stoppers, luted in with a mixture of silicate of soda and manganese dioxide, were used, but

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[1] "Artificial Production of Diamonds," by J. B. Hannay, F.R.S.E., Proc. Roy. Soc., No. 204, 1880.

after heating for four hours in a reverberatory furnace, the tubes on opening were found to be empty, owing to leakage. Later, he tried plugging with iron balls, the upper end of the tube being narrowed after the introduction of the ball, which was then drawn up and luted. This method was worse than the former, not as regards leakage, but damage, as they either burst with considerable violence or the balls were blown out. After this, welding was resorted to. Now it is obvious that, when three parts full of spirit, this proceeding required considerable skill, the ends of the tubes having to be immersed in a freezing mixture. There were many failures due to bursting whilst firing, or very often a tube would burst with a loud explosion when being opened. This latter operation was in almost every case very difficult, owing to the hardening of the inner part of the tube by conversion of the iron into steel. The mixture used by Mr. Hannay in his three successful experiments was 4 grams of lithium in a solution of bone oil 90 per cent. and paraffin 10 per cent., the tube being three parts full, welded off and brought to a red heat in an inclined reverberatory furnace for fourteen hours. The hard crystalline cake obtained yielded minute Diamonds having all the properties of real stones and consisting of 97·85 per cent. pure carbon with a trace of nitrogen.

Since 1893 various experiments have been carried out, and with the advance in electricity a great power has been placed in the hands of the experimentalist. The late H. Moissan, of Paris, obtained very successful results with the electric furnace, and produced many different minerals, including Diamonds over 0·5 m.m. in size. It would be of interest as showing the time and skill required to make a few small splinters of Diamond to here give Moissan's method from Sir W. Crookes' paper on "Diamonds,"[1] by that author's kind permission:—

"For the manufacture of—I am afraid I must say an infinitesimal—diamond, the first necessity is to select pure iron—free from sulphur, silicon, phosphorus, etc.,—and to pack it in a carbon crucible with pure charcoal from sugar. The crucible is then put into the body of the electric furnace, and a powerful arc formed close above it between carbon poles, utilising a current of 700 ampères at 40 volts pressure. The iron rapidly melts and saturates itself with carbon. After a few minutes' heating to a temperature above 4,000° C.—a temperature at which the iron melts like wax and volatilises in clouds—the current is stopped, and the dazzling fiery crucible is plunged beneath the surface of cold water, where it is held till it sinks below a red heat. As is well known, iron increases in volume at the moment of passing from the liquid to the solid state. The sudden cooling solidifies the outer layer of iron and holds the inner molten mass in a tight grip. The expansion of the inner liquid on solidifying produces an enormous pressure, and under the stress of this pressure the dissolved carbon separates out in transparent forms—minutely microscopic, it is true—all the same veritable diamonds, with crystalline form and appearance, colour, hardness, and action on light the same as the natural gem.

"Now commences the tedious part of the process. The

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[1] "Diamonds." A lecture delivered before the British Association at Kimberley, September 15, 1905, by Sir William Crookes. Published at the *Chemical News* Office, 16, Newcastle Street, Farringdon Street, London. Price 1*s*.

metallic ingot is attacked with hot nitro-hydrochloric acid until no more iron is dissolved. The bulky residue consists chiefly of graphite, together with translucent chestnut-coloured flakes of carbon, black opaque carbon of a density of from 3·0 to 3·5, and hard as diamonds—black diamonds or carbonado, in fact—and a small portion of transparent colourless diamonds showing crystalline structure. Besides these, there may be carbide of silicon and corundum, arising from impurities in the materials employed.

"The residue is first heated for some hours with strong sulphuric acid at the boiling point, with the cautious addition of powdered nitre. It is then well washed and for two days allowed to soak in strong hydrofluoric acid in cold, then in boiling acid. After this treatment the soft graphite disappears, and most, if not all, the silicon compounds have been destroyed. Hot sulphuric acid is again applied to destroy the fluorides, and the residue, well washed, is attacked with a mixture of the strongest nitric acid and powdered potassium chlorate, kept warm—but not above 60° C., to avoid explosions. This treatment must be repeated six or eight times, when all the hard graphite will gradually be dissolved, and little else left but graphitic oxide, diamond, and the harder carbonado and boart. The residue is fused for an hour in fluorhydrate of fluoride of potassium, then boiled out in water, and again heated in sulphuric acid. The well-washed grains which resist this energetic treatment are dried, carefully deposited on a slide, and examined under the microscope. Along with numerous pieces of black diamond are seen transparent colourless pieces, some amorphous, others with a crystalline appearance. Although many fragments of crystals occur, it is remarkable I have never seen a complete crystal. All appear shattered, as if on being liberated from the intense pressure under which they were formed they burst asunder. I have singular evidence of this phenomenon. A fine piece of artificial diamond, carefully mounted by me on a microscopic slide, exploded during the night and covered the slide with fragments. Moissan's crystals of artificial diamond sometimes broke a few weeks after their preparation, and some of the diamonds which cracked weeks or even months after their preparation showed fissures covered with minute cubes. This bursting paroxysm is not unknown at the Kimberley mines.

"So far, these specimens are all microscopic. The largest artificial diamond is less than 1 m.m. across. These laboratory diamonds burn in the air before the blowpipe to carbonic acid. In lustre, crystalline form, optical properties, density, and hardness, they are identical with the natural stone.

"In several cases Moissan separated ten to fifteen microscopic diamonds from a single ingot. The larger of these are about 0·75 m.m. long; the octahedra being 0·2 m.m."

Again, to quote from Sir William Crookes' paper:—

"A NEW FORMATION OF DIAMOND.

"I have long speculated as to the possibility of obtaining artificially such pressures and temperatures as would fulfil the above conditions. In their researches on the gases from fired gunpowder and cordite, Sir Frederick Abel and Sir Andrew Noble obtained in closed steel cylinders pressures as great as 95 tons to the square inch, and temperatures as high as 4,000° C. According to a paper recently communicated to the Royal Society, Sir Andrew Noble, exploding cordite in closed vessels, has obtained a pressure of 8,000 atmospheres, or 50 tons per square inch, with a temperature reaching in all probability 5,400° absolute.

"Here, then, we have conditions favourable for the liquefaction of carbon, and were the time of explosion sufficient to allow the reactions to take place, we should certainly expect to get the liquid carbon to solidify in the crystalline state.

"By the kindness of Sir Andrew Noble I have been enabled to work upon some of the residues obtained in closed vessels after explosions, and I have submitted them to the same treatment that the granulated iron had gone through. After weeks of patient toil I removed the amorphous carbon, the graphite, the silica, and other constituents of the ash of cordite, and obtained a residue among which, under the microscope, crystalline particles could be distinguished. Some of these particles, from their crystalline appearance and double refraction, were silicon carbide; others were probably diamonds. The whole residue was dried and fused at a good red heat in an excess of potassium bifluoride, to which was added during fusion 5 per cent. of nitre. (Previous experiments had shown me that this mixture readily attacked and dissolved silicon carbide; unfortunately it also attacks diamond to a slight degree.) The residue, after thorough washing and then heating in fuming sulphuric acid, was washed, dried, and the largest crystalline particles picked out and mounted. All the operations of washing and acid treatment were performed in a large platinum crucible by decantation (except the preliminary attack with nitric acid and potassium chlorate, when a hard glass vessel was used); the final result was washed into a shallow watch-glass and the selection made under the microscope.

"From the treatment they have undergone, chemists will agree with me that diamonds only could stand such an ordeal; on submitting them to skilled crystallographic authorities my opinion is confirmed."

Another method, evidently new, is put forward by Mr. C. V. Burton, of Cambridge. This gentleman, writing in *Nature*,[1] states that lead containing about 1 per cent. of calcium is capable of holding a certain amount of carbon in solution either in the free state or as calcium carbide. This carbon crystallises out in the form of minute octahedral crystals, having all the properties of the Diamond if the calcium be eliminated. To get rid of the calcium, or rather to render it inert, he passes steam through the molten mass, converting it by this means into calcium hydrate. The lead is unaffected, and at a dull red heat the carbon crystallises out as above, but if at a full red heat only Graphite is obtained.

Besides the above experiment, Mr. Burton has been successful in the reduction of carbon compounds, such as benzene, toluene, carbon tetrachloride, etc., in sealed tubes and bombs, at temperatures of 200° C. and 300° C.

In 1898, J. Friedlander produced some smoky crystals having all the properties of the Diamond by fusing the mineral Olivine (an iron silicate of magnesia) in a gas blowpipe, the fusion being stirred frequently with a stick of pure Graphite; after cooling this was found to be encrusted with exceedingly small crystals of Diamond.

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[1] "Artificial Diamonds," *Nature*, p. 397, Vol. 72, August 24, 1905.

It is obvious from the foregoing remarks upon various experiments and their results that the Diamond market is not likely to be threatened in the near future by their wholesale and retail manufacture in the chemical laboratory.

Many of the experiments, however, are interesting from another point of view—they throw some light upon the probable origin of the Diamond. Moissans' experiments help to explain its occurrence in meteoric iron, or perhaps the origin of the South African stones. Sir William Crookes considers that the latter have been formed in some such manner, the matrix in the "pipes" being highly ferruginous. Friedlander's experiment, on the other hand, seems to suggest that they may have been formed by the action of a molten silicate upon Graphite or other carbonaceous matter. It is possible both reactions may have taken place together, but it is hardly within the scope of the present chapter to consider it, and the writer can only refer those at all interested to Sir William Crookes' paper.

Without any hesitation, it may be said that the first precious stone to be successfully prepared in the laboratory was that most beautiful of precious stones—the Ruby—the only stone that ranks with, and can even rank above, the Diamond in value.

St. Claire Deville and A. Carron in 1858,[1] succeeded in producing crystals of Ruby, Sapphire and Corundum by fusing at a high temperature a mixture of boric anhydride and aluminium fluoride; the boron combining with the fluorine volatilises off, and the aluminium is oxidised into

[1] "Comptes Rendus," vol. xlvi.

alumina, which crystallises out as one of the above three varieties according to the colouring medium added; this may be a trace of potassium dichromate or chromium fluoride, the colour produced depending upon the amount used, a mere trace of the latter giving the Ruby, a little more the Sapphire, and still more producing green Corundum.

J. Morozewiez employed somewhat similar methods, and obtained Spinels (oxide of magnesium and aluminium) and crystals of Corundum 1·5 m.m. in diameter, the colour, however, not being due to chromium, but iron.

For good Sapphire blues the writer has found a trace of cobaltic nitrate to be the best.

From a commercial point of view, the most successful experiments ever carried out were by Fremy and Verneuil in 1878, and later in 1890, when they produced Rubies of such good quality and size that they were sold for watchmakers' purposes. They fused in a clay crucible, at a temperature of about 1,500° C. a mixture of alumina and barium fluoride containing a trace of potassium di-chromate. The fusion was kept molten for a week, and then cooled down very slowly, small crystals of Ruby—and, if cobalt oxide was substituted for the di-chromate—Sapphires separating out in the mass.

In 1885 Rubies were put on the market of sufficient size and quality to be mounted, cut or uncut, for jewellery. These stones, upon examination with a lens, were seen to have been artificially made, as they contained many minute bubbles and other signs of strain. They were produced in Geneva, and received the name of "Geneva Rubies," but the method of their production was a trade secret, and, as far as the writer is aware, is still so.

In a paper by A. Verneuil, in 1904, "On the Artificial Reproduction of the Ruby by Fusion,"[1] he describes a new method devised by him that has proved highly satisfactory, some of the stones prepared weighing up to 15 carats and measuring over 5 m.m. in diameter. The smaller stones are, however, the best, being free from bubbles, which are unfortunately always present in the larger ones, and at once indicate their origin.

M. Verneuil found that one of the chief difficulties to overcome was cooling; for if cooled too quickly the alumina becomes slaggy and an enamel is produced. He invented a most ingenious piece of blow-pipe apparatus, by means of which he could bring about the gradual fusing and as gradual cooling. The blow-pipe and furnace-tube were made vertically, and very finely powdered alumina containing a trace of chromic oxide was fed into the tube through a sieve by means of a series of regular taps controlled by an electro-magnet. This arrangement causes the material to fall down the tube intermittently in a series of thin layers. These layers gradually grow upwards in the shape of a cone, the apex of which fuses on reaching a hot enough part of the tube; the fused mass then extends in the form of a long filament. This, on reaching a still hotter part of the furnace-tube fuses into a spherical mass, which on cooling slowly, has all the properties of the natural Ruby.

As the cost of producing artificial Rubies is very high, they are quite as dear as the natural stones.

Having described some of the methods of making Rubies,

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[1] "Memoire sur la Reproduction Artificielle du Rubis par Fusion," By A. Verneuil ("Annales de Chèmie et de Physique," 8e séne t. ii., Sept. 1904).

Sapphires, and Corundum, we might briefly consider one or two experiments carried out upon the preparation of Zircons, Emeralds and Turquois, these stones being the only others successfully reproduced in the laboratory.

By the action of gaseous silicon fluoride upon zirconia (zirconium oxide), crystals of Zircon (silicate of zirconium) were formed. Experiments of this nature are somewhat dangerous to do, as fluorine compounds, especially if gaseous, are very deadly, and will attack almost anything. The acid used for etching glass if it comes in contact with the skin produces painful sores. Substituting beryllium oxide for zirconia in the above experiment, hexagonal plates similar in hardness to the Emerald were obtained. None of these methods are, however, of commercial importance.

The Turquoise, owing to its amorphous nature and opacity, has, besides many forms of imitation and substitutes, such as Malachite, Bone Turquoise or Odontolite, etc., been so successfully prepared artificially that without destroying the stone it is difficult to distinguish between the natural and the laboratory production. They are as a rule mixed up with parcels of natural stones in the rough, and are in many cases much finer than the real Turquoise. To make their appearance more natural, they are stained with Limonite (hydrous oxide of iron), and their detection as a consequence is somewhat difficult. It is stated by Dr. Max Bauer, in his admirable book on "Precious Stones,"[1] that if these stones are put into water they darken in colour, and minute cracks may be seen on the surface if examined with a lens. The only

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[1] "Precious Stones: their Characters and Occurrence," by Dr. Max Bauer, translated by L. J. Spencer, M.A. Griffin & Co., London, 1904.

reliable test, however, seems to be in the destruction of the stone. The real Turquoise, on strongly heating in the blowpipe flame, decrepitates violently and turns brown to black. The artificial production under the same treatment fuses quietly to a black glass.

The exact method of their preparation is not known, but seems to consist in applying great pressure to small quantites of powder having the composition of Turquoise (hydrous phosphate of alumina with a trace of copper oxide); the powder is chemically precipitated, and is in a very fine state of division. The stones produced by this method are all small, no large ones having been detected.

With increase of knowledge, as each branch of science grows, we may yet live to see the day when Diamonds will be made on the " while you wait " system. In these days of scientific marvels, one wonders, not at what has been done or what is likely to be accomplished in the future, but what will be left undone. In point of fact, we have almost ceased wondering at all.

The more scientific methods of identification have been mentioned elsewhere, so no mention has been made in this chapter of specific gravity solutions, refractometers, or the colouring effects of radium or the Röntgen rays upon the Diamond and Sapphire.

CHAPTER VI.

THE DIAMOND.

Although this mineral is not referred to, so far as can be ascertained, by the most ancient writers, there seems reason to believe that it was known to some of the great princes of olden times, but to few of the people. Thus Pliny says it "was long known to none but kings, and to but very few of them." The first authenticated reference to it occurs towards the end of the Augustan period, when Manilius speaks of it as the Adamas. The term Adamas had been used previously by the Greek writers for any extremely hard substance. Once known, it seems to have immediately become the most coveted of stones. Although doubt has been cast on the identity of Pliny's Adamas with Diamond, his description would, as King points out, apply to the Diamond, for he speaks of it as "pointed at the two extremities as though two turbines" (whipping tops of the form of a many-sided pyramid) "were joined together by their broadest ends." The name Adamas is said to be derived from a Greek word meaning "unconquerable," because it was supposed that the hardness of the Diamond was so great that it would not only break into fragments the hammer with which it was struck, but would also splinter the anvil on which it was laid. Further, the greatest heat was reputed unable to make the stone red hot. As already mentioned, its external application to the human body was held to be an antidote to poisons, and a cure for enchantments and insanity. Great virtue was ascribed to it as a preservative from lightning and pestilence. In the mouth it had the effect of causing the teeth to drop out; but one quaint writer refutes this, on the ground that he had known it used in powdered form to clean the teeth—for which purpose it would probably be very efficient—while the teeth lasted. But taken internally, it was a violent poison. It maintained affection between man and wife.

In the East it was known as "ripe Diamond" or "pakka," to distinguish it from the "unripe Diamond" (kacha) or Rock Crystal.

As it occurs in Nature its physical characteristics are remarkable; in colour there is a considerable range. The crystallised variety may be colourless, or of a peculiar steely white colour in the most sought-after specimens, but they only form some 25 per cent. of the stones found. A similar proportion are faintly coloured, and quite half are more or less dark in colour. As a rule, the presence of colouring matter detracts from the value of the stone, but an exception is made when the colour is of any very fine shade. The commonest shades found are honey-yellow, though other shades of yellow are frequently found, except sulphur-yellow. Various shades of green are the next most common, but as a rule the tint is a dull one, and only in very rare cases is it rich, only a few good green stones being known, and most famous amongst these is the "Dresden Green," a gem of nearly fifty carats. Various shades of grey are common, but black is rarely seen in well crystallised stones, though in the Bort (*vide infra*) it is common. Red is a very rare shade, too, but when it does occur the tints are usually brighter. A ruby-red Diamond of ten carats is said to be amongst the Russian crown jewels, and a rose-red one of three times this size belongs to Austria. Blue is the rarest shade of all. It may occur as a light or dark blue. Probably the most noted stone of this colour is the "Hope" Diamond, of forty-four carats.

Brazil seems to have produced most of the coloured stones of note, though recently a fine red specimen was obtained in Borneo.

Many Diamonds, when found, are coated with a coloured film, frequently of a greenish tinge. This is particularly the case with Brazilian stones, and as a rule is found only to be superficial, so that by cutting a perfectly colourless stone may be produced. Some of the South African stones are "smoky," especially on the dihedral and solid angles.

The lustre of well crystallised Diamonds is adamantine in a splendant degree. From this high lustre all grades may be found to greasy and dull. Water-worn stones often show almost a metallic lustre. Crystals are usually transparent, while Bort is only translucent, and Carbonado is opaque. The degree of transparency varies greatly with the condition of the surface. Thus water-worn crystals may be likened to ground glass—seemingly translucent only; but if their surfaces be polished, as in the process of cutting, the stone may be found to be transparent in a high degree. Stones which show more than a certain degree of cloudiness cannot be utilised as gems.

The refractive index is high, and dispersion is very high. Des Cloizeaux gives the following value of n—

Red.	Yellow.	Green.
2·4135	2·4195	2·4278

The difference between the indices for the B and H lines of the spectrum is ·0574, which figure is therefore the coefficient of dispersion in Diamond.

Since the "fire" of a stone depends on the degree to which white light is split up into its components, it at once becomes obvious that the fire of this gem is very marked.

Diamond, being a cubic mineral, should always show single refraction; but this is not always found to be the case, anomalous double refraction frequently being present, especially in stones that are coloured, or contain enclosures of impurities. It is found that many crystals of Diamond show signs of great internal strain, so great at times that a stone will sometimes fly to pieces on being handled. This suggests that the mineral is often formed under conditions of great pressure. Max Bauer quotes the similar instance of "Prince Rupert's Drops," small beads of glass formed during the blowing of glass vessels, in which great internal strain is set up on cooling, and in which, too, double refraction is seen, due to this strain, although glass, being a colloid body, should only show single refraction. The smoky stones from South Africa show the phenomenon in the most marked degree. Under the polariscope, with the Nicol's prisms crossed, a stone showing single refraction when rotated gives a complete dark field; but specimens having these internal strains show irregular light portions of the field under the same conditions. Precautions must of course be taken to ensure that light is not entirely cut off by total internal reflection, by surrounding the stone with some highly refractile medium during examination. Diamond occasionally shows asterism.

Phosphorescence is strongly marked in most Diamonds, but is not, as a rule, produced to any marked degree by the direct act of light, especially in the case of larger stones, though smaller ones may more often show it; when, however, the mineral is rubbed on cloth or paper, most stones are found to become phosphorescent, though the light emitted is as a rule not strong, and does not last for any considerable time; yellow is the commonest colour shown. The high tension electric discharge from a vacuum tube causes Diamond to phosphoresce.

Under X-rays, Diamond is found to be remarkably transparent, a Sapphire appearing quite opaque in comparison; thus a convenient means is at hand for examining a large parcel of stones, other substances which could be substituted for Diamond casting a shadow, and thus discovering any attempt at substitution.

Under the influence of heat no change is observed as a rule until high temperatures are reached, though a few specimens may phosphoresce on heating, but all have this property destroyed by great heat. Moissan gives the temperature of ignition in oxygen as 690° to 840° C., but if heated out of contact with air or oxygen no change occurs up to an intense white heat, and then only a very slow conversion into the allotropic form of carbon, Graphite, takes place (*vide infra*). Diamond is a good conductor of heat; hence moisture rapidly condenses on it and rapidly evaporates again.

With regard to its electrical behaviour, Diamond shows a charge of positive electricity when rubbed, and this whether the faces are in the natural form or cut; it is of a very high electrical resistance, a fact of greater interest since other forms of carbon, as Graphite and coke, are good conductors.

The specific gravity is high for a gem stone, that of crystals being 3·516 to 3·525; the variety Carbonado is, however, rather less dense, 3·15—3·29, while Bort is almost the same as the crystallised variety, 3·5.

When broken, if a fracture is developed, it is seen to be conchoidal, but cleavage is much more often seen than fracture.

The cleavage of Diamond is parallel to the faces of the octahedron, and is highly perfect, so that the cleavage planes appear bright, smooth and regular; cleavage is obtained with great ease by the means described under gem-cutting, and use is very frequently made of this property in the cutting of the gem into brilliants, since this particular shape may be said to be derived from a regular octahedron. Hence, whatever the external form of a rough Diamond, if it is a single crystal or a portion of one, it can be reduced easily to a suitable form for cutting. In cases where no actual crystal faces are to be seen on the rough stone a careful examination will usually reveal some of the octahedral cleavage planes, and thus we can determine in what direction the remaining planes of the octahedron may be produced. To recognise these planes when unequally developed requires some practice, and it is well worth while to obtain some lumps of Fluor Spar, which has the same cleavage, and to practice the recognition of existing cleavages and the production of fresh ones on this cheap material, which can easily be obtained in single crystals the size of one's fist. Twinned crystals of Diamond cannot be cleaved into an octahedron by simple cleavage.

In hardness Diamond exceeds all other known substances, and on Mohs' scale it is therefore numbered 10. The crystallised varieties are not the hardest, as Bort and Carbonado may slightly exceed them. Crystals, too, vary somewhat in hardness in different directions, probably more so in specimens showing strain than in others, but there is a fairly constant difference in the direction of the crystallographic axes, the hardness being greater along the axes than along the intermediate directions. Different faces of the crystals, too, vary in hardness, and the exterior of a crystal is usually harder than the interior. Crystals from various localities differ: thus the Australian stones are remarkably hard, and the South African ones relatively soft, especially before they have been long exposed to the air.

With regard to frangibility, it may be noted that the old idea that a Diamond would splinter the anvil on which it was laid to be broken is erroneous, for on the contrary it is a mineral easily reduced to powder by a steel pestle and mortar.

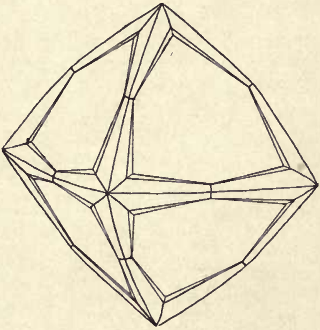

Fig. 9.—Diamond: A Natural Crystal.

Crystalline Form, Occurrence, and Genesis.

Diamond crystallises in the cubic system, and although the number of known crystal forms is not great, there may yet be an enormous number of planes on a natural crystal, since some of these forms, when complete, may be composed of as many as forty-eight planes or faces. The "habit" of the crystal, too, varies considerably, though most commonly the octahedral forms predominate (Fig. 9); twin crystals are often seen, both of the contact and interpenetration types. By suppression of alternate faces of the octahedron, forms of the regular tetrahedron arise. The plane of twinning is parallel to the octahedron, and the twins are often flattened parallel to the same form so as to have the general appearance of basal slices of two triangular pyramids applied to one another. The faces are

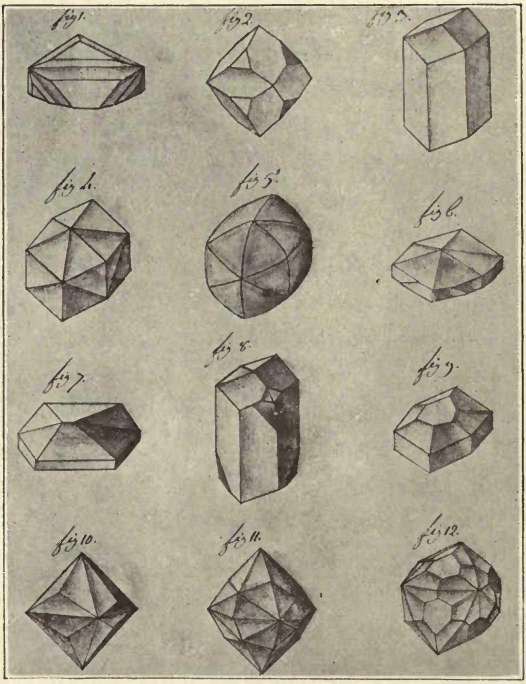

FIG. 10.—Drawings of Crystals of Diamond.

commonly curved; the true explanation of this is a matter of uncertainty. The great majority of minerals which are found crystallised occur bounded by true planes, but on the other hand a few, and prominent amongst these few is the Diamond, are more often found in curved forms. Still more interesting perhaps is the fact that certain crystallised minerals may have the majority of their surfaces quite flat, yet some one or two crystal forms of the same mineral may almost constantly be found curved; the writer, in the

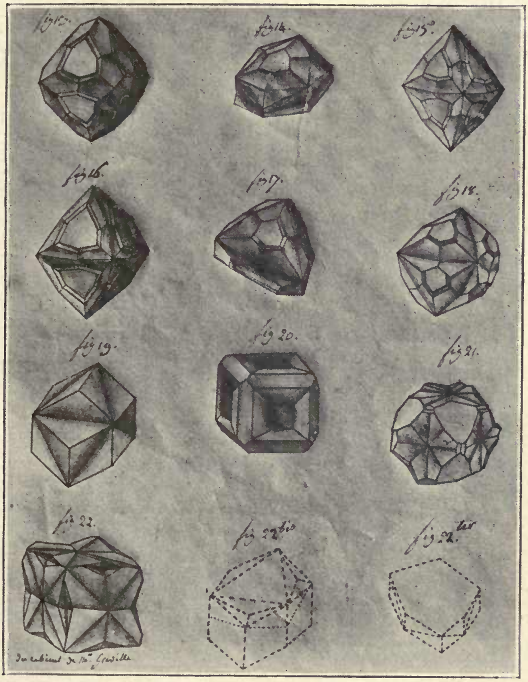

FIG. 11.—Drawings of Crystals of Diamond.

examination of many thousands of crystals of Barytes, has invariably found one or two crystal forms, when present, to be curved, and this in a mineral that may show over thirty forms on one crystal, all the others being remarkably flat. This would rather suggest that the curvature, which is undoubtedly developed at the time of the growth of the crystal, is due not so much to the surrounding conditions as to some special surface force acting on particular planes of the crystal in a much greater degree than on others. This curving of the faces may in some types of crystal lead to an almost spherical form, as in No. 5 of the drawings from the Raith collection (Figs. 10 and 11); again, it leads to great difficulty in the exact measurement of the angles on Diamond crystals, and for this reason the interesting question of the exact group of symmetry to which the mineral belongs is still unsettled. Another characteristic of the crystals is the presence of numerous striations on some of the faces, usually parallel to the intersection with the octahedron. Two crystal forms show characteristic markings on their faces: thus the cube faces have little depressions, as if a truncated four-sided pyramid had been pressed into them smaller end first; the faces of the octahedron, too, show sunk triangular pits with the triangular outline inverted in relation to the outline of the octahedral face.

Although Diamond crystals are as a rule idiomorphic, this is not invariably the case, some being found impressed by other crystals, such as Quartz; inclusions of a mineral which is very likely Chlorite, and more rarely of Hæmatite, occur; some crystals contain innumerable minute cavities; Diamond also occurs included in Quartz and Anatase.

Crystals of cubic habit are most frequently found in

Brazil; the rhombic dodecahedron is also seen in Brazilian specimens; crystals from the Urals usually show the four-faced cube according to Parrot; Indian and South African crystals are more frequently octahedral in habit, though not necessarily having the octahedral face itself largely developed.

The variety of Diamond known as Bort (also spelled Boort and Boart) occurs in rounded forms, having a confused crystalline structure, and hence no definite external crystallised form, and no definite cleavage. In colour it is usually grey or black, the lustre is greasy, the specific gravity less than of the crystallised variety and the hardness slightly greater. There seems to be a regular gradation from one of these varieties to the other, and also from Bort to Carbonado. Although useless as a gem, Bort is very valuable for many technical purposes which will be mentioned later. In the Diamond trade not only is the term used as here, but any specimen of the crystallised variety which by reason of bad colour, flaws, deficient size, or other cause, is unfit to cut, is included under the term Bort. Carbonado is the same mineral in a still more confused state of aggregation; frequently it is called Black Diamond, but as under that term it might be confused with the black varieties of the true Diamond, it is better to adhere to the mineralogical term. Carbonado may be granular, or quite compact; it shows no cleavage. Its hardness may be greater than Diamond in crystals, but it is less brittle, and thus is also largely used in technical processes. Its specific gravity is less than Diamond proper, possibly due to some degree of porosity. It chiefly comes from the Serra da Cincorá, in the state of Bahia in Brazil, where it is found in considerable masses—up to 731 carats, according to E. Boutan. It has here been found enclosing Diamond.

The origin of Diamond has for ages been a point of dispute, and innumerable theories have been advanced dealing with the subject. One of the difficulties is that in most cases the mineral is not found *in situ*, but only in alluvial deposits, either recent or ancient, containing the *dêbris* of many different rocks, as a rule.

The earliest definite theory advanced was that of Brewster, who held the mineral to be formed by the consolidation of a resinous substance resulting from plant life. Jameson held it to be a separation product from sap. Later a large number of scientists regarded it as certain that the carbon came from the decomposition of organic matter, either vegetable or animal, but they were divided as to the means by which carbon in its ordinary organic combinations could be transformed into the allotropic form Diamond, some holding that a very high temperature was necessary, and others that the change could be accomplished at comparatively low temperature. Of the latter group, D'Orbigny and Wöhler were some of the first thinkers. Later, when it became known from experimental work that Graphite, and not Diamond, was formed by the action of great heat on amorphus carbon, there were several who held to the low temperature theory, among these G. Bischof. J. D. Dana, of the former group, believed it to result from the alteration of carbonaceous matter by processes then invoked to account for the metamorphism of rocks. Parrot believed the change to occur from the sudden cooling of highly heated organic matter, and Carvill Lewis, from a study of the South African deposits, came to the conclusion that the

Diamond was there formed in the rock *in situ* at the time of its consolidation from the molten condition, and that the carbon was derived from the carbonaceous shales caught up in the molten mass during its intrusion. C. von Leonhard thought it arose as a sublimation product. Liebig believed various products were formed, ever growing richer in carbon, and from the final substances pure carbon crystallised out as Diamond. Others held its formation to be due to the decomposition of a gaseous hydrocarbon or of carbon dioxide. Simmler suggested that carbon was soluble in carbon dioxide under great temperature and pressure, deriving this idea seemingly from the presence in Diamond of liquid carbon dioxide in minute cavities. St. Clair Deville advocated an origin from halogen compounds of carbon. Sorby felt that the presence of carbon dioxide in the cavities was irreconcilable with the association of more than a very little water in the formation.

Any consideration of the subject must necessarily take into account the modes of occurrence at the various localities, so it may be convenient to briefly consider here where and under what conditions Diamond is found.

By far the most important locality at the present day is South Africa, for this region now produces at least nine-tenths of the total output. The discovery of Diamond there only took place in 1867, and the exact circumstances are variously given. According to the more general story, the child of a Boer, named Jacobs, was seen playing with some bright stone picked up in the neighbourhood. A visitor to the house, named Schalk van Niekerk, saw it and offered to purchase it, as it seemed peculiar to him, but his host insisted on making him a gift of it. Van Niekerk, according to this version, handed the stone to O'Reilly for identification, and the latter pronounced it to be a Diamond; it weighed rather more than 21 carats. The other version states that the stone passed to O'Reilly from Jacobs, and that O'Reilly sent it to Dr. Atherstone, of Grahamstown, who identified it by scientific tests. Be that as it may, the Diamond was found near Hopetown, in Cape Colony. It was sent to the Paris Exhibition of 1867, and afterwards purchased by the Governor of Cape Colony for £500. Careful search by the settlers of the district brought to light more stones, and next year workings on the Vaal river added to the number. Up to the end of 1870, these river workings were the only ones that were productive. The stones were found chiefly in the Vaal about Barkly West, some occurring in the gravel in the bed of the stream, and often quite a number being found in the "pot-holes," eroded by the river setting stones whirling round in its bed. It was also found that the old river terraces bordering on the present bed yielded Diamonds, even to a height of 200 feet above the present level. Specimens were found as far up as Christiana, in the Transvaal, though the lower workings were most productive. Since the stones occurred amongst water-worn material, and themselves showed signs of such erosion, it is obvious that they have been transported some distance by the stream; the gem is associated with other minerals, such as Quartz, and several varieties of Chalcedony, Garnet and Ilmenite. In quality these "river-stones" are good, and hence they command a price above that obtained for stones from the "dry diggings," to be mentioned next.

At the end of 1870, some chance discoveries of Diamonds on the farm of Du Toit's Pan led to the opening up of the mine now known by that name, and soon there was a rush. This discovery was followed by another close by, on the site now occupied by Kimberley; this was the famous De Beers' mine. In all there are now four large deposits close to the town. Two other deposits were also found south-south-east of Kimberley, namely, the Koffyfontein and Jagersfontein mines, in what is now the Orange River Colony. A very important deposit has more recently been found at the New Premier mine, near Pretoria, from which the famous Cullinan Diamond was obtained.

There was little on the surface to mark the position of these deposits around Kimberly; some of them were slightly raised above the surrounding country, some showed a slight depression. When they came to be worked, however, it was soon seen they were anything but surface deposits, as at first supposed, for the material in which the Diamonds were found was utterly unlike the neighbouring rock, from which, moreover, it was separated by a sharp line of demarcation. This surrounding rock consists of beds of the Karoo formation. Under a layer of reddish earth is a bed of calcareous tufa which has evidently been deposited long subsequent to the formation of the material in which the Diamonds are found, and therefore, too, later than the Karoo beds, which are themselves of comparatively recent geological age, belonging as they do to the time of the New Red Series. The Karoo beds, as seen in the Kimberley mine, consist of a layer of shale, varying in colour from a greenish tint above to yellowish below; an intrusive sheet of dolerite of late Karoo age follows, and with the shales makes up a thickness of 50 feet. Below this comes a bed of black shales some 250 feet in thickness; the black colour is due in part to carbonaceous matter and in part to disseminated Pyrites, as is the case in many of the black shales of carboniferous age in England. Below this again is a layer of somewhat decomposed basic volcanic rock containing amygdules, of 394 feet. Lower still comes a 400 foot bed of quartzite, and under that is another 260 feet of black shales; both the quartzite and the black shales are penetrated by dolerite dykes. The general disposition of these rocks is horizontal, or nearly so, except near the pipe, where a dip away from the vent is sometimes seen. Below the lower shales there is over 1,000 feet of quartz-porphyry in the Kimberley mine.

The Diamond-bearing ground consists of a mass of irregular fragments of rock of various shapes and sizes, usually with more or less angular outline, and consisting not only of the shales and basic volcanic rock from the surrounding Karoo beds, but also of rocks not seen in the neighbourhood; some blocks belonging to the Middle Karoo sandstones, blocks of ultrabasic rock called eclogite, masses of mica schist, and pieces of granite. Some of these masses may contain many thousand cubic yards of material, others are minute splinters, and every gradation is found between these extremes. All these fragments are embedded in a bluish-green material consisting largely of a hydrous magnesium-iron silicate, with some carbonate of calcium. The whole mass has a general bluish tinge, except near the surface, due to the dissemination of this material, and from this appearance it has been named "blue-ground." Where this has been exposed to the weathering influence of surface water, that is for a depth of 50 or 60 feet, the process of oxidation has converted some of the ferrous compounds into ferric, with the result that the colour is yellow instead of bluish, and this upper weathered portion is therefore known as "yellow-ground." At the point of junction of yellow-ground and blue-ground there is sometimes a transitional layer of "rusty-ground," marking a lower stage of oxidation.

On carefully examining this mass of Diamond-bearing material, we find it is roughly in the shape of a tube. The Kimberley mine "pipe" has the form of an inverted coaching horn. In other words, the plan on the surface is circular in general outline, and at successively lower levels the cross section becomes less, though it decreases at a slower rate as the depth becomes greater. In all the mines the surrounding rock abuts suddenly against the mass, often with the beds turned upwards next the pipe, separated only by slight fissures filled with secondary minerals, if separated at all. Thus the material is filling a huge "pipe" of unknown depth and of a surface diameter varying from 200 to 700 yards in the different pipes. There seems little doubt that the material filling these pipes consists of the larger fragments ejected by an ancient volcano into the air, thence to fall back again into the throat or vent along with a certain amount of finer volcanic dust and probably large quantities of water condensed from the steam accompanying the eruption; this volcanic origin of the pipes was first suggested by Cohen in 1872. The bell-mouth of the pipe in the Kimberley mine suggests that no very great thickness of rock overlaid the present surface at the time the volcano was active, so in that case almost certainly all the "foreign" rocks contained in the pipes are from below, and in the other cases there is a probability that they are also rocks from lower strata. Such a mass of volcanic material is called an agglomerate, and, as is not infrequently the case in other agglomerates, it shows signs of more than one outburst of volcanic activity, for the whole mass is sub-divided in several of the mines into vertically columnar portions which seem to mark a later eruption, which has resulted in the material already choking the vent being broken through and a fresh vent being formed, to be itself afterwards choked up. Much of the matrix material must originally have consisted of a ferro-magnesian silicate by the hydro-metamorphism or thermo-metamorphism of which the serpentinous minerals have originated. It is entirely in this blue ground that the Diamonds occur, none ever having been found in the surrounding rock.

In the De Beers mine a dyke some five feet thick traverses the blue ground in a sinuous path, and is hence known as the "snake rock." It is of much the same composition as the blue ground, but contains no Diamonds. In the South African Museum there is a specimen of dyke from the blue ground of the De Beers mine, which shows good crystals of Olivine in a ground mass of Perofskite, Magnetite, and Calcite. The occurrence of Diamond in agglomerate near Pretoria is of interest, as here the geological horizon is far below the carbonaceous shales (Molengraaff).

The associated minerals in the Kimberley district consist of a large variety of species, chief among which in point of abundance are Garnet, Enstatite, and altered Mica. The Garnet is of the variety Pyrope, and occurs in broken fragments, often fresh, but sometimes partly decomposed Chromium is always present in it. The Enstatite is often found enclosing Garnet. Amongst other minerals of less frequent occurrence, but in some cases of greater interest from the point of view of the origin of the Diamond, are Diallage, Tremolite, Wollastonite, Ilmenite, Magnetite, Chromite, Zircon, Sapphire, Topaz, Tourmaline, and Rutile.

Other minerals of more recent secondary origin, as Calcite and some of the Zeolites, are found, but they are of much less importance in the present respect. The Diamonds themselves occur either in crystals or in broken fragments, often in cleavage octahedra.

India for long furnished the whole output of Diamonds, but to-day the case is very different. Still, the localities where the mineral has occurred are numerous, and have furnished some of the most interesting data for consideration with regard to the origin of the gem. When the Diamond was first found in India is not known, but Ptolemy refers to its occurrence there.

The famous Golconda mines are really far from the place of that name, being situated in various groups, distant 100 to 200 miles to the south and east of Golconda. The most southern of these mines are along the Penner river, and to the south of Karnul, and between it and the Penner is another series. To the north-east again, on the Kistna river, are the mines of Kollur, whence are supposed to have come the Koh-i-Noor, the blue "Hope" Diamond, and the Great Mogul. In all these mines the mineral occurs in some derived rock, sometimes in a loose sand, as at Kollur and Partial, or in alluvium, as at the Chennur mines. At the mines to the south of Karnul the Diamond occurs in a bed of conglomerate of fragments derived from shales and Lydian-stone, only a few inches thick. At Muleli, between the rivers Kistna and Godavari, the rock containing the

Diamonds is also composed of the cemented detritus of other rocks.

But at Wajra Karur, near Bellary, in north lat. 15° and east long. 77°, where the Diamonds are often found lying loose on the surface after a rain, a much more interesting and instructive mode of occurrence is recorded. Chaper, ("Comptes Rendus," vol. xcviii., 1884), a French traveller, states that he himself found two Diamonds in this neighbourhood in 1882, in some of the pegmatite veins, with Epidote, traversing the gneiss which underlies the soil here. The Diamonds were associated with Ruby and Sapphire. It has been suggested that Chaper was deceived by his native attendant, and that the associated Corundum showed signs of workmanship. As Max Bauer points out, the association of Diamond with Corundum and Epidote, is met with elsewhere in India, and the detrital rocks in which the mineral occurs in these other localities may possibly have originated from the disintegration of a rock similar to the gneiss of Wajra Karur. To the west of this town a pipe of material similar to the agglomerate of Kimberley was found, but it yielded no Diamonds. Still, many similar pipes in South Africa have shown no signs of this gem.

Some 400 miles to the north-east of the Kollur group of mines there are found many deposits in the Mahanadi river, chiefly in its upper part. This river has been by some identified with the river mentioned by Ptolemy. The Mahanadi deposits occur in the sand and gravel brought down by the river, so the only light thrown on the origin of the mineral is what is derived from a consideration of the associated minerals. These, besides Quartz and some varieties of Chalcedony, include Garnet, Beryl, and Topaz.

Other deposits in river gravel occur about 200 miles south-west of the previous group at Wairagarh; also 100 miles north-east to 200 miles north-north-east of the Mahanadi deposits, near Jushpur, and about Sumelpur. Many of these seem to have been of considerable importance at the time Tavernier visited them (1560), but now they are not of great interest as productive deposits.

A large group of deposits extends south-west from Allahabad for 150 miles or so, and is known as the Panna group. At none of these Panna mines is the mineral actually found in the rock in which it was developed. In some of the workings it occurs in thin beds of detrital rocks of great age; in others, again, simply in sands and gravels derived from a further disintegration of these detrital rocks. Only at Birjpur has the material been cemented into a firm conglomerate. The associated minerals do not seem to be of special interest, consisting only of siliceous minerals in most cases.

In the early part of the eighteenth century Diamonds were found in Brazil in the gold washings in the State of Minas Geraes, though not definitely recognised as such until they came into the hands of the Dutch consul at Lisbon. They are usually said to have been found first a short distance to the west of Tejuco, a town which afterwards became known as Diamantina, lying some 340 miles north of Rio de Janeiro. The mineral is found under different conditions in the various kinds of workings, but the most important from the point of view of the origin of the mineral are what are known as "plateau workings." These occur on the high ground around Diamantina at a height of 4,000 feet above sea level. A mountain chain, the Serra do Espinhaço, running generally north and south, ends in this high ground of the plateau; the surface rock is a thinly laminated sandstone containing flakes of a green Mica. It has the peculiar property of flexibility, just as some of the Indian sandstones have, and much interest would attach to a microscopic examination of this rock to determine the shape of the sand grains. In places the rock is of a coarser nature, more approaching a conglomerate. The age of the stratum is not definitely known, but is almost certainly of considerable geological antiquity; from its extensive occurrence in the Serra Itacolumi it is generally spoken of as itacolumite; it is interbedded with schists in which Hornblende, Hæmatite, and Mica are developed. This is a point of great importance, for it points to the rocks having undergone considerable metamorphism. Underlying these rocks are others described as gneiss; the itacolumite and the schists are penetrated by "veins" containing a good deal of Quartz.

Where the rivers have cut through layers of Diamond-bearing rock the gem is found in thin beds, often for a considerable distance; thus the Rio Jequetinhonha and its tributaries have Diamond-bearing gravels as far down as Mendanha, though the tributaries coming in from the plateau to the west are most productive. Other streams which do not cut these rocks yield no Diamonds, as, for instance, the Rio Doce.

The gravels worked in the present river beds are the "river deposits." It is found that the larger Diamonds occur in the upper part of the stream, while lower down the stones are smaller. This is as one would expect, for not only would a substance of a moderately high density such as the Diamond be difficult to move by any but more rapidly running water, but also transportation over many miles of country would mean a considerable reduction in size even to the Diamond. As in South Africa, the pot-holes in the river beds are often found to yield a large number of the stones.

What are known as "valley deposits" are very similar to the river deposits, except that they represent much older detrital matter carried down by the stream when its bed was at a higher level than now. This detritus is now left along the banks in the old river terraces. In some cases material of this kind is found to have been re-cemented into a conglomerate.

The "plateau deposits" near Diamantina consist of large broken fragments of the rocks from the district around, embedded in a red earthy ground mass. This mass is known locally as "gurgulho." A noteworthy point is that the rock fragments are angular, or only very slightly rounded, suggesting an origin similar to that of the "brockram" of the New Red Series in England.

Some distance to the west of Diamantina, at São João da Chapada, the Diamonds occur in a very peculiar plateau deposit, lying in great trenches of over 100 feet in depth, and twice that in width, and several hundred yards long. These trenches are filled with alternating beds of clay and itacolumite; the beds are well marked and have a pronounced inclination to the east. Penetrating these beds are "veins" containing Quartz, Hæmatite, and Rutile. Other minerals in association with the Diamond are Tourmaline, Anatase, and oxides of iron. All the minerals are found in crystals without any sign of erosion, and it has been noticed that where these associated minerals are more abundant the Diamond is more common also.

Gorceix (" Comptes Rendus," vol. xciii., 1881), has been led to conclude from an examination of this deposit that the Diamonds here occur *in situ*, that they have actually been formed in the Quartz " veins " which so frequently penetrate the rocks here. So far no Diamonds have actually been seen in the "veins," though they have been found adhering to Quartz and to the other minerals occurring in the " veins."

One cannot but wish more definite information was available as to this deposit, especially as to the geological history of the trench and its contents and their relation to the surrounding rocks, the past physical history of the district, and most particularly the relation of the " veins " to the rocks they penetrate.

At Bagagem, some 200 miles west of Diamantina, in the Serra dos Pilons, are other deposits, famous as having yielded in 1853 the Star of the South, a fine stone of 254¼ carats. South of Bagagem, at Agua Suja, Diamonds have been found associated with Magnetite, Ilmenite, Rutile, Garnet and Perofskite, in a ground-mass consisting of blocks of rock derived seemingly from rocks which are *in situ* close by.

At Grão Mogol, near the southern extremity of the Serra Diamantina, some hundred miles north-north-east of the town of Diamantina, there is a deposit of the gem in a sandstone; this sandstone has green Mica developed along its bedding planes, and contains the same minerals as are associated with the Diamond in the itacolumite. This has led to the belief that this sandstone is derived from the weathering of the older itacolumite, and that it is identical with the sandstone seen lying unconformably on the itacolumite in the Serra do Espinhaço. Diamonds were first discovered at Grão Mogol in the "gurgulho" in 1827, but were not found in the sandstone till 1833.

The state of Bahia, which was formerly of small importance as a Diamond producing region, has latterly been more productive than Minas Geraes. Diamonds were discovered in this state in 1755.

Near Salobro, on the Rio Pardo, nearly 200 miles south-south-west of the town of Bahia, Diamond occurs in clays, in crystals of good quality, octahedral in type. They are supposed to be derived from the crystalline rocks around, but the absence of certain minerals characteristic of these rocks in Brazil has led to doubt being thrown on this origin. Further, although the general mineral associates are much the same as elsewhere in Brazil, there are some remarkable exceptions in the presence here of Corundum and the absence of Tourmaline and the oxides of titanium.

West of Bahia about 200 miles, in the Serra da Cincora, a rich deposit was discovered in 1844, and since that time a large quantity of stones has been obtained from the locality. The Diamond here occurs in alluvial and other detrital deposits, although the hills around are of granite and gneiss.

Most of the Carbonado produced comes from this locality.

In Borneo deposits have been known for a long time, but have never been of any great importance in comparison with the foregoing great areas of production. One group, in the south of the island near Bandjermassim, is in gravels lying on Tertiary rocks, which in turn lie on very old schists; there are also eruptive rocks associated with the Tertiary sedimentary rocks. The minerals here associated with the Diamond are Quartz, Corundum, Magnetite, Chromite, and some of the noble metals. Another group in the west of Borneo, near Pontianak, is in ancient detritus, or in conglomerates composed of rounded fragments of silicious rocks, of schists, clay slates and volcanic rocks. The Diamonds occur usually in sand and alluvial deposits resulting from a further disintegration of these rocks. Associated minerals are Corundum, Magnetite, some Gold, etc. The Diamonds themselves, though rarely of any great size, are remarkable for their colour, especially the very rare black Diamonds previously mentioned. The varieties Bort and Carbonado are also present.

Australia has never produced any large stones, the heaviest being one of 5⅝ carats found in New South Wales, the part of the Commonwealth which has so far been the most productive. Diamonds were first discovered in the gold-washings near Bathurst in 1851 on a tributary of the Macquarie river, along which stream ancient detrital matter has since afforded numerous but small stones, averaging about ⅓ carat. This deposit is an old river terrace, overlaid by a layer of basalt. The mineral is accompanied by Quartz, varieties of Chalcedony, Cassiterite, Topaz, Corundum, Brookite, Garnet, Zircon, Magnetite, Ilmenite, Tourmaline, etc. Other deposits have been found along the upper part of the Lachlan river. In the north of New South Wales, not far from the Queensland border, deposits occur on the Gwydir river, a tributary of the Darling. Here, too, the Diamonds occur in old alluvium, and associated with much the same group of minerals as at the locality near Bathurst, but on the Gwydir the miners attach special importance to the presence of Tourmaline as an indicator of the proximity of Diamond. However, in 1901, Mr. Pittman, of the New South Wales Geological Survey, described the occurrence of Diamond in breccia filling an old volcanic pipe very similar to the pipes of South Africa; the breccia contained angular fragments of sedimentary rocks and acid volcanic rocks as well as of the basic volcanic rocks, basalt and eclogite, and besides Diamonds, Zircon, Garnet and Diopside were seen.

Diamond has been found in all the other other parts of the continent; that is, in Victoria, at Beechworth, and other localities; in South Australia, to the south-east of Adelaide; in Western Australia, near Freemantle, with Zircon, Topaz, Ilmenite and Quartz; and in Queensland, on the Palmer river, etc. Diamonds are also said to have been found at Courina, in Tasmania.

In 1829 the Diamond was discovered in Europe, at a deposit of detrital matter of the Adolfskoi gold washings, not far from Bissersk, and later at other places, as Kuschaisk; also ten miles east of Katherinenburg and other places; later, they have been found in the southern part of the Ural mountains. At Adolfskoi the mineral was found in a gold-bearing sand, associated with, besides Gold, such minerals as Magnetite, Limonite, Quartz, and varieties of Chalcedony, Platinum and Anatase. The sand seems to be derived from matamorphic rocks in the neighbourhood, such as a chlorite-talc-schist, with much Quartz.

Lapland has provided a most interesting occurrence of Diamond; the mineral was found on the border of Russian

Lapland, close to the Norwegian frontier, in a valley near Varanger Fjord. The whole district consists of gneiss traversed by bands of pegmatite, and it was in sand derived from these rocks that the discovery was made. Of the associated minerals, Vélain gives (the most abundant coming first) Garnet, Zircon, Hornblende, Glaucophane, Kyanite, green Augite, Quartz, Corundum, Rutile, Magnetite, Staurolite, Andalusite, Tourmaline, Epidote and Oligoclase felspar, and he believes the Diamond originated in the pegmatite, and at the same time as that rock was formed.

It is of interest to note that Professor Heddle obtained a specimen of rock from three miles north-east of Ben Hope, in Sutherland, Scotland, containing a "red Mica, red Zircons and either colourless Garnets or Diamonds," and it is recorded in the "Mineralogy of Scotland," vol. ii., p. 194, by Mr. A. Thoms, that Dr. Heddle was confident, in his own mind, from their optical properties, that these were Diamonds. The point is of great interest, as beyond this there seems no record of this mineral occurring in the British Islands. At Carratraca, in Spain, Diamond is reported to have been found in a stream with Serpentine.

In North America Diamonds have frequently been found since 1850, when the first one was discovered in the alluvial workings for gold in California. Since this time they have been found at intervals both in the recent alluvium and also in the ancient detritus covered by lava flows. The Californian localities include, in Amador Co., Volcano, where an association with Garnet and Chalcedony is seen; Fiddletown, with Gold and lead- and copper-ores; in Butte Co., the Cherokee ravine with Zircon, Chromite, etc.; in El Dorado Co., at Forest Hill. In

North Carolina, at Brindletown Creek, in Rutherford Co.; at Portis Mines, in Franklin Co., with Gold in placer workings; at Dysortville, in M'Dowell Co. Diamonds have also been found sparingly in Idaho and Oregon, in the west, and in Georgia (Hall Co.). One stone of 23¾ carats was found at Manchester (Virginia) in 1855. It is of interest to note that much of the rock in North Carolina consists of a schistose rock, and that a flexible sandstone similar to the itacolumite of Brazil is also found, though it has not yielded Diamonds so far. In Wisconsin Diamonds have been found in glacial deposits with Quartz, Garnet, Ilmenite, and Magnetite. It is pointed out by Professor Hobbs that the direction of the ice movement shows that most of this glacial *dêbris* came from the neighbourhood of Hudson Bay.

In British Guiana Diamonds have been found in gold-bearing gravels at Omai Creek (Harrison). The gravels seem to be composed of weathered dolerite, with Quartz and concretions of iron-stone. On the upper part of the Mazaruni river they have been found in gold-bearing gravels associated with Spinel, Tourmaline, Ilmenite, Topaz, and Corundum.

Diamonds have also been found in a rock on the Sea of Tanjan in Malacca, in Java, and in Celebes; also at Serra Madre, in Mexico, of the variety Carbonado. King ("Precious Stones"), quotes Ammian for a locality known in the fourth century beyond the Sea of Azov.

Minute Diamonds have been found in meteorites, first in one that fell at Novo-Urei, in Russia, in 1886; but as this is an extra-terrestrial origin, the reader must consult such special articles as Sandberger ("Jahrbuch für Mineralogie," 1889).

On reviewing the whole of these occurrences, it will be noticed that in the great majority of cases the Diamond is found in material derived from the wasting of older rocks. In some cases this wasting is undoubtedly the result of ordinary weathering by the chemical and physical effects of water in decomposing and mechanically wearing away the rocks. In other cases it is more than likely it was due to the influence of great alternations of heat and cold in the atmosphere, principally aided by wind and blown sand. The resulting detritus may occur as a loose sand or gravel, or may be re-cemented into a more or less compact sandstone or conglomerate. In such cases we can learn little of the original rock in which the Diamond was developed except by a study of the associated minerals. Where these occur in a fresh condition we may reasonably assume they fairly represent the original constituents of the rock from which they came; but in all cases it must be borne in mind that the Diamond, by its hardness and chemical stability, might have, so to speak, outlived all its companions, and later have become associated with a fresh group of minerals. In such a case we should expect the associated minerals to be different in many instances; but a review of the whole associates shows a remarkable similarity in their kind, so we may here tabulate the principal associated minerals mentioned in the foregoing pages:—

Vaal River.—Garnet, Ilmenite, Vaalite (a hydrous ferro-magnesian silicate).

Kimberley.—Garnet, Enstatite, Biotite, Ilmenite, Magnetite, Bronzite, Chrome Diopside, Smaragdite, Tremolite, Asbestos, Zircon, Cyanite, Sapphire, Topaz, Rutile, Tourmaline, Wollastonite, Serpentine.

Mahanadi River.—Quartz, Carnelian, Garnet, Beryl, Topaz.

Wajra Karur.—Epidote, Corundum (Ruby and Sapphire), Limonite. Here said to be *in situ* in a pegmatitic band in gneiss.

San João da Chapada.—Quartz, Hæmatite (and other oxides of iron), Rutile, Anatase, Tourmaline. Here also stated to be *in situ* in "veins."

Agua Suja.—Magnetite, Ilmenite, Rutile, Garnet, Perofskite.

Rio Jequitinhonha.—Rutile, Anatase, Brookite, Hæmatite, Ilmenite, Martite, Quartz, Garnet, Zircon, Cyanite, Topaz, Tourmaline, Euclase, Lapis Lazuli, Gold, Limonite, Iron Pyrites, Monazite, Sphene, and others.

Salobro.—Many of the associates of the Rio Jequitinhonha, but without the oxides of titanium, and with the addition of Corundum.

Bandjermassim.—Quartz, Corundum, Magnetite, Chromite, Gold.

Pontianak.—Magnetite, Corundum, various forms of silica, Gold.

Upper Macquarie River.—Chalcedony, Cassiterite, Rutile, Quartz, Ilmenite, Magnetite, Brookite, Zircon, Topaz, Tourmaline, Corundum, Garnet.

Gwydir River (alluvial).—Very similar to the Macquarie associates.

Gwydir River (in breccia).—Zircon, Garnet, Diopside.

Freemantle.—Quartz, Zircon, Ilmenite, Topaz.

Adolfskoi.—Magnetite, Quartz, Chalcedony, Limonite, Anatase, Gold, Platinum.

Varanger Fjord.—Garnet, Zircon, Hornblende, Glaucophane, Cyanite, green Augite, Quartz, Corundum, Rutile, Magnetite, Staurolite, Andalusite, Tourmaline, Epidote, Oligoclase; there is here a strong presumption that the Diamond is from the pegmatite bands in the gneiss.

Omai Creek.—Spinel, Ilmenite, Corundum, Tourmaline, Topaz.

Some of the minerals yield us little information from the mere fact of their occurrence in association with Diamond. Quartz and the other varieties of silica, for instance, occur under such diverse conditions that we can here draw no conclusions as to the conditions under which Diamond was developed.

Many of the others, however, are found to occur under very similar geological conditions in different localities. Thus Tourmaline, Rutile and Zircon are usually found in rocks which have been subjected to marked deformation; they are minerals of dynamo-metamorphic origin, in other words. Beryl, too, often so results, but it and Topaz are sometimes found to have crystallised out late in the consolidation of granite masses. The oxides of iron, titanium, and chronium form an interesting group with many interrelations. Many basic eruptive rocks contain as an original constituent a slightly titaniferous oxide of iron; their pyroxenes too often contain titanium, replacing silicon; the titaniferous oxide of iron occurring thus was designated Iserine to distinguish it from ordinary Magnetite. When such a rock is subjected to dynamo-metamorphism, the Iserine splits up, true Ilmenite resulting in some cases, possibly with accretion of titanium from the pyroxenes. At other times a titaniferous form of Hæmatite results, as is often seen in the Hæmatite-schists such as have been mentioned as occurring in the neighbourhood of Diamond deposits. Other titanium minerals, as Rutile and Sphene, may also result this way, though the latter may be an original constituent, or may result from thermo-metamorphism. Should the pyroxenes contain chromium, Chromite may be formed; more often this is the result of hydro-metamorphism in conjunction with the formation of Serpentine. It is almost impossible to draw any sharp line between these various forms of metamorphism; probably the action is always complex. Of the minerals found in association with Diamond, many usually result from thermo-metamorphism or from complex changes in which it bears an important part. Thus many of the Garnets, Tremolite, Wollastonite, Sphene, Spinel, may be found where a rock containing much calcium is acted on; in argillaceous rocks Cyanite, Andalusite, Staurolite, and some of the Garnets may result. The action of water under great pressure and probably at a considerable temperature in most cases, which brings about the formation of these minerals is at the same time changing the whole rock so that a pegmatite or gneiss may result where the pressure is very great and is only relieved slowly, whereas if the pressure is somewhat less and relief takes place suddenly an eruptive rock may result (J. G. Goodchild, H. M. Geol. Survey., "Proc. Royal Phys. Soc." Vol. XIV.). The theory that such rocks are the result of a regeneration of this kind seems in accordance with the facts as observed in the field; if so, many of the difficulties surrounding the apparently diverse origin of Diamond become much less. In the two most reliable instances of occurrence *in situ* recorded until lately—namely, at Wajra Karur and in Lapland—both observers referred the original site to the pegmatite bands in those localities. In the Lapland instance the gem was not actually *in situ*, but the surrounding rocks were of so similar an origin as to make the presumption strong. Moreover, the pegmatite bands and the gneiss would appear to be but an earlier and later stage of the same metamorphosis. Gorceix concluded the San João Diamonds had also originated in pegmatite "veins." The fact that in these bands Quartz, Anatase and Hæmatite, seem to have been simultaneously formed with the Diamond, recalls the changes described above concerning these oxides. Rodgers ("Geology of Cape Colony") points out that although the materials filling the pipes of South Africa differ so, yet there are gradations from one type to another; and Prof. Bonney (*Geol. Mag.*, 1899, p. 309) records the presence of Diamond in eclogite (an ultra-basic rock without Olivine) from Newland's mine in Griqualand West. Rodgers concluded that the Kimberley Diamonds probably originated in a deep-seated ultra-basic rock-magma, explosions proceeding from this or a lower horizon having filled the pipes with brecciated material containing a large proportion of ferro-magnesian silicates; subsequent hydration would convert the material into a serpentinous mass such as is there seen.

Great stress has been laid on the association with Olivine, but there are many occurrences without this associate, and in any case, if Diamond originates by this action of heated waters the same action could affect, and apparently does affect, rocks containing no Olivine. Although it has been allowed that the pegmatite bands might represent the solidification of fused silicates saturated with water, the full importance of the water does not seem to have been given due prominence to, although Daubrée in 1876 stated that highly heated water would, even in a few *days* transform three times its weight of amorphous silicates into Quartz and crystallised silicates. This in man's laboratory; in Nature's laboratory, with great time and great stores of energy, how much greater changes can conceivably be wrought! The formation of gneiss has been assumed to be independent of the action of water; such is probably not the case, water being on the contrary an essential factor.

Chemical Composition.

Diamond consists of pure carbon, an element which also occurs in Nature in an allotropic form, Graphite. As might be expected, the composition of this remarkable mineral very long ago was the subject of speculation. Boetius de Boot, in 1609, stated his supposition that it was a combustible substance, and in 1673 Robert Boyle discovered that under the influence of a high temperature it was "dissipated in acrid vapours." About twenty years later two Academicians of Florence experimented in the presence of the Duke of Tuscany and confirmed Boyle's observation, and a hundred years after that again, Macquer and Bergman continued the experiments with the same result. In 1772 Lavoisier showed that it was only when heated in contact with air or oxygen that it so disappeared, and he further proved that the product of its combustion caused a precipitate in lime water which effervesced on treatment with an acid, as did also the product of the combustion of carbon. Then, in 1797, Tennant showed that the amount of carbon dioxide formed from a given weight of Diamond was the same as that formed from an equal weight of carbon, and hence established the identity.

According to Moissan, Diamond unites with oxygen when a temperature of 620° to 840° C. is reached, and Lavoisier gives the temperature of ignition in air as 916° C. In oxygen it burns with a pale blue flame, and continues burning after the source of heat is withdrawn. It is insoluble in all the ordinary solvents (see Sir W. Crookes' account of Moissan's experiments under Artificial Production).

When heated in the electric arc away from oxygen, a slow conversion to Graphite takes place, and Despretz, by the use of an electric spark from some five hundred Bunsen cells, detected some beads as though fusion took place when the heating was very prolonged. Only specimens containing impurities leave any ash on ignition. From the variety Carbonado, Rivot found the ash varied from 0·24 to 2·03 per cent.; the ash consists chiefly of the oxides of iron, silicon and calcium. Inclusions of other minute Diamonds have been observed, and also of Hæmatite, and possibly of Rutile or Ilmenite. As with many other minerals, enclosures of liquid carbon dioxide are sometimes seen; in some cases these are so numerous and so minute as to give the crystal a clouded appearance.

METHODS OF MINING.

The means taken to separate Diamond from its surroundings vary with the nature of the deposit, but may be generally classified as to whether the deposit is a river or alluvial one, or one in more solid material as at Kimberley. In river workings the usual method adopted is to divert part of the stream by means of a dam, or by cutting a flume, the bed of the river so exposed being then cleared of all its gravel, which is carefully saved. The stream is diverted when the water is as low as possible, and the gravel put aside till the rainy weather when work in the river is no longer feasible; then the gravel is placed on a sloping table some 5 feet by 2 feet, with a pit at the lower end, in which the workers stand. About a barrowful of material is treated at a time; the gravel is placed at the upper end of the table and water thrown over it to wash away the lighter minerals; the residue is hand-washed in bowls in much the same way as in "panning" for gold, and the Diamonds picked out by hand. In searching the river bed particular attention is paid to the pot holes, as they often give a rich yield. Thus Dr. Cliffe records that one such hole in Brazil yielded 10 lbs. of Diamonds and 28 lbs. of Gold when discovered in 1847.

In the Kimberley deposits the original method of working was somewhat similar, but gradually as the claims were worked further and it was found that the deposit extended to greater depths, other methods had perforce to be adopted. Different claims were worked with varying degrees of enthusiasm, and soon the workings presented a wonderful assortment of rectangular pillars, with corresponding depressions here and there where some miners had pushed on the work at a greater rate. The material was hauled up on wire ropes, one for each claim, and the maze of wires added to the extraordinary appearance. Tracks left between groups of claims to act as roads began to give way and several large slips occurred. Soon one gigantic pit resulted, and to add to the difficulties of the miners still more, water began to give trouble in the wet weather, its absence in the dry season being equally troublesome. These difficulties were overcome by the gradual combination of the workers, and finally the whole group passed into the hands of the De Beers Company, whose great capital has enabled work to be carried on in a scientific way.

At present in the Kimberley mines the blue ground is worked by shafts sunk in the solid Karoo beds, from which levels run out to cut the pipe. The blue ground so obtained is laid out on depositing floors of large area; on these, the blue ground spread out to a depth of 30 inches or so, crumbles down under the influence of atmospheric changes, the process requiring from a few months to two years, the resistance of the material varying in different mines, and in different parts of the same mine even. Any material which does not soften under this treatment is disintegrated mechanically. The broken down material is next washed and concentrated in machines somewhat like the "buddles" and "jiggers" of metalliferous mines, advantage being taken of the higher specific gravity of the Diamond to separate it from the lighter minerals, though several of its associated minerals being of nearly as great, or in some cases greater, density, remain with it; from such the Diamond was till recently separated by hand, the washed gravel being fed on to a long shallow trough lined with zinc, and having a slight slope. The gravel reaching the table at the higher end along with a stream of water was moved along by the sorters standing at the side by means of small flat pieces of thin metal, and any gems picked out and placed in small dishes, according to their kind and quality. Great dexterity was shown in this sorting and a remarkable keenness of sight, any doubtful mineral being adroitly tapped with the metal, apparently with a view to determining its nature by its "feel." Now, however, the gravel is passed over a vibrating table with a stepped outline, the steps being covered with a thick layer of grease, to which the Diamonds adhere (Claremont).

APPLICATIONS.

Besides its use in ornament there are certain technical purposes for which Diamond is used. Perhaps the most familiar use is in cutting glass, and it is a common belief that any bit of Diamond will do for this purpose; but a glazier would soon tell one this is not the case. It is found that the best form for this purpose is a natural crystal having markedly curved faces, meeting in a not too obtuse edge. When such a crystal is mounted in its holder and lightly applied to the glass with the faces bounding this edge making equal angles with the glass, and the glass itself making a tangent to the curved edge, a clear scratch will result almost like a cut, though only about $\frac{1}{200}$ inch in depth. Even with a suitable Diamond it requires considerable skill to cut glass properly, and different cutters have to be used for different kinds of glass. In mounting the crystal, attention should be given to the varying hardness in different directions, so that if a suitable edge presents it may be utilised. Wollaston ground other gem stones into a form similar to that between two curved faces of Diamond and found them satisfactory, though not so durable as the usual cutter.

Diamond is also largely used in the manufacture of rock drills. For this purpose the varieties Bort and Carbonado are preferred on account of their smaller liability to damage, cleavage being less prominent than in the crystallised variety, or absent. Some specimens of Bort and Carbonado also show a hardness superior to the gem variety. In use, circular rings of steel, called "crowns," are drilled on the flat surface with small holes, in each of which a small piece of Bort is set, usually by drawing the mild steel partly over the stone; so armed, the crown makes a rapid rock-cutting tool for boring artesian wells or making prospecting bores. An advantage of this method is that solid cores are brought up and can be retained for reference as to the rocks passed through. The use of Diamond as an abrading agent has already been referred to under the cutting of gems; it may be noted that the dust produced in the bruting of Diamonds is more efficient on account probably of the flakes being taken off with a definite relation to the directions of greatest hardness. Diamond powder is used now not only in the grinding and polishing of Diamond, but also, on account of the resulting increased speed of work, in the grinding and slitting of such gems as Ruby, Sapphire, Chrysoberyl, Topaz, etc.

Diamond has been used for making small drills to pierce the other gem stones for ornamental purposes, and for wire-drawing dies, and for drilling the jewelled bearings for watches; also for use as a small milling cutter with which to engrave gems and cut seals and cameos.

Dr. Goring suggested its use for microscope lenses, and these lenses were actually made by Pritchard; but a difficulty arose from the specimens used showing optical anomalies due to internal strain, also from the great labour and cost of manufacture.

It is used to provide a cutting edge for lathe tools intended for the working of very hard steel, and Max Bauer instances its use in tools for boring cannon at Krupp's works at Essen.

Of its more frequent use for personal adornment little more need be said. From the time it was first known Diamond has held its place with a uniformity more marked than any other precious stone. An exception is given by King, who states that the Persians only allowed it to rank after Pearl, Ruby, Emerald, and Chrysolite.

In the earliest times the gem seems to have been used largely as a spell against plagues, and the more alarming manifestations of Nature's activity; in mediæval times, chiefly as signs of magnificence and wealth. Thus the robes and crowns of kings were adorned with them, and it was not till the middle of the fifteenth century that it became much in vogue for personal adornment by women, at which time it was introduced by the ladies of the French court.

Diamond as a rule requires little preparation before cutting begins. Should the stone show surface films these are usually easily removed by treatment with "aqua-regia" (a mixture of hydrochloric and nitric acids). Any imperfections are removed as far as possible by cleaving, and the stone at the same time brought to the octahedral form, ready for grinding, if it is to be cut as a brilliant. By far the greatest number of stones are cut after this pattern now. So much has Diamond come to be associated with the brilliant cut that the term "brilliant" is often erroneously used as synonymous with Diamond. Even very small stones can be cut as brilliants by the Dutch cutters, though as a rule the full number of facets are not worked on them. Specimens which are too thin to be cut as brilliants are rose-cut, and very thin cleavage slices are often polished on the two parallel surfaces and used as a cover for miniatures.

Brilliants are almost always mounted now in an open setting, or set "à jour"; that is, they are held by a series of metallic prongs, projecting towards the girdle. These prongs are notched at the end, and one part goes above the girdle and the other below, thus firmly holding the stone and leaving the culasse exposed. Previously Diamonds were always set in a closed setting, completely covering the culasse; and this portion of the stone was covered with a "tincture," a varnish made of mastic, coloured with ivory black, which was supposed to add to the beauty of the gem. A stone showing darker patches is sometimes mounted in a closed setting, and this varnish applied so as to come below the lighter portion; thus the stone will seem of more uniform appearance. This is known as "mounting on moor."

Rose-cut stones are always mounted in a closed setting.

VALUE.

Of the value of Diamonds it is difficult to speak with any precision, as so much depends on the quality of the stones, and in the case of large stones, which very few people could afford to buy, so much depends on whether any such people wish to buy at that time. The old rule of Tavernier to find the value of a given Diamond, cut as a brilliant and of the finest quality, was to square its weight in carats, and multiply by eight. Hence a stone of two carats was worth

2 × 2 × 8, or £32 while one of three carats would be 3 × 3 × 8, or £72; this however gave too high a value even at the time it was introduced; in 1869 when a rough Diamond of one carat was worth about £5, Schrauf suggested another rule by which the value in pounds would be found by dividing the weight in carats by two, and multiplying this dividend by the weight in carats plus two, and by the value of a stone of one carat. Thus, if a stone of one carat were worth £12 cut, a stone of the same quality, but weighing two carats, would be worth $\frac{2}{2}$ (2 + 2) × £12, or £48. A rose-cut stone of the "first water" is worth about four-fifths as much as a brilliant-cut one of the same quality. First water stones are those which are perfect; those of the "second water" are such as only show slight imperfection—either flawless, but tinged with colour, or colourless, but with slight flaws. "Third water" stones show more marked flaws, or departure from the colourless ideal. "Fancy stones" are those of marked and beautiful colour, and such cannot be valued by any rule. A brilliant of the second water is worth about two-thirds as much as one of the first water, but a rose-cut stone of the second water does not differ so much from one of the first water. With the increased production these values are not very reliable, and smaller stones of all but the first water only increase in value in direct proportion to their weight. A first water stone of one carat cut as a brilliant may now bring £15 to £25.

Counterfeiting and Recognition.

The Diamond may be imitated by other colourless gems, as Topaz, Corundum, Spinel, Quartz, Phenakite, or Tourmaline, or by Zircon whose colour has been discharged by heating. Diamond differs from all these by its greater dispersive power and consequent greater "fire." Its lustre is much higher than that of any of the other minerals mentioned, except Zircon, which may approach it. Probably the most ready test of all is that of hardness, and for this purpose carborundum is very well suited, for should the stone be genuine, it will not be scratched, but should an inferior stone have been fraudulently substituted the carborundum will scratch it, even if it be of hardness equal to 9 of Mohs' scale (Corundum). It should be noticed that both the crown and the culasse should be tested (see "Doublets" under Artificial Production). In considering the purchase of a valuable stone it should always be seen unmounted. Its single refraction would show it to be a cubic mineral, while of the above imitations only Spinel agrees in this respect, and Spinel is readily distinguished by its inferior hardness. The specific gravity of Diamond also is of some help, though Spinel, Topaz and possibly Tourmaline might be confused with it in this respect.

Glass imitations have almost as high a dispersive power, if good, but their inferior hardness is very marked, and good glass imitations are usually sold as such.

The great test in De Boot's time was that of applying the "tincture"—the varnish mentioned above; a Diamond became more brilliant, but an imitation became less brilliant when the "tincture" was applied to the under surface.

Famous Diamonds.

A Diamond whose history is as old as any, perhaps, was the one worn by Charles the Bold in his pendant. It was not very large in comparison with many stones now known, measuring some $\frac{5}{8}$ inch on the edges of the girdle, and it would probably weigh about 30 carats; but it is of great interest as being the first stone cut by De Berquem. Some of the traditions concerning it have been given when dealing with the history of cutting.

The Sancy, with which Charles the Bold's Diamond has often been confused, is a stone of $53\frac{3}{8}$ carats. It is said to have belonged to a French nobleman called De Sancy, from whom it passed to either our Queen Elizabeth or Henrietta Maria; it finally passed back to France to the possession of Louis XIV., but was stolen at the time of the Revolution and not recovered. After being amongst the Spanish regalia, it passed in 1828 to Prince Demidoff, and it is now owned by the Maharaja of Patiala. It is cut as a double rosette.

Three other stones whose history is obscure and interwoven are the Great Mogul, the Koh-i-noor, and the Orloff. The Mogul was seen by Tavernier in 1665, during his visit to India, amongst the jewels of Aurungzebe, when it was weighed and drawn by him. It is supposed to have been found in the mines of Kollur, and to have weighed 560 to $787\frac{1}{2}$ carats in the rough; it was cut into a high-crowned rose by Borghis of Venice, the finished weight being 280 carats. King records that Aurungzebe was so enraged at the diminution in size, that instead of paying his jeweller for cutting the stone, he fined him 10,000 rupees. What came of the Great Mogul is not definitely known, but it has been supposed that it was divided into three stones, of which the Koh-i-noor and the Orloff are two. It has also been stated that the Mogul was taken by Nadir Shah at

Delhi, and it may be still amongst the Persian jewels. It is noteworthy that De Boot mentions a stone of 187½ carats as an Indian one, of which there is no other record unless it is identical with the Koh-i-noor, which weighed 186½ carats before it was recut. In this case it seems likely that the Great Mogul was not divided.

The Koh-i-noor also passed from the Mogul Empire at the conquest of it by the Persians in 1739. Later it was in the possession of Runjeet Sing, who wore it, alone, on his arm; at times it was used to decorate the trappings of his horses. On the annexation of the Punjab it passed to the East India Company, by whom it was presented to Queen Victoria in 1850. It was exhibited at the Great Exhibition and recut in London by Dutch cutters in 1852, the work costing some £8,000. In its recut state its weight is 106 carats.

The Orloff Diamond has also a mysterious past; it is reported to have formed an eye for an idol in a Brahmin temple at Seringham, to have been stolen by a French soldier, and passed by the hands of an English sea captain to Amsterdam, where it was bought for Catherine II. of Russia by Prince Orloff. It is now set on the top of the Imperial sceptre of Russia. Its weight is 195 carats.

Another famous Diamond from the Kollur Mines was the blue stone lately belonging to Mr. H. P. Hope. It also was exhibited at the 1851 Exhibition, set, with a border of twenty brilliant-cut Diamonds of the first water, as a medallion. It is of a rich Sapphire blue with great fire and brilliancy; its weight is 44¼ carats.

The Regent, or Pitt Diamond, is usually considered one of the finest and most perfectly cut stones in existence. It was found at the Partial Mines in India in 1701, and was bought by Governor Pitt for £20,400; later it was bought by the French Regent for £80,000, and was cut in London at a cost of £5,000. It was stolen with the Sancy Diamond in 1792, but recovered, and still remains the property of the French nation. In the rough it weighed 410 carats, when cut it was 137 carats; in form it is a typical brilliant (Fig. 8).

Of the few engraved Diamonds three may be mentioned. The "Shah" is an elongated stone chiefly bounded by cleavage planes; on it were engraved the names of three Persian kings; it is amongst the Russian jewels. The Akbar Shah was engraved with an Arabic inscription; it is now owned by the Gaikwar of Baroda. Queen Victoria had in her collection of engraved gems a large yellow Diamond engraved with the Prince of Wales' crest; it belonged to Charles II. when Prince of Wales.

The "Dresden Green" Diamond and the "Russian Red" have already been referred to.

The "Star of South Africa" was found in 1869 in river diggings, and passed from a Kaffir to Schalk van Niekerk. Its weight in the rough was 83½ carats, and when cut as a brilliant 46½.

The "Victoria" is also a South African stone; its weight, rough, was 457½ carats. In 1893 a stone of 971¾ carats was found at the Jagersfontein Mine. From it a perfect brilliant of 239 carats was cut, and this is known as the "Excelsior," or "Jubilee" Diamond. A stone of 655 carats was found at the same mine in 1895.

But far exceeding all previous South African Diamonds, and also all previously heard of specimens, is the stone found at the New Premier Mine near Pretoria on January 25th, 1905. It was found in the yellow ground, about 18 feet below the surface. It was named the "Cullinan," after the chairman of the Premier Company. Its weight is 3,024¾ carats, and in size it may be roughly compared with a man's tightly-clenched fist, its longest measurement being rather over 4 inches. A detailed account of it will be found in the paper by Dr. Hatch and Mr. G. Corstorphine ("Trans. Geological Soc. of S. Africa," Vol. VIII., p. 26). A great satisfaction will doubtless be felt by all lovers of precious stones at the decision of the Transvaal Colony to present this famous Diamond to His Majesty the King, thus ensuring to the Empire its possession for all time.

The largest Brazilian Diamond is the "Star of the South," found near Bagagem in 1853. It weighed 254½ carats when rough and was cut into a brilliant of 125 carats.

A great mass of information concerning Diamond will be found in the work by M. E. Boutan ("Le Diamant," Paris, 1886).

CHAPTER VII.

175. FLUOR SPAR.—OPAL.

THIS mineral, although it occurs in such a variety of beautiful colours, is but rarely used as a precious stone. This is largely due to its comparative softness, but also, in all probability, to its abundance; and when it is used it is too frequently with the prefix "false"—"false Topaz," "false Emerald," for instance. This is jarring to the lover of minerals, for why not accept its undoubted beauty for what it is worth, and under its own simple name?

The range of colour it shows is as varied as any mineral known, but the shades of most importance from the present point of view are those that are pure and well marked. Thus it is found of a rich blue, bright green, rose-red, sometimes almost ruby-red, a rich honey-yellow, lilac, amethystine-violet and many other colours.

Its lustre is usually vitreous, but may be almost adamantine; it varies from perfectly transparent to subtranslucent.

Refraction is normally single with a refractive index n_y 1·43, but it often shows anomalous double refraction, which persists even at a dull red heat.

When heated gently it shows marked phosphorescence, the colour of the light emitted varying and having no relation to the colour in daylight. Some varieties give a distinct green light.

Fluorescence is strongly marked in some specimens. Other effects of heat are seen, one of the most striking being the way it decrepitates if heated suddenly, due, it is supposed, to minute cavities within the mineral, containing in many cases liquids. A change of colour may also occur on heating, the blue and violet shades changing to purple. By itself it is not readily fusible, but when mixed with some other substances it easily fuses to a slag and on this account is largely used as a flux; hence, possibly, the name.

On heating, a difference of electrical potential is induced between the cube faces and angles of the cube; this also occurs when light falls on the crystal.

The specific gravity varies between 3·01 and 3·19.

Crystals show a conchoidal fracture and a very perfectly developed octahedral cleavage. On account of this cleavage, Fluor Spar may be used to practice on to gain skill in the cleavage of Diamonds, and Tennant has used the mineral to make models of well-known Diamonds with a view to ascertaining the probability of the Great Mogul Diamond having been broken up into smaller gems. On account of the ready cleavage and natural brittleness of this mineral it is very easily damaged if knocked or allowed to fall. The powder of Fluor Spar of any colour, if sufficiently fine, is white, hence the mineral gives a white "streak" when drawn over a harder substance. The hardness of Fluor Spar is the standard No. 4 of Mohs' scale.

The crystalline form is cubic, and crystals may have the general habit of the cube or the octahedron, often with the edges and solid angles highly modified by faces of other crystal forms. Crystals occur up to a foot or more across the cube face, and in some places in enormous quantities.

The intimate structure of the crystals may be in the form of thin lamellæ crossed, thus possibly accounting for the anomalous double refraction (Hussak). Crystals usually show a definite point of attachment, and as a rule form a two-layered coating in mineral veins. In some cases crystals are found seemingly perfectly developed all over, but these have very likely had some definite point of attachment from which they have become detached, afterwards having the deficient parts made up before the circulation of water bearing the substance in solution ceased.

In its mode of occurrence there are many interesting points to notice. By far its most common situation is in the mineral veins along the line of faults, and in the fault-breccias of such faults. While not strictly confined to the neighbourhood of calcareous rocks, there is yet no doubt that it is more often found in such relation; its distribution in such a vein is curiously irregular, it may be abundant at one point and entirely absent a short distance above or below, or a quarter of a mile further along the fault. As a rule there is evidence of it having been deposited, at nearly the same time as many of its associates, by uprising heated waters bearing it in solution, when these waters reached such a point that relief of pressure and decrease of temperature made it no longer possible for the water to carry so much mineral in solution. These deposits, in most cases at any rate, occurred after the last great movements along the fault ceased, for the crystals rarely show any sign of crushing. Much more rarely, deposits of Fluor Spar occur in volcanic rocks, and here they are probably due to the slow solution of the disseminated material and its redeposition in a seggregated condition at lower levels. An interesting case is that of the Fluor Spar occurring in geodes at Gourock in Scotland.

The associated minerals include most of those found in mineral veins, the commonest being Galena, Quartz, Chalcopyrites, Barytes, Calcite, etc.

Its chemical composition is fluoride of calcium $Ca\ F_2$. Chlorine is sometimes present in traces, and the colouring matter is usually considered to be a compound of carbon and hydrogen. Enclosures of minute grains of Quartz are sometimes seen, and the blue shades with a greasy lustre are most prone to contain bubbles of liquid.

Its distribution is so wide that only the more important localities can be indicated. In England one of the best localities is the district of Alston Moor, comprising the great upland tract to the east of Cross-fell. Here on the old "Corpse-road" from Garrigill to Kirkland, Fluor Spar from the adjacent lead mines has been used as road metal; and to one who is fortunate enough to be passing over it when the sun comes out after a shower, the sparkle of colour is not likely to be forgotten. From the mines of Weardale beautiful violet crystals are obtained. Others, of a green colour by transmitted light, show the property of fluorescence in a marked degree, turning to a blue when viewed by reflected light. Fine honey-yellow crystals occur at Scordale, in Westmorland. Derbyshire is famous for the massive variety known as "Blue John," from which vases and many ornamental objects are made. This variety is particularly fine from Tray Cliff, near Castleton. Cornwall and Devonshire produce crystals having a wide range of colour. Huel Mary Ann, in Cornwall, is noted for the beautiful blue crystals; also Huel Trelawney. St. Agnes yields lilac specimens. In North Wales, at Moel-y-Cria, dark amethyst-violet crystals occur. At Gourock, in Scotland, both purple and green. In Ireland, from Slieve Carne in Antrim, of a green colour. Yellow crystals of various shades are found at Gersdorf and Freiburg, in Saxony. The rare rose-red and pink crystals are found in the Alps (St. Gothard); flesh-red crystals at Münsterthal, in Baden. Green specimens are commoner; Petersburg, near Halle, and Schlackenwald may be cited; also Macomb, in New York State. Blue crystals are found in the salt-mines in the Tyrol, and the tin-mines of the Erzgebirge.

Of its industrial applications, besides its use as a flux in smelting, the manufacture of hydrofluoric acid is dependent on Fluor Spar. It has also been used in the manufacture of apochromatic lenses.

Its use in jewellery is largely in imitation of rarer minerals, which it resembles in colour, and when used for this purpose it is cut after the style that is usually adopted with the gem imitated. Such cut specimens are styled "False Topaz," "False Sapphire," etc. Fluorescent crystals are sometimes mounted openly ("à jour") to display their varying colour. It is a mineral capable of receiving a high polish, but it needs great care in handling. Vases made of the variety "Blue John" can be turned in a lathe until very thin by first treating the material with resin to make it more durable; when so thinly cut the colour is well seen. The purple and red shades are often produced artificially by heating the blue and violet kinds; it has been suggested that the colour is here due to the presence of two hydrocarbons of different degrees of volatility, that which causes the blue shade volatilising at a lower temperature, and thus leaving behind the one producing a reddish tint.

210. Quartz.

This mineral is more abundantly distributed in Nature than any other, yet though so plentiful, in its different varieties, it is largely drawn upon to provide material for use as precious stones. It was the Crystallus of Pliny and other early writers. Theophrastus mentions it as one of the stones set in rings. Amongst the Romans it was very highly prized for the purpose of making vases and cups, and fashion decreed that such "crystal cups" should only be used for iced drinks, hot liquids being served in the Murrhine vases (King).

The known varieties of this mineral are so many that we must confine the general account of the physical properties to the purer forms, and point out, in the consideration of the different kinds that more particularly concern us, any exceptional features in which they differ from the normal.

Pure Quartz is colourless, but small amounts of impurities or enclosures may give it various shades of yellow, brown, green, red, or blue. The lustre is characteristically vitreous, and often in a splendent degree; some kinds have a greasy lustre. The diaphaneity may range from perfectly transparent to opaque. It shows weak double refraction, the indices for the yellow ray being 1·544 and 1·553; and the dispersion is feeble also, the refractive index of the ordinary ray for red light being 1·541, and for violet light 1·558. It follows from this that the separation of the two images seen on looking through a cut piece of the mineral is never great, and that the "fire" is not marked. Also if the mineral be examined under the polariscope with the Nicol's prisms crossed, on rotating the specimen the field becomes lighter, unless viewed along the optic axis, when all remains dark.

It is moderately diathermanous, and conducts heat well; but better along the optic axis than at right angles to it. It is very infusible, requiring the temperature of the oxy-hydrogen blowpipe to fuse it. A difference of electric potential is developed by heat, and also by pressure. Its electrical resistance is high, and hence it is useful as an insulator. Fine spun threads of Quartz retain their insulating properties well, even in moist surroundings.

The specific gravity in pure forms is about 2·65; in some crypto-crystalline forms 2·60.

Fracture: Conchoidal in a marked degree in well crystallised specimens; some massive varieties show a splintery or flat fracture. Rarely, a cleavage parallel to the faces of the positive and negative rhombohedra is seen; the frangibility varies from brittle to tough. The hardness is the standard 7 of Mohs' scale. The streak left on a harder substance is white in the colourless varieties, or of a pale colour in other kinds.

Crystalline Form: Quartz belongs to the rhombohedral division of the hexagonal system, and thus, though crystals appear purely hexagonal, it is found that alternate faces have different physical properties; often the rhombohedral character is marked. The commonest type of crystal is a prism terminated at one or both ends by two rhombohedra which often look like a hexagonal pyramid. The prism faces may be long or entirely absent; when present they often show transverse marking. It is noteworthy that the basal face, or plane normal to the vertical axis, is only very rarely seen; crystals may be highly modified by many crystal forms. The more purely crystallised varieties usually show a point of attachment at one end of the vertical axis. Twinned crystals are often seen.

In its origin, Quartz shows great variety. It is an original constituent of most volcanic rocks, but the kinds we have to deal with more particularly are usually the result of solution of the disseminated mineral, or of the decomposition of silicates, and redeposition in larger masses. The wonderful groups of Rock Crystal found in fissures in the rocks of the Alps, originated in this manner. It is a common constituent of mineral veins, more often as a deposit from uprising heated waters, but sometimes as a later infiltration probably from above.

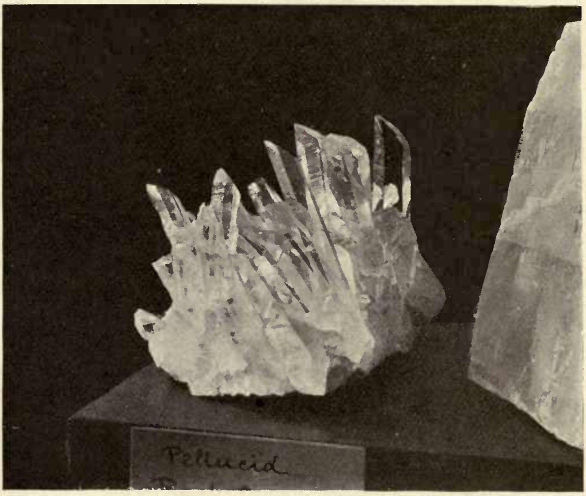

FIG. 12.—Quartz: Var. Rock Crystal. From Dauphiné.

From the varied origin it will be seen that its associates may be almost any other known mineral.

Chemical Composition: Silicon dioxide, SiO_2. Impure forms may contain clay, oxide of iron and many other substances. Inclusions are common and will be referred to below. Although Quartz by itself is so infusible, it is readily fused when mixed with an alkaline carbonate, but this is a chemical action and results in the formation of an alkaline silicate (" water-glass ") which is soluble in water.

A. PHENO-CRYSTALLINE OR VITREOUS VARIETIES.

1. Rock Crystal is the ordinary colourless variety; it is always crystalline and often crystallised. The crystals are usually elongated, and of sizes varying from a small pin to several feet in length. Fresange records a crystal from Madagascar measuring 20 feet in circumference. Dauphiné (Bourg d'Oisans) is famous for its groups of Rock Crystal (Fig. 12). The Alps generally have afforded fine specimens, and a notable group in the Museum at Naples may be mentioned. In 1719 a cavity was found at Zinken, in the Bernese Oberland, from which crystals weighing altogether 50 tons were taken, and sold for some £60,000, some of the crystals weighing up to 8 hundredweight. In Upper Valais, crystals were found in a cavity which were of extraordinary size, up to over half a ton in weight. The Carrara marble quarries have also afforded good specimens. A specimen in Paris, taken by the French in Italy in 1797, weighs 8 hundredweight and is 3 feet in diameter. The Caucasus, Siberia, Brazil, and particularly Japan, have produced fine specimens. In North America,

Moose Mountain, in New Hampshire, may be cited as a locality.

The so-called "Bristol Diamonds" belong to this variety of Quartz, and so does the "Brazilian pebble." Lake George, in New York, has also given its name to "Lake George Diamonds." Many other localities have also had their names used in this way. Speaking generally, when Rock Crystal is cut to simulate Diamond, the word "occidental" is prefixed. The real nature of the mineral may be recognised by its lower specific gravity than other colourless precious stones, by its hardness being exactly 7, and by its want of fire. From Diamond and colourless Spinel it differs in being doubly refracting.

The applications of this variety in the Arts are numerous. As Quartz sand it enters largely into the composition of better qualities of glass, and now pure fused Quartz is being used for some special purposes where glass was used previously. The fashionable ladies of ancient Rome used it to cool their delicate hands with, for this purpose carrying small spheres of Rock Crystal in hot weather. Pliny was informed that a ball of it formed the best means of cauterising any part of the body by physicians, the patient being placed in sunshine for this operation, and the rays passing through the sphere brought to a focus at the desired point. King ("Precious Stones") amongst a wealth of other illustrations of its use in past times quotes an amusing dialogue in Aristophanes in which the use is suggested of a Crystal sphere to conveniently dispose of an unwelcome writ. The use of "Brazilian pebble" in the manufacture of spectacle lenses has long been known. Rock Crystal is also used in lamps for some forms of light treatment in medicine. Fine fibres spun from a bead of molten Quartz are used to suspend the magnets in delicate galvanometers, since they allow the magnets to return very readily to the position of rest when no current is passing. The Chinese make buttons of it.

In ancient times it was highly valued, especially perhaps by the Romans, for the production of vases and cups, some of which were of remarkable size, for it is recorded by Ben Mansur that at the capture of Ghasna in 1159 four vases made of Rock Crystal were found, each of which would hold two skinfuls of water. Pliny records that the material then used came from the Alps, and at that time it was believed to be water frozen so hard that it could not be thawed at ordinary temperature; this is said to have led the Romans to only use it for cold liquids. One of the most beautiful pieces of work in this material was a vase belonging to the French Kings; it was 9 inches high and 9½ inches in diameter, and was carved with figures illustrating the intoxication of Noah. It cost some £4,000.

The Indians used the material also in the production of imitations of the rarer gems, for this purpose staining it in various ways; but though these methods seem to have been known to Pliny, he declines to record them, on the ground that they were fraudulent. Dutens ("Pierres Précieuses") states that the methods were as follows: The Rock Crystal was made red hot and then plunged into various coloured solutions. By this means innumerable minute cracks were produced, into which the coloured liquid penetrated. The colours used were: for Ruby, tincture of cochineal; for Topaz, tincture of saffron; for Sapphire, tincture of Turnesol; for Amethyst, the juice of Nerprum; by using both Turnesol and saffron, an emerald-green was produced.

A cold method consisted in soaking the crystal in a solution of the coloured resins in turpentine or alcohol; how staining occurs in this case is not clear, as ordinary Rock Crystal will not absorb colour; still, the Indians seem to have had some secret method of *uniformly* staining Quartz. More simple methods were to coat the lower part of the cut stone with some coloured varnish, and then mount it in a closed setting. The clear colourless varieties were nearly always set with foil at the back.

The sub-variety known as Iris or Rainbow Quartz, is ordinary Rock Crystal containing fine flaws, into which air has penetrated as a very thin film, giving rise to the optical effect of colour as seen in Newton's rings and in thin soap bubbles. The flaws may be present when found, or they may be induced by a blow or by cooling suddenly after heating. It is cut with a low curved surface kept as close to the flaw as possible.

Iridescent Quartz is Rock Crystal with a thin film of some mineral on the surface of the crystals; this film often consists of Limonite or other oxide. If used for ornamental purposes it must be kept in its natural state, as the beautiful colour is only a surface effect. Very fine colours are seen on some of the Quartz from the Caldew in Cumberland.

2. The variety known as Asteriated or Star Quartz, shows a six-rayed star when cut normal to the vertical axis, similar to the Asteriated Sapphire.

3. Amethyst, Quartz of a violet colour.

Although the name is usually derived from *α* and *μεθυ*, that is "without wine," King suggests it is more likely that the Greeks adopted an Oriental name, and derived their own term from it; and further, attributed to it the property of being an antidote for intoxication. It is sometimes designated "occidental Amethyst" to distinguish it from the very rare amethyst-coloured Corundum, to which the term "Oriental Amethyst" is applied. It is often rather turbid in colour, and not infrequently alternate layers of colourless and amethystine Quartz may be seen in one crystal. Such kinds as are transparent and of a good even colour suitable for use as gems, are designated "precious Amethyst." Good specimens were held in very high repute by the ancients—too valuable to be engraved as most of their precious stones were. Now, however, it is of little value, though even a hundred years ago it was much prized, and Queen Charlotte's necklace of fine Amethysts was valued at £2,000; now the very best qualities are only worth 10*s.* a carat, or less.

In addition to its presumed virtue in allowing of liberal potations without unpleasant effects, it was reputed to enable the wearer to interpret dreams, maintain presence of mind, and cast off evil thoughts, and so on.

It was the eighth stone of Aaron's breastplate, and it has from its use as a ring stone by Bishops of the Roman Church, been called "Bishop's Stone."

Amethyst exhibits a feeble dichroism, the images being a reddish-violet and bluish-violet respectively.

It usually occurs in short prisms with the two rhombohedra, or even without the prism form at all. As indicated in the section dealing with the origin of precious stones in general, Amethyst is often found in vapour cavities in lavas, sometines lining the unfilled portion of an Agate; it also occurs similarly to vein Agate, deposited in fissures by downward percolating water. The formation of one pound of Amethyst in a vapour cavity has been estimated to occupy over one and a quarter million of years (Rudler, "Pop. Science Review," Vol. I.).

What the colour is due to is not absolutely certain, but probably most specimens owe it to the presence of traces of manganese compounds, which impart an almost identical tint to glass when fused with it. Manganese is certainly present in many Amethysts, though in very small percentages, a deep coloured stone only showing 0·01 per cent. (Heintz). The colour is easily discharged by heat.

It is found in many localities. In England, chiefly in the south-western counties—Cornwall, Devon, Somerset and Gloucester. In Scotland, at many places, as Loch Morar in Inverness-shire, Campbeltown in Argyllshire, etc. Ireland, near Cork, and on Achill Island, both providing fine specimens. Abroad, at Oberstein, there was at one time a plentiful supply, but now it is exhausted, though the chief seat of the cutting industry is still there, the material being imported from Brazil, where it is found in large amount. Thus in the Serra do Mar a cavity was found containing 35 tons of Amethyst in 1900 (Max Bauer). Uruguay also provides a good deal. At Mursinka in the Urals it is largely worked, here occurring in veins and cavities in decomposed granite, other cavities at greater depths containing Beryl and Topaz. Transylvania also yields a certain amount. In China large crystals are found, but most of them are turbid. Ceylon yields the finest qualities, it being here found in gravels derived from the weathering of granite rocks, associated with many other gem stones. In North

America, near Greensboro in North Carolina, in the districts around Lake Superior, especially the north-west.

It is usually step-cut and mounted *à jour*. A massive variety, called Prime d'Amethyst, is cut into cups and vases.

4. Rose Quartz is a pink or pale red variety, usually showing a vitreous lustre and small conchoidal fracture; usually not crystallised, and but rarely transparent. Its colour is due to traces of titanic oxide, and is prone to fade on exposure, though it may to some degree be restored by moistening the specimen. When of fine colour it may be cut and sold as "Bohemian Ruby"; more often it is cut into plaques with a curved upper surface. It is rather a rare variety. Localities where it is found are Rabenstein and Königswerth in Bavaria, Ekaterinburg in the Urals, and Beinn Doireann in Scotland. It is distinguished from glass imitations by its hardness and double refraction.

5. Yellow Quartz, or Citrine, is a variety that is often used to imitate yellow Topaz, which it much resembles in colour, hence it is often called "Occidental Topaz" or "Spanish Topaz." Like Rose Quartz, it is one of the rarer varieties. Scottish localities are Loch Avon and Goatfell; in France at Bourg d'Oisans; mostly found in Brazil and Uruguay (often with Amethyst), and is thence sent to Oberstein to be cut. In the Sierra Morena in Spain a variety which assumes a good yellow colour on heating is found; this is cut and sold as "Spanish Topaz." It is distinguished from Topaz when in the rough state by its want of cleavage and by being softer. When cut it may be distinguished by its lower specific gravity and very weak dichroism.

6. Smoky Quartz, or Cairngorm, derives its alternate name from the Cairngorm mountains in Scotland, where it occurs in numerous places. It is the Mormorion of Pliny, but Morion is now rather restricted to the dark opaque varieties. In colour it varies from a pale sherry tint through all degrees of smoky brown to almost black. Transparent to opaque; the darker coloured specimens show a distinct dichroism, one image being yellow-brown and the other a purer warm brown. It occurs in crystals identical in all respects except colour to Rock Crystal; its commonest mode of occurrence is in fissures in granite and allied rocks; sometimes in spaces in the outer parts of a granitic mass, probably due to shrinkage on consolidation; in such cavities sometimes associated with Beryl, Topaz, and crystals of Felspar.

The colour is due to disseminated volatile compounds of hydrogen and nitrogen, which are largely discharged at a comparatively low temperature, so that specimens which are naturally too dark to use as gems may, by boiling in oil, be brought to a rich colour and rendered transparent. One crystal of very dark colour in the Royal Scottish Museum was so treated by Professor Heddle fourteen times, but without attaining the desired result; this, however is exceptional. Usually by raising the temperature to 200° C. the colour is completely discharged.

Of the Scottish localities, Cairngorm and other hills of that range provide good crystals, also Stirling Hill in Aberdeenshire, and Beinn a Bhuird in the same county. Very beautiful crystals are found in the Goatfell granite in Arran. The somewhat similar granite of the Mourne Mountains in Ireland yields beautiful specimens. The central Alps provide the largest crystals, some from the Tiefen Glacier, found in 1868, measuring nearly 26 inches in length; one of the best of the specimens is now in the Museum at Berne; altogether some 15 tons of crystals were found in this one cave. One specimen in the national collection in the British Museum is over 3 feet long. Other localities are Mursinka in the Urals, where also Amethyst is found; and with Amethyst and other precious stones in the gravels in Ceylon. North American localities include Paradise River, in Nova Scotia; Pike's Peak in Colorado; Magnet Cove, Arkansas; Goschen, Massachussets.

It is usually step-cut, sometimes brilliant-cut. In Scotland it is largely used in the mounting of Highland dress accoutrements.

Its specific gravity alone is sufficient to distinguish it from other gem stones of the same colour. In addition its hardness and faint dichroism would distinguish it from any glass imitation.

7. Milky Quartz is a crystalline variety, showing, as its name implies, a milky colour. It is not important in the present relation.

8. Sapphire Quartz, or Siderite, also known as Azure Quartz, is a blue variety, showing a finely fibrous enclosure; it is rarely cut as a gem stone; it is found in an impure limestone at Golling, in Salzburg.

9. Sagenitic Quartz is a crystalline variety, containing enclosures of minerals in fine needles. The forms met with in use as gems are also known as Needle Stone, Venus' Hair Stone, and *Flêches d'Amour*. The substance enclosed may be Rutile or Göthite in the Venus' Hair Stone; coarser acidular crystals of Rutile are seen in the Needle Stone. Fibres of

Actinolite or other members of the Amphibole group occur in the kind known as Thetis' Hair Stone. The high adamantine lustre and rich reddish-brown colour of the Rutile crystals give a striking effect when contained in a polished piece of clear Quartz (Fig. 13).

Madagascar yields specimens containing Manganite and Hornblende. Quartz with needles of Göthite is found near St. Petersburg; that with Rutile occurs in Savoy and Switzerland.

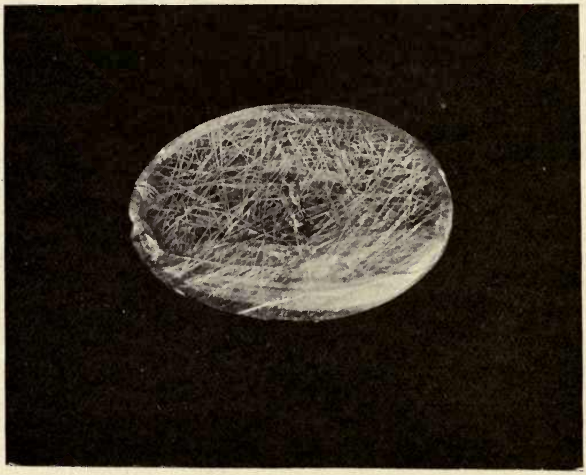

FIG. 13.—Quartz : Var. Venus' Hair Stone.

10. Coming under this head, but worthy of separate mention, is the variety known as Cat's Eye, further distinguished from Cymophane, a variety of Chrysoberyl, as Quartz Cat's Eye, or Occidental Cat's Eye. It is crystalline Quartz, containing delicate closely-packed and parallel fibres of Asbestos, which give it a greenish or grey tint. On

turning the specimen about, however, a wave of milky white light is seen to cross the stone, due to reflection from the innumerable fibres of Asbestos. In some cases the Asbestos has been removed from the more durable Quartz by weathering, and thus a series of minute tubes are left. These, however, give the same optical effect.

Most specimens are from India and Ceylon; in the latter locality the mineral occurs in the gem gravels as pebbles.

It is usually cut *en cabochon*, with the lower surface parallel to the fibres; on turning the stone the band of light is seen to move across; the ideal is to have the light band as narrow and bright as possible.

11. Aventurine is a sub-transparent to sub-translucent Quartz, containing numerous scales of some glittering mineral, which may be Mica, Hæmatite, Limonite, or other mineral. The Quartz is colourless, but the enclosures are usually a golden or muddy brown, sometimes silvery or green, rarely blue. The flakes of the enclosed mineral are often arranged in a definite way, so that on turning the specimen a brilliant metallic reflection is obtained. It is sometimes distinguished from the Aventurine varieties of the Felspars by calling it Quartz Aventurine. When cut as a gem it is usually given a low, rounded surface; more often it is used for the production of vases and similar objects.

Amongst the localities where it is found Pliny mentions it, under the term Corallachates, as coming from Crete. There is a possibility that the Sandaster of Pliny may have been Aventurine in part. In Scotland it occurs on Ben Hope, in Sutherland, coloured by a red Mica and red Zircon; also on Ben Eibhinn, in Inverness-shire. In Spain it is found at Cape de Gatte; at Nantes, in France; in

Piedmont; in the Urals at Kossulina and Kolivan; near Bellary, in India.

It is distinguished from the Aventurine varieties of Felspar by its greater hardness.

12. Varieties containing impurities are not of much importance in the present relation, though a few used to be cut at the beginning of the eighteenth century. The only kinds we need consider are: (1) Quartz, containing Gold in the form of filaments, or scattered particles; in America a considerable amount is cut for use as a fancy stone; but elsewhere it is not often used, except by those who have had to do with gold-mining. Material suitable for this purpose is found in Australia, South Africa, and particularly in the Western States of America. Similar inclusions of Silver are very rare. (2) Quartz containing Hæmatite. This is known also as Sinople, Hyacinth of Compostella, and Eisenkiesel. It is Quartz richly impregnated with the red oxide of iron, Hæmatite, from which it derives its blood-red colour. It has been used to imitate the variety of Zircon called Hyacinth, but is distinguished from it by its inferior specific gravity. It is found in beds of Gypsum at Compostella, in the north of Spain; also in Saxony, Bohemia, and Hungary. The iron mines of West Cumberland afford some very beautiful specimens, the colour in them possibly being due to Turgite, and not to Hæmatite. The Compostella specimens usually occur in short prisms, with a termination at each end.

13. Quartz containing Liquids in Cavities. These forms, though of considerable scientific interest, are rarely used now for ornamental purposes. Some are cut in the United States as curiosities.

B. CRYPTOCRYSTALLINE VARIETIES.

All these consist of a mixture of silica in a colloid or opaline form, and silica in some crystalline form, which has been termed Quartzine, and without or with added impurities.

1. Chalcedony may be regarded as the mixture defined above, without any impurities. It is, so to speak, the foundation material from which, by the intermixture of various other substances, all the further cryptocrystalline varieties of silica, as Agate, Heliotrope, Carnelian, Jasper, etc., result.

The origin of the name is difficult to trace. It seems to have come to be applied to the mineral we now know under this name by a slowly evolved confusion, for the Chalcedonius of Pliny would appear to be Dioptase from the copper mines of Chalcedon. The Leucachates of Pliny and Iaspis of Theophrastus would seem to be, in part at any rate, our Chalcedony.

The colour is characteristically a white or greyish-white, but minute traces of impurities are sufficient to alter the colour, when distinctive names are often applied. The lustre is waxy to slightly greasy. Not being of a definite crystalline structure like Quartz, it lacks the special properties of Quartz dependent on that structure; further its specific gravity is rather lower, 2·59—2·60. The hardness only equals about 6½. Its fracture is flat, and often rather splintery. It is transparent in only a few cases, more often sub-transparent, or only translucent. It has no definite crystalline form of its own, though often found pseudo-morphous after other minerals. In intimate structure it shows a finely fibrous arrangement, which may be only seen under the microscope, or may be apparent to the unaided eye. It occurs in rounded masses (mammillated or botryoidal), sometimes in stalactites, more often in cavities in rocks.

The history of its origin introduces us to so many features of interest in the consideration of the origin of the large groups of minerals formed by downward percolating water, that it has been described in detail when speaking of the origin of precious stones in general.

Chemically it is essentially silicon dioxide, but many specimens are found to contain some water, varying in amount from practically nothing till it approaches the quantity contained in Opal (*q. v.*). The general appearance of the mineral differs somewhat with this varying percentage of water. Under the influence of solvents, such as alkaline solutions, it shows a greater readiness of solution than Quartz. Bands having different degrees of porosity are common.

It is of very wide distribution in rocks of volcanic origin, which have been subjected to some disintegration by water acting chemically. The best specimens come from the Faröe Islands, Iceland and India.

Chalcedony has been much used for vases, cups, beads, dishes, etc. When cut for a ring stone or a brooch, it gives the finest surface if the cut is across the fibre of the mineral. It is sometimes stained before cutting, but not so frequently as the sub-variety Agate, hence the staining will be considered under "Agate."

2. Carnelian.—This is Chalcedony coloured by the oxide of iron, Hæmatite; it was the Sardius of old writers, and

is still sometimes called Sard. Except in the matter of colour, it has the same properties as Chalcedony, and it occurs either as an ordinary Agate, or in fissures as Vein Agate. Although of wide distribution, the chief localities are only two. In India it is found in the Rajpipla hills on the river Nerbudda; also on the Mahi river, north of Baroda. When found *in situ*, the colour is usually very dark, sometimes almost black, sometimes greenish, but on heating it assumes its well known red colour; it is considered that a better colour results by exposing to the rays of the sun, the process requiring as long as two years. It is cut at Cambay.

In Brazil it is found at Campo de Maia, associated with Agate. Arabia, New Zealand, Scotland, Saxony and many other parts, also yield this variety. Pliny mentions a mine of Sard at Babylon.

The modern name Carnelian was given to it on account of its flesh-colour. Inferior coloured specimens may be improved by soaking in a solution of an iron salt and then heating to produce the ferric oxide. It is rather curious that this variety containing iron should have been held to be specially efficaceous in the healing of wounds inflicted by iron instruments. Epiphanius also mentions its value for the cure of tumours.

It has always been a favourite substance in which to carve devices for use as signets, and Pliny mentions the ease with which it left the wax then used for sealing.

3. Chrysoprase is the variety coloured green by Nickel. It is not the same as the Chrysoprasius of Pliny, which was probably Peridot; the Chrysoprase we know seems to have been unknown to the ancients. It occurs in veins in a

serpentinous decomposition product at Kosemütz in Silesia, specimens from which showed 0·5 to 1·0 per cent. of nickel oxide on analysis. The colour is destroyed by moderate heat and also by strong light; if used as a seal to any great extent much of the colour is discharged, but it can be regained to a large degree by soaking the stone in water; the colour is supposed to be due to nickel in the form of a hydrous silicate, and colourless Chalcedony can be made to very closely simulate Chrysoprase by impregnating it with a solution of a green nickel salt. There is a locality where it occurs in India, but it is not known definitely, and other occurrences, though widespread, are not of great importance. At one time it was a very fashionable stone, then its use almost entirely died out, but in recent years it has again come somewhat into favour. It is usually cut in a low rounded form, often with one or two rows of facets above the girdle.

4. Prase is a dark green variety; some forms of crystalline Quartz of the same colour are also known as Prase. It is translucent, and owes its colour to fine filaments of Actinolite as a rule. It was a favourite substance for engraving in Roman times, and is still sometimes so used; also cut into flat pieces for inlaying. Saxony and Scotland may be mentioned as two of the numerous localities. This was the Heliotrope of Pliny.

5. Plasma is a form of Chalcedony containing a chloritic or asbestos-like mineral, or what is known as Green Earth (Delessite or Saponite). It was the Iaspis of Pliny in part. In colour it varies from a dull leek-green to almost emerald-green, often showing white spots. It was fashioned by the Romans, but now is seldom used; the best specimens come

from the Deccan in India and the first cataract of the Nile; though fairly common in many other places, the quality is not so good.

Bloodstone is the same as the above, but with small red spots. Heliotrope, again, is similar with rather larger spots of red; it was the Prasius of Pliny. The best qualities have bright red well-defined spots on a uniform translucent ground of dark green. Such specimens are found in India, west of Cambay; also at Creag nan Stardean in Rum, one of the Inner Hebrides.

6. Agate.—Most Agates consist entirely, or almost entirely, of crypto-crystalline silica; but from this normal type many departures are to be recognised, and thus as the term Agate is now used it has reference rather to the origin of the stone than its special variety; thus true Agates are all formed in the steam cavities of eruptive rocks, usually lavas; it is a curious fact that Agates are practically only found in rocks whose percentage of silica is about 45 or 50, and by no means all rocks having this amount of silica contain Agates. The other variety of Agate known as Vein Agate is rather different in origin and will be referred to later.

It will thus be seen that the Agates have their shape determined by that of the cavity in which they are formed, that they are of newer formation than the rocks in which they occur, and that they are inorganic in origin. They consist essentially of innumerable fine bands of silica in one form or another, of which bands the outer are the first formed normally; the bands are of extraordinary thinness, and Sir D. Brewster, who carefully measured them, stated they varied from $\frac{1}{17220}$ to $\frac{1}{55760}$ of an inch; thus Agate in a thin section across the bands acts as a diffraction grating when held to the light, and produces a spectrum.

The Agate is mentioned by both Theophrastus and Pliny, though "Achates" included many other substances besides this. They were used very largely by the Greeks for intagli, and by the Romans for their supposed medicinal virtues.

Although Agates, as known cut, are of such various colours, many of these colours are due to natural changes, after formation, and still more to unnatural staining by the cutter of the Agate. As already stated, Chalcedony is either colourless or is tinted with grey, which may, in thick pieces, appear a slate-grey to blue-grey; this gives the predominant tint to an unweathered Agate. The presence of disseminated zeolitic material in those parts known as Cachalong bands produces various soft tints of cream and lavender colour. The outermost part of all is coloured by Saponite, to a dull green, and the whole Agate may have its Chalcedony so mixed with Saponite or Celadonite that its colour may be deep green. More rarely an iron compound (probably in the ferrous condition) is carried in, and on oxidation yields either the red oxide of iron Hæmatite, or the yellow hydrate Limonite, with the formation of bands of Jasper of these colours. Where the ferric oxide has separated as minute spheroids, the colour is a transparent one instead of opaque, and then the Agate is termed Carnelian Agate. Other Agates show a later infiltration by iron salts with the deposition of Hæmatite in certain bands only, for once formed, some bands hardly absorb any such solution at all; such specimens have quite a distinct appearance from the Carnelian Agates. Another later change which may affect the colour is the segregation of the zeolitic matter in the Cachalong bands, which has the effect of leaving these bands quite translucent in part or in whole. Again, the Opal bands, which seem to have a tendency to lose their water, may have passed into ordinary Chalcedony, only showing their original character by their evidence of deposition under the influence of gravity alone, surface tension not having affected them apparently. Still further forms of colouring are due to weathering of the Agates, and, as one might expect, the change is seen to occur first on the outer, or older, layers of the Agate, since they are most exposed; the commonest change is for a red coloured Agate to be bleached to a chalky white, either throughout or on the outermost layers. Cracks are found developed from the same exposure, and through these arises another form of Agate known as Mocha, by the infiltration along the cracks of solutions of manganese, and the deposit within the cracks of Pyrolusite in dendritic forms. In some cases, the whole of the Agate within the "skin," or perhaps only the most recently formed part, may be filled with crystalline or even crystallised Quartz, either as Rock Crystal, Smoky Quartz, or Amethyst, thus giving a colourless, a smoky or a violet interior to the stone; the Agate in such a case may consist of anything from a mere hollow shell to a solid mass. The Quartz in these instances may contain needles or scales of Göthite; more rarely the interior of the Agate may be pink from the presence of Dolomite.

The lustre varies with that of the different constituents, as do the diaphaneity and other physical characters.

The origin of Agate has been considered in dealing with the origin of precious stones in general.

Of the shape of Agates it must suffice to say it follows that of the containing steam cavity; if this cavity were formed in a stationary viscid mass of rock it would have much the form of a bubble of air slowly rising through glycerine; this common form may be called balloon-shaped. Where the lava stream has been slowly moving at the time the cavity was formed the cavity becomes drawn out just as our imaginary air bubble would if the glycerine were slowly poured on a cold day from one vessel to another: it is lenticular or almond-shaped, and hence such cavities are called amydaloidal cavities. Two cavities may coalesce just as solidification is proceeding, and in this case an Agate having a compressed dumb-bell shape may be found. Or again a slight faulting may occur after consolidation before the filling of the cavity, resulting in the dislocation being apparent in the Agate. All these points help in the field to determine an Agate amongst a mass of other generally rounded stones. The size of the cavities varies from a microscopic one to one of many feet in diameter.

The varieties of Agate have already been indicated for the most part, but it may be well to summarise them.

The commonest form is the Banded, and this when the bands are nearly circular is called the Ring Agate. If the bands are well marked, narrow and fairly straight, it is a Ribbon Agate, though this term is frequently applied to a certain kind of Vein Agate too. Onyx Agate owes its character to the opaline bands causing a parallel arrangement of the layers, the straight-banding being the characteristic point of Onyx. Stalactitic Agates show stalactites hanging down from what was the roof or dome of the cavity.

In some cases the stalactites are free, in others they have at a later stage in growth been surrounded by Chalcedony, and in this case surface tension has caused the bands to be thicker in the proximity of the stalactite. Eyed Agates, by the increased surface afforded by minute tufts of other minerals (often zeolitic), have had an increased growth of Chalcedony at certain points until the layers have formed small spheroidal outgrowths, and these spheroids on sections give the appearance of an eye. Fortification Agates are those which through numerous "eyes" have had their bands formed with sharp salient and re-entrant angles. Moss Agates owe their character to an early bursting in of the Saponite layer in moss-like fragments. Mocha Stones show dendrites of Pyrolusite along the cracks caused by weathering. Jasper Agates have Hæmatite or Limonite in a finely divided state enclosed in them, causing opacity with a red or yellow colour. Carnelian Agates have Hæmatite enclosures in disseminated spherules. Red Banded Agates are ordinary Agates in which the absorbent bands have been coloured red by a subsequent natural staining by Hæmatite. Bleached Agates are any of those containing oxide of iron or zeolitic matter which by subsequent change is partly decolorised or removed. The Cloud Agates are those in which the removal of the zeolitic matter has been irregular, so as to give a cloud-like effect.

The distribution of Agates is very wide, but some localities are of outstanding interest. Thus for long the chief supply of cut Agate came from Prussia, being not only found there but cut there also. Thus at Birkenfeld in Oldenberg, Galgenberg near Idar, and Struth near Oberstein, the material was found in large quantities in the amygdaloid volcanic rocks, and it was cut at Idar and Oberstein. As these stores became exhausted, fresh deposits discovered in Brazil were drawn upon ; these occur in similar rock in a mountain range running between the coast in the southern part of Brazil (Rio Grande do Sul) and the Uruguay river in Uruguay. North of the Jacuhy, Carnelian is found in the beds of its tributaries, and Agate on the mountains around, while in the plains to the south, Onyx with alternate red and white bands (Sardonyx) is found in large masses. Unweathered Agate is found in the western part of the district in Uruguay.

In India, Agate is abundantly found in the Deccan rocks in the Kathiawar Peninsular to the west of the Gulf of Cambay, and is largely cut at Cambay (Kambayat). Also in Rajpipla, and in the Rajmahal Hills.

Minor localities are Jeschkenberg and other places in Bohemia, in Sardinia, Sicily, Arabia and Surinam. The Scottish localities are numerous, and though the Agates found are usually not large, they are remarkable for their variety and beauty ; the principal ones are Montrose, Glen Farg, and near Cupar, all in lavas of Middle Old Red Sandstone age ; a magnificent collection of specimens from Scottish localities is in the Royal Scottish Museum.

The Applications of Agate.—There are many purposes besides those of ornament to which this material is put ; such are, its use for the knife-edges of chemical balances, for the pivots for marine compasses, in the manufacture of pestles and mortars for grinding hard substances, for burnishing metals, rollers for use in textile industries, dies for moulding plumbago for lead pencils, etc. But by far the greater part produced is wrought into vases, bowls, paper-knives, trays, signet rings, seals, brooches, beads, sleeve links, and other such articles. Most of this work is carried on at Oberstein, to which the Agate is now taken from Brazil and other places, and from which it is sent to all parts of the world. Damon records the curious case arising through the demand in Egypt for objects made of Agate, visitors liking to take away this "local product" as a souvenir. What they buy would seem to be Brazilian Agate worked at Oberstein. We need not go out of England for similar instances. Cumberland being a county justly noted for its variety of minerals is expected to produce Agate; hence in some of its tourist towns one sees large quantities of gorgeously stained Agate which in all probability came from Brazil in the first instance, and Oberstein in the second. Another curious case is the exportation to Central Africa from Oberstein of a large quantity of Agate cut and polished in cylindrical forms, to be sold as charms.

Many very beautiful works of art have been produced in this material. France possesses a complete service in Agate, valued at one time at £20,000; and many fine examples of this work are to be seen in most of our larger museums.

Before the Agate is cut it undergoes some important processes of preparation in many cases; these consist chiefly in staining the material different colours; the staining depends on the various layers having different porosities. Probably the earliest kind of staining known was the black, which seems to have been first practised in Italy; it is produced by soaking the material in some carbonaceous matter, sometimes an oil, more often a solution of sugar or honey; the material is placed in vats, covered by the solution, and the whole kept at a temperature a little below boiling point for a time, varying from a few hours in the "softer" (or more absorbent) varieties such as the Brazilian, to a week or more in the case of the "harder" kinds. After being washed, the Agate is next placed in sulphuric acid, which dehydrates the sugar; this results in a fine black deposit being left in the pores of the absorbent bands. Staining is said to proceed more rapidly in radial directions. Much of the material so treated is not true Onyx in the mineralogical sense, but Agate, having alternate bands of Cachalong and Chalcedony; but where the bands are uniform, and capable of taking a good stain, it is known under the trade name of Onyx.

Another well-known method of staining is by treating the material in hydrochloric acid at a moderate temperature for about two weeks, when many of the bands assume a rich lemon-yellow colour.

Agate may also be made to resemble a Carnelian Agate by allowing a solution of ferrous sulphate to soak into the absorbing bands; this, on heating, oxidises to ferric oxide, and gives the well-known carnelian-pink.

Green is produced by treatment with chromic acid and subsequent heating, and an apple-green tint may be induced by soaking in a solution of a green nickel salt.

Blue of various shades is imparted by treating first with a solution of potassium ferro-cyanide, and afterwards by a warm solution of ferrous sulphate. The tint varies from indigo to azure and ultramarine.

Many of the methods, however, are kept as strict trade secrets, but other methods, as the use of aniline dyes and the induction of coloured chemical precipitates by double decomposition, will suggest themselves to the reader.

The staining is chiefly carried out at Idar and Oberstein, where also the cutting is performed. The apparatus formerly used in cutting—or more properly, grinding—was a large grindstone, about 4 feet in diameter, and 1 foot thick, driven by a water-wheel, the streams in the neighbourhood affording a plentiful supply of cheap power for the purpose. At Oberstein practically the whole population is engaged in this work. The grindstones are fixed on a horizontal axis, slightly above the floor level, and the grinders lie on their chests at full length, supported on a low rest; the Agate is held on a level with the axle of the wheel, and pressed against it; the wheel turns at about 180 revolutions per minute, so that a peripheral velocity, or cutting speed, of about 2,000 feet per minute is obtained; in skilful hands, this enables the work to be done at a much greater rate than one would expect. The grindstones are provided with grooves of different curvatures, so that a large number of pieces can be ground to a similar form with rapidity. Although the wheels are kept wet, the occupation is a dangerous one to the health. At Birkenfeld, also on the Nahe, the worker usually owns his own machinery, or it is held in a small partnership, representing about £100 capital, and there a good worker can earn £3 to £5 per week. Now most of the works at Oberstein are fitted with more modern machinery, including grinding discs rotating in a horizontal plane. The polishing is performed by women, and even children, on smaller wheels of softer material dressed with a mixture of tripolite and water.

The value of the rough material varies, according to its suitability for staining, from £5 to £250 per hundredweight (Max Bauer).

Vein Agates are similar in composition to the true Agates, but they are found in more or less elongated fissures in the rocks instead of in closed spaces; hence they are more prone to contain sufficient foreign matter to render them opaque.

The two chief varieties are the Ribbon Agate, in which the bands are arranged nearly parallel, and the Brecciated Agate; the latter is of interest in indicating movement in the fault, in which it has been formed, after partial filling of the space with silicious material, and then a uniting of the broken fragments into a solid mass by a further deposition of silica. The former kind is found in Saxony at Schlottwitz and Halsbach, and the latter at Altendorf, besides in many less important localities in other parts.

The varieties 7, Onyx; 8, Sardonyx; and 9, Jasper Agate, have been dealt with above.

10. Silicious Sinter is a cellular form of Quartz which has been deposited by uprising heated waters.

11. Flint, formed by the deposition of compact silica by downward percolating water, often around organic remains, does not concern us in the present relation.

12. Hornstone is a compact brittle form of silica, with a splintery fracture, slightly translucent.

13. Lydian Stone, or Touchstone, is a shale which has been altered by heat in the vicinity of masses of intrusive rock; it sometimes shows rather pretty banding of greens and browns, but is very rarely cut and polished.

14. Jasper includes the opaque, compact varieties of silica, coloured by various impurities. It is of various colours, according to the impurities present; thus disseminated

ferric oxide gives a bright red; the hydrated oxide of iron, Limonite, imparts various shades of yellow. Some of the minerals allied to Chlorite and Saponite impart a dark leek green; more rarely a grey-blue is seen, or black. It has a dull lustre and a large conchoidal fracture. The impurities may amount to as much as 20 per cent. of the substance. What has been said of the origin, application, and cutting of Agate applies to Jasper in most cases, only two special kinds demanding further notice.

Egyptian Jasper is a form occurring in nodules in the Egyptian deserts and showing the characteristic surface erosion caused by blown sand. The nodules are derived from the nummulite rocks, and are of a general brownish colour, showing concentric markings outlined in various shades of brown and yellow.

Wood Jasper is a fossil wood silicified. On polishing, all the structure of the wood is well seen. It may occur with the silica in a colourless form, when it would be more rightly classed with Chalcedony or Quartz. It is not often used now for ornament, except perhaps for inlaying work, but it was used in ancient times much more. It is found at Chalcedony Park, Arizona, and Yellowstone Park, in North America.

The localities where Jasper is found are numerous and widely distributed. Many very beautiful varieties are found in Scotland, chiefly in association with the Old Red Rocks, as in the neighbourhood of Edinburgh, in the Garleton Hills, and at Burn Anne, near Galston. Red Jaspers are largely obtained from various parts of Germany, yellow from Sicily, green from the Urals, and blue from Bohemia.

Further information about these interesting and often beautiful forms of silica will be found in Mr. Rudler's article on "Agates and Agate Cutting" (*Popular Science Review*, Vol. I.); and in the article on "Agates, Carnelians, and Jaspers" ("Trans. Scot. Nat. Hist. Society," Vol. I.); and the "Guide to the Collection of Scottish Agates" (H.M. Stationery Office), both by the late J. G. Goodchild, of H.M. Geological Survey.

212. OPAL.

Opal is a mineral of very similar composition to Quartz, yet its whole character differs from that of Quartz in a marked way. It was known in ancient times, and Pliny gives as good (and as often quoted) a description of it as can be worded. The great value set by the Romans on the gem may be gathered from Pliny's account of the Opal belonging to Nonius, who was proscribed in the hopes of making him give up his gem to the Triumvir. Rather than do this he fled. His gem was valued at what would now be £20,000, and yet it was no larger than a hazel-nut (King).

It is a stone that has always been surrounded in the popular mind with a mass of superstitions. In early times it was held to be a protection to the sight. This seemingly led Marbodus to alter the name of it to Ophthalmius, and at the same time to endow it with the further virtue of rendering the wearer invisible. Thus at this time it was rather a "lucky" stone. Now it remains as one of the few stones to which one hears superstitions attached; but its property has mysteriously changed, and it is not unknown to hear "Oh! I never wear Opals, they are so unlucky."

The outstanding feature of Opal is its colour—at any rate, so far as the variety used as a gem stone (Precious Opal) is concerned. What the colour is due to has never been quite ascertained, though there is no doubt it is an optical effect; it has been suggested that minute cavities cause refraction and reflection (Brewster); also that it is due to interference of light in cracks; more recently Behrends has ascribed it to the existence of numerous thin lamellæ, which have at one time been parallel, but later bent and cracked into a curved form. The colours shown in Precious Opal are remarkable for their intensity, and may be likened to the light emitted by some of the double stars, or to the colours seen in the feathers of certain birds. Thus brilliant and pure greens, vivid crimsons, electric-blue are seen, with often a dominant soft blue; sometimes a rich violet or a sherry yellow appear, very rarely rose-red and black. Owing to the substance being sub-transparent, and of a pale amber colour by transmitted light, an Opal often shows a blending of this yellow light transmitted through the stone with the optical colours, giving an appearance known as "opalescence." Other varieties of Opal may show different colours, as white, yellow, brown, grey, green, etc., quite apart from any play of colour.

The lustre varies from vitreous to resinous, or rarely pearly; sub-transparent to opaque.

Refraction is normally single, $n_r = 1{\cdot}442$—$1{\cdot}446$; but anomalous double refraction is sometimes seen through internal strain.

The specific gravity is 1·9—2·3, purer forms about 2·19—2·2. It has a conchoidal fracture, and gives a white streak.

It is always amorphous, and occurs in reniform or stalactitic masses. Precious Opal more often is found mixed with matrix and forming disseminated patches and veins.

The hardness is 5·5 to 6·5.

The origin seems very similar to that of many other forms of silica—deposition in cracks and cavities in rock from watery solutions of silica, usually percolating downwards, as described previously. It is usually met with in decomposing volcanic rocks, but may be found in any silica containing rock. It is associated with Quartz, Chalcedony, and other modifications of silica as a rule.

In chemical composition it is a hydrated oxide of silicon, SiO_2, nH_2O, the amount of water varying, so that one may almost say there is a transition from Opal to Chalcedony. The water percentage varies from 0·1 to 10·0 per cent. or more. Heating drives off this water and ruins the gem.

Varieties:—

1. Precious Opal—that showing the fine play of colour described above. According to the form in which the colour appears (the "pattern" of the Opal), it is subdivided into

a. Harlequin Opal ,that in which the light appears in small angular patches ;

b. Pin Point Opal, in which the points of light are very minute ;

c. Flame Opal, with the colour in streaks ;

d. Gold Opal, showing a yellowish light over a large area

Precious Opal in Pliny's time came solely from India, though none is known from that country now. Even early in the seventeenth century India still produced the best stones, though the Hungarian locality was known. It is very likely that many of the supposed Indian specimens were Hungarian ones that found their way to the West from Constantinople.

The Hungarian locality is at Czerwenitza, near Eperies (Presova), in Saros. The Precious Opal here occurs in fissures in a weathered andesitic lava with other forms of Opal; it was formerly quarried in open workings, but now a perfect network of levels has burrowed into the mountain. The largest mass found here is in the Imperial collection at Vienna; it weighs about 3,000 carats, and is of the size of a man's fist. When the Opal is in small disseminated patches in the matrix, the whole is sometimes cut and mounted together, the matrix being oiled to darken it. Such material is known as "Mother-of-Opal." Cutting the Precious Opal is a very delicate operation on account of the liability to breakage of the gem from the numerous flaws. It is partly cut in Hungary, the operators using a leaden disc, with emery as an abrasive. The form of cutting employed is nearly always one with a low curved upper surface without any facets.

These mines have certainly been known from the fourteenth century. Hungarian Opals show the finest fire, and their colours deteriorate least with exposure.

Precious Opal is also found in a weathered volcanic rock in the west of Honduras, where it occurs, as in Hungary, as patches in common Opal.

In Mexico it occurs in the State of Queretaro, north-west of the city of Mexico, in volcanic rock, and associated with other forms of Opal. The colours are often intense, but in larger patches than the Hungarian specimens show, and the colours do not change so much when the stone is moved. The sub-variety, Lechosos-Opal, which occurs here, shows specks of emerald-green and carmine.

In New South Wales, in a decomposed amygdaloidal volcanic rock, Precious Opal occurs, associated with other forms of Opal; this is at Rocky Bridge Creek, in Georgina County. Also at White Cliffs, Yungnulgra County, there is a deposit of considerable importance, both because of its commercial value and also on account of its peculiar matrix, which is a white sandstone. The Precious Opal, along with common Opal, occurs in the joint- and bedding-planes of the rock. Cretaceous fossils are found in some cases filled with Precious Opal, and fetch very high prices as curiosities; it also is found pseudo-morphous after Gypsum (E. F. Pittman).

In Queensland, at Bulla Creek, Precious Opal again is found in a silicious rock, in this instance a highly ferruginous sandstone, in the fissures of which it occurs in thin layers in association with common Opal. The colour of this Opal is of a deep blue in general, with large areas of the same shade nearly; it of course has the green and red "fire."

2. Fire Opal is of a reddish tint from the presence of ferric oxide, but it may show the same play of colour as Precious Opal. The name refers to its red colour, and on the same account it is sometimes called Sun Opal. It is particularly liable to deteriorate through exposure. It is found usually associated with other varieties at Zimapan in Mexico, in Honduras, and in the Faröe Islands.

3. Girasol is a bluish white variety with a rather feeble red "fire"; on moving the stone a faint wave of bluish light may be seen to move across it. It is found in the

Faröes, and rarely in Scotland at Usan. Fire Opal is sometimes called Girasol also.

4. Common Opal includes a considerable number of subvarieties. In one form or another it is very common, large masses of hydrous silica occurring in some parts. As in the case of Chalcedony, the pure kinds are translucent and colourless, but with the addition of various impurities many varying forms arise. Milk Opal shows white, bluish, or greenish tints. Resin Opal, or Pechopal, has a resinous lustre and a yellow colour. Semiopal is a sub-translucent kind. Hydrophane is a light coloured variety, which is absorbent enough to adhere slightly to the moistened finger, and it has the property of becoming more translucent when placed in water, hence the name.

The more massive forms of Common Opal are ground and polished for much the same purposes as Agate is, *e.g.*, pin trays, knobs for umbrellas, sleeve-links. Common Opal is found in all the localities mentioned under Precious Opal, also in Moravia and Bohemia, at Kosemütz in Silesia, in Iceland, Ireland, Scotland.

5. Cacholong Opal is very feebly translucent from the presence of disseminated mineral matter, which is often zeolitic. It is often present in Agate alternating with Chalcedony, and such banded specimens may be used for cameo-cutting. The Faröe Islands may be instanced as producing very fine specimens.

6. Opal Agate is more correctly included under Agate.

7. Menilite is a concretionary form found at Menilmontane, near Paris, embedded in a clayey shale. It is brown or grey in colour, and sometimes shows alternate bands of these two colours.

8. Jasp-Opal is a form containing sufficient diffused impurity (often an iron compound) to render it opaque.

9. Wood Opal consists of the fossil remains of wood infiltrated with hydrous silica. When cut and polished it shows all the detailed structure of the wood very clearly. It is found near Hobart Town in Tasmania, Kremnitz in Hungary, and many other places.

10. Hyalite, or Muller's Glass, is an absolutely colourless and usually transparent Opal occurring in small botryoidal masses resembling beads of fused glass. It resists solution by alkalies more than other forms; it is found at Kremnitz in Hungary and in Bohemia, amongst other places.

11. Silicious Sinter is a more porous form, chiefly of interest from its origin in deposition from uprising heated water in fumaroles and hot springs.

The applications to which Opal is put are all those of ornament, and these have been already indicated. All kinds are cut in thin slices, usually with a curved upper surface (*en cabochon*), except the Fire Opal, which may be cut in a deeper form and facetted. The value depends very largely on the quality of the colour and on the pattern. The favourite type is a Harlequin Opal showing bright green and crimson flashes; such a stone of one carat may fetch over £2. More recently Opal cut in the matrix has been fashionable, though how long it will remain so is uncertain.

Opal is rarely imitated, but sometimes glass imitations are mounted with foil in a closed setting to give the effect of play of colour; such an imitation can be detected at once by the inferior hardness of the glass.

CHAPTER VIII.

231. CORUNDUM.

This mineral species includes some of the most important precious stones, its blue crystalline variety being the Sapphire and the red the Ruby, while other colours are known as Oriental Topaz, Oriental Amethyst, etc. Since these are all the same mineral, with only slight variations in the colouring matter, they will all be treated collectively so far as possible. To the old writers they were regarded as of many species. Thus the Sapphire was the Hyacinthus of Pliny, and included his variety Asteria. The Ruby was regarded by him as belonging to the Lychnis group of the Carbunculi; but much confusion of terms has crept in in the writings of many of the early mineralogists.

Dependent on the colour is the jeweller's classification of the varieties; mineralogically these are sub-varieties of the crystallised Corundum. The two most common kinds are the blue Sapphire and the red Ruby; but, as indicated above, a number of other colours occur which are practically identical with the colours of other well-known gems, and hence to distinguish the more valuable forms of Corundum the jeweller prefixes the term "Oriental" to the name of the gem whose colour is that of the stone in question. Thus Topaz is the mineral known to the mineralogist by that name; but Oriental Topaz is a yellow Corundum, and the opposite term "Occidental" would be applied to such a less valuable mineral as yellow Quartz—thus "Occidental Topaz." The red of the Ruby varies a good deal, the "masculine" Ruby showing the deeper tints of carmine or blood-red (often referred to as "pigeon's blood"-red, from a Burmese simile), while the "feminine" Ruby is paler, and more of a rose-red; in this, as in other varieties of Corundum, a transition is seen, and the feminine Ruby may pass gradually to colourless Corundum. The masculine Ruby, in its most admired shades, has a slight blue tone in the red, which thus tends to magenta. The colour is usually evenly distributed in the Ruby, but in the Sapphire it is quite usual to find much variation in depth of colour. All shades of blue are found and of all depths. Perhaps the most characteristic colours are a smalt-blue and a cornflower blue. Deep-coloured stones are known as Lynx- or Cat- Sapphires, and the paler ones as feminine stones or Water-Sapphires, though the latter term is more often applied to the blue Iolite (Cordierite). Pale Sapphires merge insensibly into the next colour variety, Leuco-Sapphire, which is really devoid of colour—simply colourless crystallised Corundum. It also passes into the blue-green variety, known as Oriental Aquamarine. In fact, in many crystals of Corundum a gem might be cut from one end which would be a Sapphire, while from the other end of the crystal a Leuco-Sapphire might be obtained. The yellow-green variety of the colour of Chrysolite (Olivine) is called Oriental Chrysolite. The intense green stones are Oriental Emerald; the pure amber, or honey-yellow stones, are Oriental Topaz; while those of a rich brownish-red are known as Oriental Hyacinth, and the violet specimens as Oriental Amethyst. All these tints are found in the first mineralogical variety. Those kinds which have a well-marked crystalline structure but are of dull tint and not transparent are classed as the second variety, common Corundum, the Adamantine Spar of Black, and the Adamas Siderites of Pliny. The more common colours seen are dull blue to grey and smoke-brown to black. The third variety does not depend so much on colour as on its less defined crystalline structure. It is called Emery, and is the substance so well known as a polishing agent; but even in "knife-powder" one may sometimes isolate quite distinct though microscopic Sapphires. Emery is usually granular and massive.

The lustre of the purer varieties is adamantine, but it passes gradually into vitreous in the less pure forms. On the basal plane it is sometimes pearly.

Diaphaneity. As indicated above, the purer forms are transparent, others sub-transparent to opaque.

It is doubly refracting, but not in a marked degree, the index for yellow light being in the ordinary ray 1·769, and in the extraordinary ray 1·760, and the dispersion is slight. Being doubly refracting, it is of course capable of lighting the field under the crossed Nicols of the polariscope. The coloured varieties show a marked dichroism, especially in specimens having a deep colour, in which the phenomenon may be so well marked as to be obvious to the eye. A Ruby, when seen through the dichroscope, shows one image of a rich red inclining to violet, while the other is of a paler red. Sapphire shows images of a rich deep blue and a pale greenish blue; Oriental Amethyst shows a rich violet image, and a very pale violet or colourless one; Oriental Emerald shows a blue and a green image.

Phosphorescence is well marked in some specimens, and is well seen in a darkened room when the stone is carefully heated. Fluorescence is seen in some kinds, as the Oriental Emerald from Siam.

It is quite infusible before the ordinary blowpipe. On rubbing with a dry cloth it shows a surface charge of positive electricity.

The specific gravity is high, varying from 3·93 to 4·08, so that it readily sinks in a saturated solution of iodine and iodoform in methylene iodide.

The fracture is conchoidal to uneven, and the mineral is brittle. Its hardness is marked, being excelled amongst minerals by the Diamond alone. It is the Standard 9 of Mohs' scale.

FIG. 14.—Corundum.

True cleavage is absent, but from a lamellar twinning parallel to the basal plane and to the unit rhombohedron there are more or less well marked parting planes parallel to these faces in such twinned specimens, and this simulates cleavage closely.

Crystalline form. Corundum belongs to the rhombohedral division of the hexagonal system, but as in the case of Quartz, the rhombohedral character is not always very apparent, the general form of the crystal being often that of a doubly terminated and rather acute hexagonal pyramid, not infrequently truncated by a basal plane (Fig. 14). Oscillations of pyramid forms between the basal plane and the prism faces causes a characteristic wavy outline in many crystals, and in nearly all cases striations can be seen running parallel to the meeting of the base and prism. Another common habit of Corundum is a stout hexagonal prism terminated by the basal plane; this type is often met with in Ruby, in which also the rhombohedral habit is seen most frequently.

Chemical composition. Corundum is pure alumina, Al_2O_3, the oxide of Aluminium. Traces of ferric oxide, silica and oxide of chromium are found in even the purer varieties often, and it is supposed (though it is by no means certain) that these substances, slightly varying in amount and proportion, give to the Ruby, the Sapphire, and the other precious forms of Corundum their beautiful colours on which the value so largely depends. The less pure forms of Corundum contain large amounts of iron, especially as Magnetite and Hæmatite.

The different forms of Corundum do not behave alike under the influence of heat. Thus a Ruby after being heated retains its colour, hence the colour certainly is not organic in nature; Sapphire, on the other hand, has its colour discharged in the majority of cases by heating, and from this it has been suggested that organic matter may account for the beautiful blue. However, the prevailing opinion is that both owe their beauty to small quantities of chromium and possibly of iron also. Ruby may with care be heated to very high temperatures; it turns a dirty grey colour when very hot, but on cooling it again turns to red, passing through white and green as it cools.

In considering the origin of these gems, it may be well to deal with their distribution at the same time, merely noticing in passing that Corundum seems in the great majority of cases to be a product of thermo- or dynamo-metamorphism, or of a combination of both.

Ruby.—The most important Ruby mines are in Burma, around Mogok to the east of the Irrawaddy, and north-north-east of Mandalay, and specimens from these mines most nearly approach the ideal in colour. A smaller area of Ruby-bearing limestone is found at Sagyin Hills, north of Mandalay. Professor Judd, in the article dealing specially with the Ruby of Burma (Brown and Judd, *Phil. Trans.*, Vol. CLXXXVIIa.), ascribes the limestone in which Rubies occur to a decomposition of the lime Felspar contained in the basic gneisses. There is a peculiar feature about the interrelation of the limestone and gneisses, for they show a considerable amount of interbedding. The limestones are not sharply marked off from the gneisses, but merge gradually into them, and Mr. Barrington Brown describes them as having their dips conformable to the contortions of the gneiss in all cases. Dr. Noetling, of the Indian Survey, regards the igneous rocks as having been intruded into the limestone in a molten state, and holds that the Rubies and other minerals contained in the limestone are the product of contact or thermo-metamorphism. The *rôle* played by heated water under pressure would seem to enable the formation of a gneiss to occur largely out of the material of the rock around, and thus to *replace* this rock, the semi-fluid magma at the same time throwing out projections and enveloping portions of the country rock. It is in the limestones alone, and in the *dêbris* resulting from their weathering, that the Rubies are found. This *dêbris* consists of a brownish clayey material, and it fills the crevices and "shaks" of the limestone and covers the sides and bottoms of many of the valleys. The

Burma Rubies show crimson and aurora-red images in the dichroscope.

In Siam the Ruby is found near the coast at Krat and Chantabun, but the stones are darker and more purple than the Burmese ones. Here again granitic rocks and limestone are found, but the Ruby is so far only known in the sands of this region. Siamese Rubies give dichroscope images respectively crimson and brownish-red.

In Ceylon Ruby is found in alluvial sands at the foot of Adam's Peak. These sands for the most part are found in old river terraces; a crystalline dolomitic limestone is supposed to be the mother rock. The stones are very clear but of a lighter colour.

In India Ruby occurs but rarely in good quality, though the poorer qualities are widely distributed. In Afghanistan to the east of Kabul, Ruby is found in an altered limestone.

In the United States, Ruby of gem quality is found at Corvee Creek, a tributary of the Little Tennessee River in North Carolina, in a decomposed garnetiferous basic rock; many much weathered specimens have been found, which have led Professor Judd and Mr. Hidden to conclude that Rubies of very large size have been formed here (*Min. Mag.*, Vol. XII., p. 144).

In New South Wales a few small specimens have been found. Also at several places in Queensland.

The associated minerals bear a close relationship in the different localities. In Burma very fine Spinel, colourless Zircon, Garnets, Apatite, different Felspars, Rubellite, Quartz, Muscovite and other Micas, Lapis-Lazuli, Graphite, Scapolite, Pyrrhotite, and other minerals are found, in addition to the Ruby, Sapphire and other gem varieties of Corundum. In Siam the associates are Sapphire, Quartz, Ilmenite and Zircon. In Ceylon the gem sands contain, besides the Ruby, Sapphire, and other varieties of Corundum, Garnets, Zircon, Quartz, Chrysoberyl, Magnetite, Amethyst, Tourmaline, Spinel, etc.

In North Carolina the associated minerals are Garnet, Spinel, Monazite, Rutile, Ilmenite, different Micas, Staurolite, Gold, etc., and the Rubies often show inclusions sometimes so minute as to give the gem a " sheen " (Judd and Hidden).

The mining of the Ruby in Burma is now carried out by the Burma Ruby Mines, Ltd. Here not only open workings are found, but also tunnels driven in to cut the gem-bearing material, which is washed to free it from as much earthy matter as possible, the remaining gravel containing the Rubies being afterwards picked over by hand. The machinery, which is somewhat similar to that employed in Diamond washing, is now driven by electricity, transmitted from some distance.

It has already been remarked that the colour of a Ruby varies with the direction in which it is viewed; the richest colour is seen on looking along the principal axis of the crystal, hence, in cutting, the gem should be so fashioned that this axis is presented to the eye of the observer, the table thus being parallel to the basal face of the crystal. The gem is usually cut as a brilliant. Some few Rubies show asterism, and are cut *en cabochon*, but this is not nearly so frequently seen in Ruby as in Sapphire. More rarely step cut stones are seen, or those in which the form of the crown is that of a brilliant, while the culasse is cut in steps. Since the dispersive power is small there is no marked play of colour, and hence there is not the same importance in giving the gem an exact form as in the case of the Diamond. Hence, too, rose cut Rubies are relatively more effective than rose cut Diamonds.

The grinding is now usually effected with Diamond dust on account of the quicker abrasion; the wheel used is an iron one. Polishing is done on a copper disc, dressed with tripolite.

Ruby ranks above Diamond in point of value for good stones; while the price of a pale Ruby of one carat may only be £1, a stone of rich deep colour, weighing when cut one carat, may fetch £25 or more. Mr. Streeter states that £20,000 has been paid for a very fine Ruby of $38\frac{9}{16}$ carats. While Rubies up to 2,000 carats have been found, most of the larger ones show considerable imperfect areas, and of large flawless Rubies very few are known compared to Diamonds of similar quality and size.

On account of the great demand for this rare gem, stones of inferior kind are not infrequently offered as Rubies. True Rubies, although they can be produced artificially (see "Artificial Production"), cannot be made of sufficient size yet for gem use, and moreover the process is a very expensive one. The most common substitutes for Ruby are the Balas Ruby (red Spinel) and the Rock or Elie Ruby (Garnet). Both these minerals are cubic in their crystalline form, hence the optical properties can readily be used to distinguish them, for they show no double refraction and no dichroism. Their hardness is in both cases inferior to that of Ruby and the specific gravity lower. Two other substitutes, however, belong to the same crystallographic system;

these are Rubellite (pink Tourmaline) and red Quartz ("Bohemian Ruby"). Here again the inferior hardness will distinguish them from the Ruby in cases where one can scratch the specimen, and also the lower specific gravity as compared with Ruby. Yellow Topaz which has been turned red by heat ("Brazilian Ruby") is distinguished by the same two tests. Red Fluor Spar, which is only very rarely used as an imitation Ruby, is again softer and less dense. The colour of the Ruby is perhaps most nearly imitated in glass, but glass is singly refracting and relatively very soft. Quartz which has been stained in cracks can be recognised by these cracks, which can never be quite hidden; it is called Rubasse.

SAPPHIRE.—What has been said of the origin and mode of occurrence of Ruby applies very much to Sapphire too, the one rarely being found without the other, though at some localities one is more abundant than the other.

The most important Sapphire mines are in Siam, at Battambang, but Sapphires are also found with the Rubies in the mines of Chantabun and Krat. At Battambang they occur in a sandy deposit; this is washed and picked in the usual manner. It is noteworthy that the larger stones are usually of better quality than the smaller. Gems of very fine cornflower blue colour are obtained from Siam; they are strongly dichroic and show images respectively blue and green.

In the Burma Ruby mines they are also found, but in much fewer numbers than are the Rubies, though the Sapphires often exceed the Rubies in size. They are of good quality, faultless stones of 80 carats having been obtained. Unlike the Siamese Sapphires, their images in the dichroscope are blue and straw-colour. They tend to be too dark in colour in many cases.

In Ceylon they occur in the gem gravels around Adam's Peak with the associates mentioned under Ruby. Most of the Sapphires are found in the southern parts of the island; they are supposed to have been developed in the crystalline limestones of the district, but as yet have not been found *in situ.* The stones are, like the accompanying Rubies, very brilliant, but rather light in colour.

A more interesting deposit, and one which is, in addition, of commercial importance, is that near the village of Soomjam in Kashmir. Here in the early 'eighties a landslip exposed a mass of garnetiferous gneiss with interfoliations of an altered limestone containing granitic veins, and in this rock the Sapphires have been found *in situ* associated with Tourmaline. Most of the gems, however, are found in detrital matter derived from the weathering of the neighbouring rocks. Specimens of very large size have been obtained—up to 300 carats; many are too pale.

In the United States there are two areas of importance as producers of Sapphires. One is the Culsagee mine in Macon County, North Carolina, where the mineral occurs with Spinel, Tremolite, Tourmaline, Magnetite, Rutile, Chromite, Olivine, and Mica, in gneiss. The other district is in Montana. Near Helena is a glacial moraine known as the El Dorado Bar and in this Sapphire has been found with Topaz, Garnet, Cassiterite, Quartz and Cyanite. In addition it has been found *in situ* in Montana in a dyke with Pyrope, at Yogo Creek near Judith River, of a fine cornflower blue.

In Australia, New South Wales, in the New England district, in Diamond localities. Here the green Corundum, Oriental Emerald, is relatively common—as a rule it is one of the rarest colours. The Sapphires are usually of a very deep blue. In Bohemia Sapphire has been found with Zircon and Garnet.

What has been said of the cutting of the Ruby applies to Sapphire also. The fact that the colour is of a richer hue when viewed along the principal axis of the mineral should guide the lapidary in cutting the stone. Sapphires are particularly prone to be patchy in colour, and bad parts may have to be removed by slitting before grinding commences. Sapphires usually show a change of colour in artificial light; some few specimens change to violet, thus, and they are highly prized. Most Sapphires have their colour destroyed by heat, some very much more easily than others.

The value of Sapphire of good quality, and in carat size, is about two-fifths that of Ruby. Moreover, since Sapphires of large size are more plentiful than in the case of the Ruby, there is not the same rapid increase with size. Small stones may be said to be very much the same in value as Diamonds, and larger stones only increase in about direct proportion to their weight.

The minerals most likely to be substituted for Sapphires are blue Iolite (Saphir d'Eau), blue Tourmaline (Indicolite), and Cyanite (the Sapphire of de Saussure). Less likely to be found under this name are blue Topaz, blue Spinel, blue Fluor Spar, blue Quartz, Aquamarine, and Haüyne. Blue Diamond may resemble it very closely in colour, but no attempted substitution is likely to be found in this case.

With the exception of Diamond all are softer than Corundum, and Sapphire is the hardest form of Corundum. Without exception all those mentioned are of lower specific gravity; but Cyanite and Spinel might sink with Sapphire in a saturated solution of iodine and iodoform in methylene iodide (the heaviest solution of Max Bauer). Of these two Spinel is a singly refracting mineral, and is not dichroic, while Cyanite is less transparent, and often has a slightly pearly lustre.

Glass imitations, though of good colour, are singly refracting, and very much softer than Sapphire.

One of the finest and most perfect Sapphires is the "Rospoli" gem, now in the Museum of the Jardin des Plantes, in Paris; it weighs 132 carats. A stone of 951 carats was in the possession of the King of Ava at one time.

Star Sapphire, or Asteriated Sapphire. This is a variety which shows a six-rayed star when viewed on the basal plane, or on a facet cut parallel to the base; if the star is well defined, and the rays are bright, the stone is of considerable value; sometimes, however, it merely shows as a bright band of light, and not a complete star. The star characteristically exhibits a shimmering silvery light. It is due either to reflection from the twin lamellæ, which give rise to the parting planes, or to the existence of three sets of planes of minute cavities, intersecting one another in the vertical axis of the crystal. Star Sapphires are always cut *en cabochon*.

Leuco-Sapphire is colourless crystallised Corundum. It is in some cases the result of acting on inferior Sapphires, which are not of a colour good enough for gem use, by heating them so that they become colourless. Of other gems with which it might be confused Diamond is the only one which will scratch it. Zircon is the only one which equals it in density, and Zircon so far exceeds all other gems in this respect that it is easily distinguishable.

Oriental Chrysolite is Corundum of the colour of Chrysolite or Olivine. This is not a very rare tint. It is distinguished from ordinary Chrysolite by the greater hardness.

Oriental Emerald is an emerald-green form of Corundum, and is extremely rare. The New South Wales Sapphire deposits have produced a relatively large number. In value it is between the Sapphire and Ruby. It is harder than Emerald, more strongly dichroic, of higher specific gravity, and is sometimes fluorescent.

Oriental Topaz includes several yellow shades of Corundum, and when of fine reddish yellow colour is of about the same value as Sapphire. It is distinguished from Topaz by higher specific gravity and greater hardness.

Oriental Hyacinth is a reddish brown variety. It is also known as Vermeille Orientale.

Oriental Amethyst, also called the Purple—or Amethyst—Sapphire, is very close in colour to the common Amethyst, but it shows a much greater range of colour than Amethyst does, and in fact may vary from a slightly purple red to a blue with a slight tint of red in it.

2. The second mineralogical variety is Common Corundum. It is less transparent than the first variety. The colour varies from dull blue to grey and from a rich smoky brown to black. It often has a very marked adamantine lustre, and the brown asteriated form, when cut *en cabochon*,

may be used as a precious stone. The coarser varieties are more suitable for use as abrasives than Emery, since the latter contains such softer impurities as Magnetite and Hæmatite. It occurs both in distinct, though often rough, crystals and in large crystalline masses. It is found in many of the localities mentioned under Ruby and Sapphire, as Chantabun in Siam; also on the Malabar coast, at Canton in China, and at Gellivara in Sweden.

3. Emery is a granular impure form of Corundum, containing Magnetite and Hæmatite. It is of great commercial use as an abrasive, though now carborundum is displacing it in this use to a large extent. It is found in Naxos, Samos, and Nicaria in the Grecian Archipelago; also east of Ephesus in a granular limestone; in the United States at many places, as Chester in Massachusetts, and in Chester County in Pennsylvania.

CHAPTER IX.

234. SPINEL AND CHRYSOBERYL.

Spinel included some of the gems called Lychnis by Pliny, and his Carbunculi Amethystizontes were Spinels also. Though it has been known as a gem stone since remote times, it was till the eighteenth century confused with other species.

As met with in jewellery, the characteristic colour is flame-red; this form is sometimes distinguished as Spinel Ruby or Ruby Spinel; lighter rose-red shades are called Balas Ruby; specimens of a violet tint are known as Almandine Spinels or sometimes Alabandin Ruby (from Alabandin in Caria); blue stones are known as Spinel Sapphire, and the orange-red ones as Rubicelle; a colourless variety is sometimes seen. Other colours occur in the mineralogical varieties, Pleonaste, Chlorospinel and Picotite.

The lustre of the gem varieties is vitreous, and often splendent, and they are transparent or subtransparent; the other varieties may occur almost, if not quite, opaque.

It is singly refracting, hence shows no dichroism, and under the polariscope the field remains dark when the specimen is rotated under crossed Nicol's prisms. It phosphoresces with a red light. Its index of refraction for yellow light is 1·72, and the dispersion is small.

On rubbing it shows a surface charge of positive electricity, but not to any great degree. It is not fusible before the ordinary blow-pipe.

The specific gravity is 3·60 to ·3·63, rather higher than the Diamond. The fracture is conchoidal, and there is a very imperfect octahedral cleavage. It is a brittle mineral, though its hardness is considerable, being equal to 8 of Mohs' scale. The streak is white.

The crystalline form is cubic, and the usual habit octahedral (Fig. 15); very rarely is the habit cubic; the faces of the octahedron are sometimes curved; twinning of the crystals is commonly seen. Crystals are usually idiomorphic and completely developed. An intimate lamellar structure is sometimes seen, due to repeated twinning in one plane.

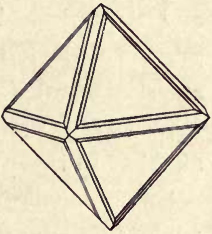

FIG. 15.—Spinel.

In origin it is very closely allied with Corundum, being usually found in limestones altered by thermo- or dynamo-metamorphism, thus naturally its associates are the same as Corundum usually has.

In chemical composition it is a combination of the oxides of magnesium and aluminium, MgO, Al_2O_3. The colour is due in all cases to the presence of other substances; thus traces of chromium or iron may cause a red colour; these metals are not so much impurities as replacement products, for some of the aluminium may be replaced by ferric iron or chromium, and some of the magnesium, by the iron (in a ferrous condition) or by manganese. We thus get three other mineralogical varieties. Ruby Spinel or Magnesium Spinel being the first, the second is an Iron-Magnesium Spinel, and is known as Ceylonite or Pleonaste; it is usually of dark colour, varying from green to very deep brown or even black. The third variety is one in which iron replaces aluminium; it is called Chlorospinel from its green colour, this colour being due to the presence of traces of copper. The fourth variety, Picotite, has replacements by both iron and chromium; its chemical formula may be expressed $(MgFe)O, (AlCr)_2O_3$.

When heated the red varieties become brown; on cooling again the red colour is restored, the mineral passing through green and colourless stages.

The distribution of Spinel is very similar to that of Ruby and Sapphire. Thus it is found in Burma, in the gem gravels of Ceylon, and in New South Wales. Other localities are Balachan (or Badakshan) in Usbec Tartary, Pegu, Mysore, and Minas Novas in Brazil. In Sweden it is found at Åker in Sodermanland in blue crystals (Åkerite).

Spinel is cut either as a brilliant or in the step pattern; when cut it may be mistaken for several other minerals; thus the Ruby Spinel and some of the Garnets are very similar, both being singly refracting, but Garnet has a higher specific gravity, and it is also less hard than Spinel. From red Topaz the Balas Ruby may be distinguished by the Topaz being doubly refracting and dichroic, and also more strongly charged with electricity when rubbed. The word "Balas" is said to be derived from the place name Balachan. Spinel and Corundum of a violet colour can be distinguished by the single refraction of the former and the dichroism of the latter.

Spinels take a high polish when cut, and when large their value is considerable. The Ruby Spinel when above three carats approaches the Ruby in value, but below that weight it is only worth about half as much as a good Ruby. Balas Ruby is worth about a quarter of the true Ruby of the same weight. What was probably the largest known Spinel of fine quality was one exhibited at the 1862 Exhibition in London; it was cut *en cabochon* and weighed 197 carats. Another large one is said to have been in the Treasury of St. Denis, and the shield of the Shah of Persia had a very brilliant Spinel at its lower point. A famous engraved specimen was one in the Rhodes Gems carved with a Gorgon's head.

242. CHRYSOBERYL.

This stone was not the Chrysoberyl of the ancients, which was probably either our Chrysoprase or our Chrysolite.

Chrysoberyl is a mineral of greenish colour, variously seen as grass-green, asparagus-green, greenish-white, yellow-green, or even emerald-green—rarely colourless; the darker rich green kinds are known as Alexandrite, they have a columbine-red colour by transmitted light. Another variety is the Cymophane or true Cat's Eye, which shows a beautiful blue chatoyancy. Chrysoberyl is rather rare in good specimens and is highly prized; were it more known its popularity would most likely be greater still. Where the surfaces are bright it is often seen to be transparent, but since as a rule it is only found in water-worn fragments and rolled crystals its more common appearance may be likened to a piece of glass that has been similarly water-worn; some specimens are but sub-translucent.

It has two optic axes or directions in which light can travel with equal velocities, and its greatest index of refraction is 1·756 and its least 1·747; its dispersive power is small. Ordinary Chrysoberyl is but feebly dichroic, but Alexandrite shows marked dichroism even to the unaided eye; when viewed in artificial light in the direction of the shortest crystallographic axis the colour is columbine-red, though in daylight the general tint is green; and in this direction, too, the dichroscope gives two distinctly coloured images, one emerald green and the other yellow, while in another direction a columbine red colour is seen. The Alexandrite is not only dichroic, but trichroic.

Alone it is infusible before the blowpipe and its colour remains unchanged when heated. When rubbed it shows a charge of positive electricity, which is retained for longer than is usually the case with minerals.

The specific gravity is 3·68 to 3·75; the fracture is conchoidal to uneven; it has a distinct cleavage parallel to one and cutting the other two crystal axes; it is brittle but very hard, ranking in point of hardness between the Topaz and Sapphire, or equal to 8½. The streak is colourless.

In crystalline form it is rhombic and when in single crystals its habit is tabular, the faces normal to the shortest axis being largely developed and showing striations parallel to the vertical axis. More often the crystals are twinned, either in three-lings or six-lings, so as to give a pseudo-hexagonal appearance to the group.

The variety Cymophane shows an interesting minute structure; this consists of a multitude of very small pores or cavities in the crystal arranged in a definite way, giving a certain degree of cloudiness to these specimens and also causing the opalescent effect seen on moving the stone. When the band of light is very sharply defined the stone showing it is called a Cat's Eye.

Chrysoberyl has rarely, if ever, been found *in situ*, but the secondary deposits in which it occurs are so constantly those derived from the weathering of granite and gneissose rocks that there is little doubt it is in such rocks that it has its origin. The principal locality for Chrysoberyl of the ordinary variety is the state of Minas Geraes in Brazil, where it is met with sometimes in association with Diamond. More often the associates are, Quartz and its varieties, Tourmaline, Euclase, Topaz, Garnet, and Spinel. In Connecticut, at Haddam, it occurs with Tourmaline, Garnet, and Beryl, in granitic bands in gneiss. In Moravia it is found at Marschendorf. An important locality is in the Ural Mountains, about sixty miles east of Ekaterinburg, associated with Topaz and Euclase. Here the variety Alexandrite is found, with Emerald, in mica-schist close to granite. Alexandrite was named after Alexander II. of Russia. More recently it has been found in the southern Urals. Much of the Chrysoberyl that is suitable for gem use is found in Ceylon in the gem gravels in rolled pieces. Here all three forms are found, the ordinary variety of different tints of green, the chatoyant variety Cymophane, and Alexandrite. The Cymophane is known sometimes as Ceylon Cat's Eye or Oriental Cat's Eye, to distinguish it from the Quartz Cat's Eye.

In chemical composition Chrysoberyl is beryllium aluminate BeO, Al_2O_3. The ordinary variety contains iron usually, and the variety Alexandrite is supposed to owe its colour to traces of chromium oxide.

Chrysoberyl is one of the minerals used as pivot bearings in watches and chronometers. Its use in jewellery is much subject to the fashion of the moment, and the demand varies considerably in different countries ; thus in Brazil it is esteemed the most valuable of the coloured gems. In Russia again the Alexandrite is in great demand. Chrysoberyl is, perhaps, the only coloured stone which shows to the best advantage when cut as a brilliant ; when the gem is thick enough this form is adopted, but thin specimens may be cut in gentle steps, or a mixed cut may be used ; it is usually mounted in a closed setting. Cymophane and Cat's Eye are cut *en cabochon* with a well-marked curvature. In cutting the Alexandrite due thought must be given to the colours as they will appear in different directions. The finest Cat's Eye known was in the collection of Mr. H. P. Hope, to which collection the famous Blue Hope Diamond belonged. Alexandrites have been found up to 60 carats.

Chrysoberyl can be distinguished from Chrysolite (or Peridot) by the greater hardness and rather higher specific gravity of the Chrysoberyl. The chatoyant variety is distinguished from the Cat's Eye variety of Quartz most easily by the much lower specific gravity of the Quartz.

CHAPTER X.

270. CALCITE.—LABRADORITE.

This mineral, so important in general mineralogy, is of but small consequence in so far as its use as a precious stone goes. A great deal of the material known to Theophrastus, Pliny, and other ancient writers, belonged to this species. A complete mineralogical description is here uncalled for, as the crystallised varieties are practically beyond the range of our subject, only some of the many massive varieties being used.

When pure it is colourless, but, like so many other colourless minerals, it is subject to much variation in colour from impurities, even when these are in very small quantity. Thus it may be cream, pink, grey, green, blue, violet, yellow, brown, etc. The lustre of pure specimens is vitreous; impure forms may be earthy. Similarly all gradations from transparent to opaque are seen.

One of its outstanding physical properties is its remarkably pronounced double refraction, and this property has given the name Doubly Refracting Spar to one of the varieties. The refractive indices for the D line of the spectrum are, for the ordinary ray 1·658, and for the extraordinary ray 1·486. On heating it decrepitates, and turns opaque white; coloured varieties may change colour. The specific gravity is 2·71 to 2·72 in pure varieties, but may be up to 2·84 in impure forms. The hardness is 3. It shows a conchoidal fracture when a fracture at all is obtained, but owing to a highly perfect cleavage a true fracture is not often seen. This cleavage is parallel to the faces of the rhombohedron, and advantage is taken of it in preparing Calcite prisms for the dichroscope and the polariscope. The streak is white. The crystalline form is rhombohedral, and the mineral often occurs in a great variety of highly developed crystals. The crystals are normally attached, and hence not fully developed.

Its modes of origin are very various, but the two chief ones are those due first to the uprising of heated water, and secondly, to the downward percolation of water usually at moderate temperature. In its hypogene form it is associated with many metalliferous ores, and in its epigene form with the great array of minerals formed by decomposition and subsequent new chemical combination.

The chemical composition is calcium carbonate, $CaCO_3$. Some of the calcium is frequently replaced by iron, magnesium, lead, manganese, or zinc.

The normal crystallised variety only concerns us in so far as it is used for the optical instruments before mentioned. For this purpose the large cleavage rhombs from the Icelandic localities on the Eskefjord and Breitifjord are used, but the material is now becoming scarce.

The fibrous variety known as Satin Spar is of more special interest; the fibres are very fine, and are arranged in a parallel manner so as to exhibit a silky effect when the specimen is broken; some forms show a wavy band of light also, and the appearance may then be compared to "watered" silk. The cause of this phenomenon is the same as in other chatoyant minerals, namely, reflection from a vast number of minute parallel surfaces. Amongst other localities are the Carboniferous volcanic rocks of Fifeshire, and in veins in the "plate" or lower Carboniferous shales of Alston Moor, in Cumberland. It is nearly always found in narrow veins, and usually completely fills them. It may be cut *en cabochon*, to show the chatoyant effect, but its softness renders it very prone to damage.

Of the massive varieties Fire-marble, or Lumachello, may be noticed. It is a fossiliferous marble, with a beautiful iridescence of red, green, and blue colours, almost comparable to the Opal. It is chiefly found in the lead mines of Bleiberg, in Carinthia.

What was known to Pliny as the Alabastrites was a form of carbonate of calcium, deposited from water, in layers. It might be either stalactitic (formed by lime-bearing water dripping from the roof of a cave), or stalagmitic (formed by the water dripping on the floor). When it showed pale creamy bands it was known as Onyx, from its resembling the finger-nails of the "well-bred person." The term Alabaster was used on account of this substance frequently forming the material of the Alabastra or ointment jars (King). Much of this Alabaster was found near Thebes, and has thus come to be known as Egyptian Alabaster, to distinguish it from the compact Gypsum, which is also called Alabaster. Much of this stalactitic material, when first formed, is probably Aragonite, a rhombic carbonate of calcium which tends to pass into Calcite. Alabaster is translucent, and is capable of taking a very fine polish, but on account of its softness it is easily scratched. "Gibraltar Stone" and "Mexican Onyx" are named from the localities where they are found.

Travertine is a form deposited by springs and streams. The name is derived from Lapis Tiburtinus of Pliny, much of the material being found near Tivoli. It shows the same banded structure.

288. MALACHITE.

The Malachites of Pliny were not our Malachite, but his Smaragdus Medicus has been identified by King as the mineral now under consideration, and the Chrysocolla of Theophrastus seems to have been Malachite in part. In the time of De Boot it was held in great esteem for variou medicinal properties attributed to it—virtues which had previously been held to belong to a variety of Jasper, but which were by the magicians transferred to Malachite, when that particular Jasper could not be obtained. It is of a rich bright green in colour, some varieties being banded with lighter and darker greens. The massive botyroidal variety, chiefly used as an ornamental stone, has a lustre that may be silky when the fibrous structure is marked, or waxy when very compact. The crystals, which are usually very minute, are adamantine or vitreous in lustre. It is translucent to opaque; when heated it turns black and readily fuses. The specific gravity is high, 3·71 to 4·01. The crystalline form is mono-symmetric, the crystals are minute and acicular.

It occurs as a decomposition product of copper ores, and is often found in pseudomorphs of the minerals Cuprite and Azurite. It is associated with the closely related mineral Azurite in most cases; although it may be found in any copper-bearing vein, whose contents have undergone alteration, and as an alteration product of the disseminated copper in some sedimentary rocks, and is thus widely distributed; yet specimens suitable for ornamental use are not at all common, most of them being found in the Ural Mountains; thus at Nizhni Tagilsk, one mass was found measuring some 160 square feet, on the upper surface. Now but few of the mines produce it in pieces large enough to cut. On the west coast of Africa, Bembe has yielded fine pieces. In Australia, the Cobar mines in New South Wales and the Burra-Burra mines in South Australia produce good specimens. In the United States, the Humming Bird mine in Arizona is a noted locality.

In composition it is a basic cupric carbonate, $CuCo_3$, $Cu(OH)_2$, containing 72 per cent. of oxide of copper. The darkening seen on heating is due to the driving off of water. It is easily reduced to metallic copper, hence is a valuable ore of that metal when occurring in sufficient quantity.

A few intagli in Malachite are known; now its chief ornamental use is for such articles as vases, letter weights and other smaller objects; often it is used as a veneer and for inlaying; rarely is it cut as a gem stone; when it is, it is usually *en cabochon*, more rarely in steps.

THE FELSPARS.

The Felspar Group contains several closely related species which are of secondary importance as precious stones. The individual members closely resemble one another in crystalline form, cleavage, hardness and specific gravity, and to some extent in origin, though some are characteristic of one type of rock, and some of another. All we are concerned with belong to the triclinic system, with one exception, that being Orthoclase. In all, the common habit of the crystal is that of a stout prism terminated by one or more faces in an oblique direction, the exact angles varying but little in the different members of the group. All possess two cleavages; in Orthoclase these cleavages are at right angles to one another, while in the other Felspars the angle does not differ widely from a right angle. The hardness of all is equal to, or slightly exceeds, 6 of Mohs' scale. The specific gravity varies between 2·5 and 2·9. All are silicates of aluminium with either potassium, sodium or calcium. Further, there is a certain amount of gradation seen from one member of the group to another, and this is accompanied by a corresponding gradual change in form and physical properties. Few of the Felspars show transparency, most are translucent to opaque; most are of a light colour or colourless. Several different members of the group are used as precious stones under the same designation.

313. ORTHOCLASE.

Orthoclase occurs in several shades of colour, usually light in tint; rarely it is colourless, as in the pure variety Adularia, which also shows a moderate degree of transparency, other kinds being translucent to opaque. Doubly refracting; specific gravity 2·53 to 2·59; two cleavage planes at right angles to one another, both well marked. Streak colourless. Its crystalline form belongs to the monosymmetric system; the crystals are sometimes attached, often crystallised from a semi-fluid magma and then frequently completely developed. It is an essential rock-forming constituent of several volcanic rocks. In chemical composition it is an aluminium potassium silicate, K_2O, Al_2O_3, 6 SiO_2.

The most important variety for the present purpose is the pure Adularia, which is often found in large transparent or sub-transparent crystals attached to the matrix in groups, the crystals often being twinned (Fig. 16). It is of frequent occurrence in the fissures of the gneissose rocks of the Alps. The sub-variety Moonstone shows a peculiar reflection of bluish-white light, which from its common presence in Adularia is known as adularescence; it is only seen in certain directions and chiefly near the face which is normal to the shorter lateral axis of the crystal. Moonstone, which is also known as Girasol, Wolf's Eye, Ceylonese Opal, and Water Opal, is not only a variety of Adularia; the term refers to the appearance of the stone rather than to its composition, and other Felspars, as Albite and

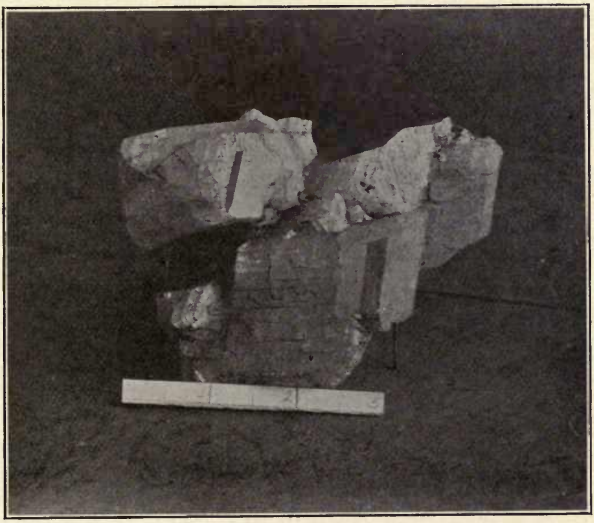

Fig. 16.—Adularia.

Oligoclase, may occur as Moonstone. The most important locality for this gem variety is to the south-east of Adam's Peak in Ceylon, where Moonstone occurs in fragments imbedded in a white clay, probably derived from the weathering of some acid volcanic rock. Another place where it is found is the Amelia Court House in Virginia in the United States; here it occurs *in situ* in the granite.

It is always cut either in flat pieces, when it shows a uniform adularescence, or *en cabochon*, when the light takes the form of a more or less well marked band. The exposed surface must be properly placed to show the full effect. Brand records that a good Moonstone of about half an inch in diameter sold for £35. It is readily distinguished from a glass imitation by the double refraction of the Felspar, and by the glass being more dense.

Rarely Orthoclase occurs in the form of Aventurine, very similar in appearance to the Aventurine variety of Quartz. The effect is due to the inclusion along the directions of the more perfect cleavage plane of numerous plates of micaceous Hæmatite which cause a bright red metallic reflection of the light. Aventurine Felspar is also known as Sunstone, and here again the term applies to appearance rather than to composition. Orthoclase Sunstone is not so common as the Oligoclase Sunstone. The Orthoclase variety is found chiefly in North America, at Amelia Court House in Virginia and in New York State. It is cut *en cabochon*, and the surface must of course be in such a position that the reflection is seen at its best.

A rare variety of Orthoclase is that which shows an optical colour effect similar to that seen in Labradorite, and hence known as labradorescence. It is found in augite-syenite at Laurvik in Norway, and though not much used for cutting in small pieces, it is frequently to be seen in this syenite, slabs of which are largely used now in facing the jambs and lintels of shops in large towns.

All these varieties of Orthoclase may be distinguished from similar varieties of triclinic Felspars by the absence of the characteristic striping of these latter species.

315. MICROCLINE.

This Felspar occurs white, cream coloured, red, and green: the only kind with which we are concerned is the green, which is known as Amazonstone. The exact colour varies somewhat, but may usually be described as a verdigris green; it is sub-translucent to opaque. The specific gravity is 2·54 to 2·57. It has a vitreous lustre, uneven fracture, and the hardness is 6 to 6½. Besides the cleavages all Felspars show it has two other less perfect cleavages. It often shows a characteristic corded structure, and it crystallises in triclinic forms. Its mode of occurrence and composition are very similar to Orthoclase, but the colour is supposed to be due to traces of copper compounds. In the Ural Mountains it is found near Minsk; in North America, at Pike's Peak in Colorado, and with other Felspars at Amelia Court House in Virginia. Fine crystals were obtained by Professor Heddle near Tongue in Scotland. It is cut for small ornamental objects and for brooches, rings, and the like. In the latter cases the usual form given is that of a thin plate either flat or curved.

316. ALBITE.

Albite is usually colourless or white when unweathered, but may show tints of pink, grey, red, or green. It is transparent to sub-translucent. The specific gravity is 2·62 to 2·65, with a fracture and cleavages very similar to those of other members of the group. The hardness is 6 to 6½. It is a triclinic Felspar and is usually twinned repeatedly in fine lamellæ, and this gives rise to a striped appearance often seen in the triclinic Felspars. As an original constituent of many granites it is very widely distributed; in these cases it is usually in crystalline masses that have been formed simultaneously with other minerals, and as a consequence the crystal faces are not developed. Again, it may frequently be found in cavities in the granites, usually in the outer part of the mass, associated with Beryl, Topaz, Smoky Quartz and other minerals. In chemical composition it is an aluminium sodium silicate, $Na_2O, Al_2O_3, 6 SiO_2$. An Aventurine variety sometimes occurs, but more important is the purer form Peristerite or Albite Moonstone, which shows the chatoyant light very well in good specimens. Other specimens show more play of colour like Labradorite, but less intense. Peristerite occurs at Bathurst and Burleigh in Ontario and at several other places in North America.

317. OLIGOCLASE.

This species is chiefly of interest because to it belong most of the Sunstones met with in use as precious stones. Its composition varies somewhat; it is essentially an aluminium-sodium-calcium silicate. It is usually white, grey, greenish, or reddish in colour, transparent to sub-translucent, of specific gravity 2·63 to 2·67. Its hardness is rather greater than the previous species, being 6—7. The cleavages are very similar to those of other triclinic Felspars. It occurs in well developed crystals of the triclinic system, and in crystalline masses. In the Aventurine variety (Heliolite) the inclusion is usually Hæmatite, possibly sometimes Göthite, but it always occurs so as to give the sheen parallel to the principal cleavage plane; on this aspect, too, it shows the characteristic striping due to polysynthetic twinning common to all triclinic Felspars. This striping affords a means of distinguishing Oligoclase Sunstone from the artificial glass and from the Aventurine Quartz; from the glass it may also be distinguished by its double refraction. Quartz is usually distinctly harder also than Oligoclase. It was at first only known from Cedlovatoï, an island near Archangel. At that time—early in the nineteenth century—it was in great demand, and brought a high price. Later it was found near Lake Baikal, and at Tvedestrand in Norway. It also occurs in County Donegal, and in the island of Tiree in Scotland. There are several localities where it is found in North America. It is cut *en cabochon*, so as to expose the metallic reflection to the observer.

319. LABRADORITE.

This Felspar is rarely seen in distinct crystals, more often in large crystalline masses of a dull grey or brownish colour, very rarely colourless; the general lustre is vitreous; very rarely is it seen transparent, usually being only sub-translucent, or even opaque. It has two cleavages inclined to one another at a little over a right angle, and, in addition, there are three other less important cleavage planes; the lustre of the more perfect cleavage plane is distinctly pearly. From the less perfect cleavage, on turning in certain directions most beautiful colours will be suddenly seen proceeding when the angle the line of sight makes with the cleavage plane is exactly right; in all other positions the mineral is but a dull grey colour. This effect, from being seen in this mineral, is known as labradorescence; the colours are very varied—green, yellow, blue, or red, and these in various shades may be seen. The colour in some cases is due to minute inclusions causing interference of light; but in the case of the blue colour it must be due to some other cause of interference, since it may be seen when there are no inclusions present.

The specific gravity of Labradorite is 2·67 to 2·76; its hardness is rather below the average of the Felspars, being only 5 to 6. In crystalline form it is triclinic, and it often shows repeated twinning, and this may cause the flash of light to be broken up by rectangular patches of dull grey, representing a portion of the crystal occupying a reversed position; when the specimen is turned the parts which were previously grey may be seen to light up with colour and at the same time the previously brilliant portions will be dull.

In chemical composition it is an aluminium-calcium-sodium silicate; it is a common constituent of basic eruptive rocks. It was first found in the island of St. Paul, off the east coast of Labrador; on the mainland of Labrador several localities near Nain are given. In Russia it was found in boulders at Peterhof, and in some of the cobbles used in paving the St. Petersburg streets. Other localities are Miolö and Åbo, in Finland; in the gabbro of the River Teterev, a tributary of the Dnieper; and in many places in the United States.

The material from the United States is largely quarried as an ornamental stone, but is inferior in brilliance of colour to the Labrador specimens, and hence is not cut as a gem; for the latter use the material must show as even a surface of colour as possible, and therefore must be free from the reversed portions due to twinning. The stone must be cut too with the exposed surface parallel to the less perfect cleavage referred to. At one time specimens that showed peculiar distributions of colour, which by a little imagination might be regarded as portraits, were in great demand and high prices were asked for them; one specimen is recorded to have shown a distinct head of Louis XVI., and for this £10,000 was asked in 1799. M. de Dree had a small table, the top of which was composed of two pieces of Labradorite, that sold for £75.

CHAPTER XI.

325. AUGITE.—CROCIDOLITE.

Augite is one of a group of minerals known by the group-name of Pyroxenes, which are metasilicates of calcium, magnesium, and iron. Of the numerous varieties of Augite we are only concerned with one, Diopside, and the description will be confined to that.

Diopside, which is also known as Malacolite, Alalite, and Mussite, occurs in green, or rarely grey, to white crystals usually attached in groups (Fig. 17). The tint of green varies from very pale to very dark. The crystals are transparent to translucent, and of a high vitreous lustre. They are doubly refracting, but show only very slight dichroism, even in the specimens possessing a deep colour. The specific gravity varies from 3·2 to 3·4, being greater in the deeper coloured varieties. Diopside is a brittle mineral. Its hardness is equal to 6, and it has a well-marked cleavage parallel to the faces of the rhombic prism. It crystallises in the monosymmetric system, and the usual habit of the crystal is prismatic, with a well-marked oblique termination. The prism faces are striated longitudinally. The prism is composed of a right-angled form, whose solid edges are truncated by the faces of the rhombic prism. The crystals are always attached at one end, and are often in groups. Twin crystals are often seen. It occurs in cavities, with the variety of Garnet known as Hessonite, and with Mica. In chemical composition it is a calcium magnesium metasilicate, $CaMg(SiO_3)_2$, usually with a variable amount of iron, that with the greater amount being darker in colour and of greater density. Diopside was originally found at the Mussa Alp, in the Ala valley in Piedmont, hence the names Alalite and Mussite. It is also found at the Schwarzenstein Alp, in the Tyrol, and at De Kalb, in New York State. When cut as a gem the clear green transparent forms are used, and they are either step or table cut. They are chiefly used in the countries where the mineral is found. It is rather difficult to distinguish from Olivine, but Diopside is the softer mineral of the two. The green Chrysoberyl and green Idocrase are both denser than Diopside, while Tourmaline and Epidote are more

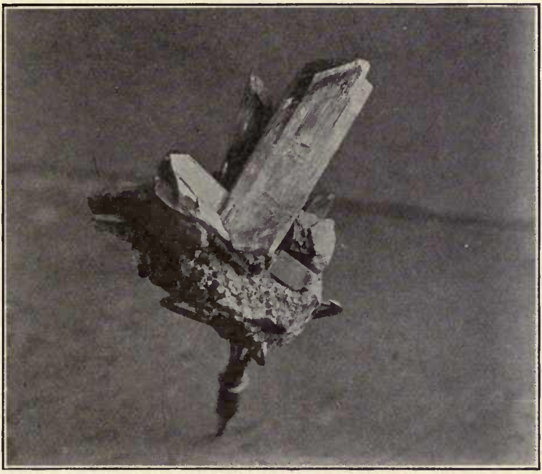

FIG. 17.—Diopside.

strongly dichroic. Emerald and Dioptase differ from Diopside in colour. A glass imitation may at once be known by the single refraction.

327. Spodumene.

Spodumene is another mineral belonging to the Pyroxene group, but until comparatively recent times it was of no importance as a precious stone. However, in 1879 Mr. W. E. Hidden discovered a beautiful variety, which has been named in his honour; and more recently still another variety has been found in California, and named by Dr. Baskerville after Dr. G. F. Kunz, the author of "The Gems and Precious Stones of North America."

The colour of the ordinary variety of Spodumene is white, grey, yellow, or rarely somewhat violet; Hiddenite varies from yellow-green to emerald-green, and it is from specimens of the latter colour that the gem stones are cut; Kunzite is found in various shades of pink, violet, and blue. The mineral is transparent to translucent, the lustre is vitreous. It is doubly refracting, the greatest and least indices for the D line being 1·68 and 1·65. It shows strong pleochroism, and the variety Kunzite has a marked phosphorescence induced by exposure to X-rays and to the emanations of radium. The specific gravity is 3·15 to 3·20, and the hardness is 6½ to 7. In crystalline form it is monosymmetric, and the habit is usually prismatic. The crystals show vertical striations, and Hiddenite often shows etched markings. There is a perfect cleavage parallel to the prism faces. The crystals of the ordinary variety are often very large, up to 4 feet long and 1 foot across. Hiddenite occurs in slender crystals of 1½ to 2 inches in length.

In chemical composition Spodumene is a lithium aluminium metasilicate, $LiAl(SiO_3)_2$.

Spodumene is usually found in crystalline rocks that have been formed under great pressure, and it is frequently associated with such minerals as Tourmaline, Magnetite, Beryl, Garnet, Monazite, Mica, and Quartz.

Two rare colours of the ordinary variety from Brazil have been found suitable for gem use. One is greenish-yellow and transparent, and was for long mistaken for Chrysoberyl, and the other is transparent and blue, and is found near Diamantina in Minas Geraes, and was mistaken for Lazulite. Greenish-yellow transparent crystals have also been found with Hiddenite in the United States.

The variety Hiddenite was found near Stony Point in Alexander County, North Carolina, in cavities in a granitic rock. There was a great demand for the gem in the United States, and the supply from this locality soon became exhausted. In value the gem is comparable to a good Diamond.

About twenty years after the discovery of Hiddenite the variety Kunzite was found, at a mine in the Pala mountains in San Diego county, California. The crystals, apart from their beautiful colour, were remarkable for their size and perfection, and the cut gem soon acquired as high a value as almost any gem, over £200 being asked for some specimens.

Most of the specimens have been retained privately in America, but the national collection in the British Museum and the American Natural History Museum collection include fine specimens.

Spodumene may be distinguished from other yellow-green minerals which are doubly refracting, as follows: Beryl is distinctly less dense, Chrysoberyl and Olivine are distinctly more dense, and Diopside is slightly denser. Beryl and Chrysoberyl are harder. Diopside is not so hard, Olivine is of about the same degree of hardness, but both Olivine and Diopside are less markedly dichroic than Spodumene, and so is Emerald, which can be further distinguished from Hiddenite by the Emerald having a colour more pure and intense. Kunzite and Amethyst may be of nearly equal hardness, but Amethyst is of lower specific gravity, and is less markedly dichroic. Oriental Amethyst (Corundum) while strongly dichroic, is very much denser than Kunzite, and very much harder. Various colours of Garnet and all glass imitations may be distinguished from Spodumene by their single refraction.

328. Jadeite.

This mineral, which is really one of the Pyroxene group, is often, with its variety Chloromelanite and the Amphibole mineral Nephrite, spoken of as Jade; thus this term includes two distinct species of mineral.

Jadeite is only known massive, though it has a microscopical crystalline structure, and is supposed to be either monosymmetric or triclinic. The masses show an intimate fibrous structure which renders the mineral remarkably tough and hard to fashion. In colour pure specimens are almost white, tinged usually with apple-green streaks; sometimes it is seen of an emerald-green colour or leek green. It is translucent to sub-translucent in thin pieces, and in the mass opaque. The lustre is sub-vitreous to pearly. Heat readily causes it to fuse to a glassy mass. The specific gravity is 3·33 to 3·35; the hardness is 6½ to 7. Little is known definitely about its origin; it is said to be found in rolled masses in a clay of reddish colour.

In chemical composition it is a sodium aluminium silicate, $NaAl(SiO_3)_2$. The variety Chloromelanite is of a dark green colour and contains a good deal of iron.

The most important locality for Jadeite is in Upper Burma, on the River Uru, where it occurs massive *in situ* in a dark serpentine, and also in boulders in the river below. Here it is extensively mined, and thence much of it is sent to China, where, with the other substance known as Jade, it is called Yu or Yu-shih. Some of it is also sent to Mandalay, and there cut.

Jadeite is also said to occur in the Yarkand regions *in situ*, and it may very likely be found *in situ* in the Alps, as rough unworked fragments are found around the Lakes Neuchâtel and Geneva, and it is said to occur in Alaska.

Ancient implements made of Jadeite are found very widely distributed in Europe, Asia, America and Africa.

It is a highly prized mineral amongst the Chinese, who fashion it into rings, vases, cups, and numerous other articles, displaying a skill and patience in their work that is truly remarkable. Many prehistoric weapons are wrought in this material, and the ancient Egyptians made some of the scarabs of it. Good specimens still command a very high price, especially in China.

The Amphibole Group.

This group, like the Pyroxene group, comprises several species of closely allied minerals, amongst which only two concern us: these are Nephrite, a variety of Hornblende, and Crocidolite. As in the Pyroxene group, the various members of the Amphibole group show forms belonging to different crystallographic systems but yet closely alike in form. Again they are metasilicates of calcium, magnesium and iron, but in this instance the alkali metals are more often found in the minerals as well.

338. HORNBLENDE: VARIETY NEPHRITE.

Although this species, Hornblende, is sometimes referred to as Amphibole, it seems better to retain the latter name as the name of the group. The crystalline varieties of Hornblende differ so widely in appearance from Nephrite that it must suffice to say the crystals are of the monosymmetric system, show a generally rather slender prismatic habit, and have a distinct prismatic cleavage. There is a marked pleochroism.

Nephrite, which is also known as Axe-Stone and Kidney-Stone, is included under the old term Jade and the Chinese term Yu. It is never found in crystals, but always in more or less irregular masses showing an intimate fibrous structure which renders it, like Jadeite, particularly tough, so that to break a piece of any size with a hammer is no easy matter. In colour it is usually greenish, but the colour varies a good deal according to the amount of iron present, that with more iron showing a more pronounced green. Very rarely it is colourless, or tinted with red or blue. Nephrite is never transparent, and is only translucent in thin pieces. The specific gravity varies from 2·91 to 3·2, but as a rule may be taken as 3·0. The fracture is splintery and the mineral is remarkably tough; the hardness is 6 or $6\frac{1}{2}$. When found *in situ* it is always in metamorphic rocks of one kind or another; thus, in Germany it occurs at Jordansmühl and Reichenstein in Silesia; in Turkestan it occurs on the Yarkand Daria below Yarkand and between there and Khotan, both *in situ* and as water-worn fragments in the rivers, also further east on the northern slopes of the Kuen-Lun (Jan Shanskii) Mountains. Dr. G. F. Kunz records the finding of Nephrite *in situ* in Siberia by members of the Russian Geological Survey, in the district of Chara Jalga. It has also been found in the rock in Alaska, in the South Island of New Zealand and in various parts of Polynesia. Nephrite has also been found in the unworked state, but not *in situ,* in the glacial deposits of Northern Germany, in the district of Irkutsk in Siberia, in the above-mentioned localities in Eastern Turkestan and in the west of the Chinese Empire, in New Zealand and in Alaska; also on the Fraser River in British Columbia. In Switzerland, Germany, Mexico, and New Zealand, Nephrite was used in very remote times for battle-axes and other weapons, and it is supposed the Chinese have worked the deposits in the Kuen-Lun Mountains for 2,000 years, using the material in the same way as Jadeite and other stones known to them as Yu. When used among Western nations it is usually in the form of a ring cut from the solid material, or for small pieces (*en cabochon*) for setting in brooches, etc.

Nephrite is most likely to be confused with Jadeite, but the latter is distinctly denser as a rule, though occasionally specimens of Jadeite are found with a specific gravity included in the range Nephrite shows. The value of well worked ornaments in Nephrite is high on account of the great time required to execute the work, and amongst the Chinese the rough material is greatly sought after and commands a high price.

341. CROCIDOLITE.

Crocidolite is another member of the Amphibole group and is of interest in that it gives the characteristic appearance to the precious stones known as Hawk's Eye and Tiger's Eye, though both of these are in a greater or lesser degree alteration products of Crocidolite.

Crocidolite occurs in narrow veins or bands having a transverse closely fibrous structure due to the parallel arrangement of numerous minute acicular crystalline growths. The colour of the unaltered mineral is a leek green. The lustre of one of these fibrous pieces, even when broken, is distinctly silky. On heating, a little water is driven off, and the mineral then easily fuses. The specific gravity is 3·2 to 3·3, but, as will be seen below, the specific gravity of the two varieties mentioned may fall to nearly that of Quartz. The hardness of Crocidolite is 4.

In composition it is a sodium ferri-ferrous metasilicate, $NaFe(SiO_3)_2, FeSiO_3$. Infiltration of this fibrous mineral with Quartz gives the variety Hawk's Eye, of a blue green to indigo blue colour; the process of infiltration is a gradual one, so all stages are found between what is an undoubted Amphibole and a substance which may be regarded as a variety of Quartz showing inclusions. Further by a gradual change the Crocidolite may be decomposed, its iron passing into the state of the hydrate (Limonite) and the silica remaining, with possibly addition of silica from outside, as Quartz, and thus the golden brown stone known as Tiger's Eye is produced ; it may also be regarded as a form of Quartz containing pseudomorphs of Crocidolite in Limonite. The Hawk's Eye may thus show a transition to Tiger's Eye; hence the only definite starting point we have in tracing the origin of these two precious stones is the original Crocidolite, and for this reason they are described under this species. It follows, from what has been said, that when the infiltration by Quartz is complete the specific gravity is that of Quartz with a slight excess due to the inclusions, and further the hardness is 7.

Tiger's Eye and Hawk's Eye both occur in veins in schists in the Asbestos Mountains in Griqualand West, and in other parts of South Africa.

At one time the material was scarce and was only used for smaller articles of ornament, but now there is a plentiful supply and the price has fallen so much that it is commonly used for paper weights, umbrella handles, and other similar articles. The variety Tiger's Eye when polished with the exposed surface parallel to the fibres had a particularly brilliant golden brown colour and shows a highly silky lustre.

CHAPTER XII.

344. BERYL—GARNET.

Beryl is one of the gem stones that has been known from ancient times. The term Smaragdus of the old writers included Beryl and its green varieties amongst many other green stones, and Pliny's Beryllus was almost certainly this mineral. It is probable that the Beryl of Aaron's Pectoral was also our Beryl. Pliny further mentions that the gem came solely from India, and that the blue-green kind (Aquamarine) was the most prized. The name is said to be derived from a Low Latin word meaning a lens, possibly on account of the Romans cutting their transparent gems with curved surfaces in many cases, though they are reputed to have cut the Beryl in the form of a low six-sided pyramid, guided possibly by the natural form of the crystal termination. It was reputed to be a cure for diseases of the eye, possibly on account of the well-known soothing effect of green light. It would appear that someone, endowed with a more exact power of reasoning than many of his contemporaries, who was wearing an Emerald or Beryl on account of its reputed value in eye affections, found that he could really see better with his Beryllus, which was probably cut with two curved surfaces so as to be a meniscus, thinner in the centre than at its periphery, and rightly attributed the effect to the shape of the stone and not to its kind, and thus led to the correction of myopia by means of concave lenses. It is also said by Pliny that Nero watched the gladiators fight, aiding his sight by an eye-glass of Emerald.

It was much used by the Romans for ear drops, and was sometimes engraved by them, though rarely, as they held it in too high an esteem to be used often as material for intagli. The Indians, too, pierced the commoner varieties, and used them as elongated beads, while the more precious kinds were mounted in gold in their natural state, and worn as pendants in very much the same way as crystals have been used quite recently.

Beryl is found in a variety of colours, and different terms are applied to the gem according to the colour.

Emerald includes the bright green shade which is so well known that this particular colour is constantly spoken of as emerald-green. Aquamarine covers the pale blue, bluish-green, and greenish-blue shades of Beryl ; the yellow-green shade is Aquamarine-Chrysolite, and the bright yellow is Golden Beryl ; these three together are known as Precious Beryl. Other colour shades include : a pale yellow-green, which may have been the Chrysoprasius and Chrysoberyllus of Pliny, in part, at least ; the apple green, pale rose red, rarely a sapphire blue, and a pale violet. Sometimes Beryl is found colourless.

The mineral occurs from transparent to subtranslucent, but the modern gem varieties are confined to the transparent kinds. The lustre is characteristically vitreous. Double refraction is only feeble, the index for the ordinary ray being 1·584, and for the extraordinary 1·578 ; and the dispersion is small, hence there is but little play of colour due to refraction. The mineral is, however, distinctly dichroic, and the difference in colour in the various directions may sometimes be seen without the aid of the dichroscope. The green colour of the Emerald is not discharged by strongly heating, hence is not due to organic matter. Before the blowpipe even thin splinters fuse with difficulty, first turning an opaque white.

The specific gravity of Beryl is 2·67 to 2·75. The fracture is conchoidal, and the mineral is distinctly brittle, and hence must be handled with care. The hardness is 7½ to 8. There is an indistinct cleavage parallel to the basal plane. The streak is white.

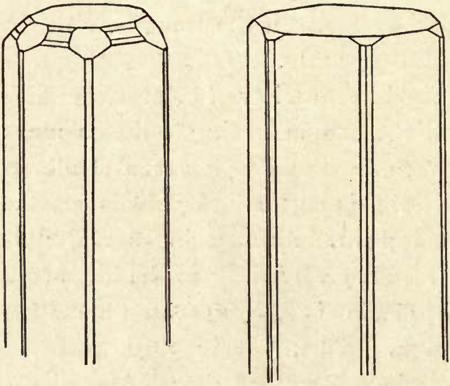

Fig. 18. Fig. 19.

Crystals of Beryl.

In crystalline form it is hexagonal, and the crystals usually show a rather slender prismatic habit (Fig. 18), and are often striated vertically by repeated oscillations of different prism faces. The Emerald in particular is very frequently seen to have numerous minute internal cracks and fissures, so that "an Emerald without a flaw" is quite proverbial. The crystals as a rule show a prominent hexagonal prism, with the dihedral angles modified by a narrower face belonging to another prism (Fig. 19). Terminated crystals are rather the exception, but when they do occur the form of the termination is often very complex. More often the prism is limited by an eroded surface (Fig. 20) (*cf.* Tourmaline). Another not uncommon feature is the transverse separation along the cleavage planes, with displacement of the fragments and subsequent cementation by Quartz. Attached crystals are often found in druses in certain granites; most of the clear terminated crystals are so found. Another common mode of occurrence

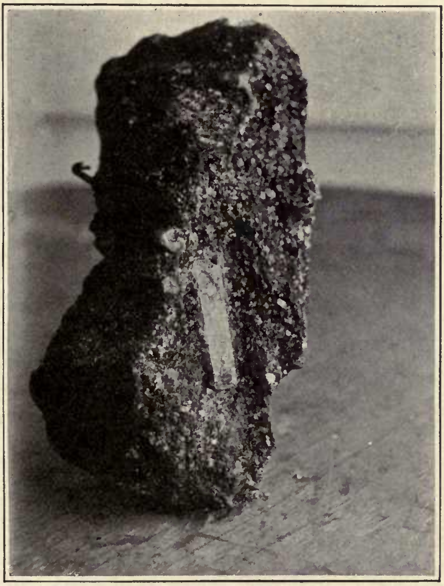

FIG. 20.—Emerald in its Matrix.

is in pegmatitic rocks which have been formed by dynamo-metamorphism, and to this group belong most of the crystals showing dislocation and absorption, and many of the more opaque varieties.

Beryl is a metasilicate of aluminium and beryllium, the latter element being so called from its presence in Beryl. Emerald probably owes its beautiful colour to the presence of traces of chromium ; many specimens of Beryl contain a little iron and calcium as well but they do not seem to be in any way essential, so the formula may be expressed as $3\ BeO,\ Al_2O_3,\ 6\ SiO_2$. Many specimens also contain 1 per cent. to 2 per cent. of chemically combined water. Beryl resists the action of all acids except hydrofluoric acid, by which it is attacked.

The distribution of Beryl is very wide. Probably the locality which, as far as is known, is the oldest is one in Egypt, where Emerald is believed to have been mined 1650 B.C., if not earlier. The crystals occur in mica-schist at Jebel Sikait and Jebel Sabara; they are of a good colour, but rather pale.

It is very doubtful if the Emerald really came from India in Pliny's time; certainly there is no authentic record of it having been found there, though other shades of Beryl, as the pale blue Aquamarine, occur in pegmatite bands in gneiss in the Punjab and in other parts of India. Many of the crystals are of large size, but are not of very good quality, being extensively fractured.

Peru was for a long time believed to be the home of the Emerald; the Spaniards undoubtedly brought large numbers of this gem from Peru in the sixteenth century; and it is recorded in "Cérémonies Religieuses" that, before the time of the Incas, the Peruvians used as an idol an Emerald as large as an ostrich egg, which the priests explained was the mother-emerald who liked daughters, and thus induced her worshippers to offer "daughter-emeralds" to the goddess, much to the enrichment of the Spanish when they conquered the country. Certain it is that, in spite of most careful search by the Spanish and by later explorers, no trace of the Emerald has been found in Peru. Still, the fact that such beautiful specimens were brought to Europe by the Spanish from Peru has given us the terms "Spanish Emerald" and "Peruvian Emerald," as indicating Emeralds of the finest quality.

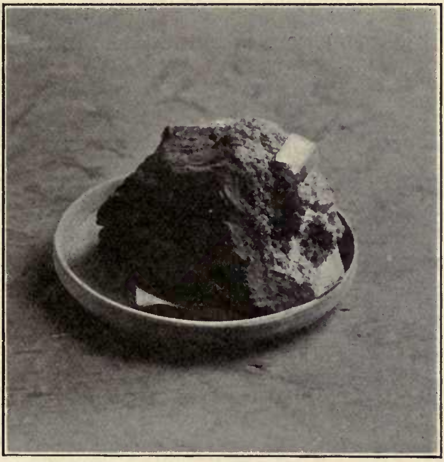

Fig. 21.—Emerald in the Matrix (Colombia).

The Spaniards, however, found Emeralds in New Granada (Colombia), and the deposits there have been worked intermittently ever since and have provided some of the finest specimens known. The place where they were first worked by Europeans, and whence they had been previously obtained by the natives, was at Somondoco on the eastern slopes of the Cordillera of Bogotá ; these deposits, though still sometimes worked, do not yield very fine quality stones. Afterwards another deposit was found on the western slopes of the Eastern Cordillera to the east of the Rio Magdalena and near the town of Muzo, lying to the north of the capital, Bogotá. This is now the principal locality in which the gem is found ; the mineral occurs in a dark bituminous limestone, and the crystals are usually implanted on Calcite, the latter occurring in cavities in the limestone (Fig. 21). This deposit is of interest in another way, because it practically forms the only exception to the rule that Emerald occurs in granitic and dynamo-metamorphic rocks. The associates are exceptional also, Gypsum, Pearlspar, Quartz, Iron Pyrites, and a rare mineral called Parisite being found with the Emerald. Many of the specimens show the dislocations, but in this case the material filling the fissures is Calcite and not Quartz. The stones, too, are prone to become turbid after a time from the formation of numerous minute flaws. Emeralds of gem quality are known locally as Canutillos, and those not fit for cutting as Morallons.

Also in South America, in Brazil, Beryl occurs in some quantity in the north-east of Minas Geraes, associated with Topaz and Chrysoberyl ; the crystals are often of several pounds weight, but the larger ones are usually, as elsewhere, cloudy and in a large part unfit to cut. The mineral here is probably derived from a granitic rock. Near Rio de Janeiro, too, Beryl occurs in pegmatite bands in gneiss. The variety Aquamarine-Chrysolite is found in Brazil.

In North America, Emerald is found at Stony Point in Alexander County, North Carolina, with Hiddenite; other forms of Beryl also occur here. Russel Gap Road, also in Alexander County, is a good locality for Aquamarine. In Maine, in Oxford County, green Beryl is found, and at Albany Golden Beryl occurs. At Royalston in Massachusetts, Beryl of a sapphire blue is found. At Grafton in Hampshire, a large Beryl crystal was found which weighed 2½ tons. Emerald also occurs at Haddam in Connecticut. In Colorado, on Mount Antero very fine Aquamarines are found, associated with Phenakite.

In the Ural Mountains Beryl is found at many places; thus in the Ekaterinburg district it is found at Mursinka and Shaitanka in cavities in pegmatitic rock. The variety Aquamarine-Chrysolite occurs here as well as Beryl of other shades, as various greens and yellows. The crystals are smooth and are associated with Topaz, Felspar, Tourmaline and Quartz. To the east of Ekaterinburg Emerald occurs in mica-schist with Chrysoberyl, Rutile, Phenakite, Apatite, and Fluor Spar. The crystals, which are often large, are in many cases poor, show dislocations, and are rarely terminated.

In the Ilmen Mountains pale green Beryl is found in pegmatite with Topaz and Amazonstone, and large crystals occur in the Altai Mountains. In the Nerchinsk district Beryl is found in the Adun-Chalon Mountains in pegmatite bands in granite with Topaz and Quartz, with over all a layer of Limonite (Fig. 22). Also on the Urulga River in fine yellow-green crystals.

Emerald has been found in the Salzburg Alps at Sedlalp, with Tourmaline and Iron Pyrites in mica-schist. In the Mourne Mountains in Ireland Beryl is found with Quartz, Felspar and Topaz, in druses in the granite.

In Australia, in New South Wales, at Emmaville, Emerald occurs in pegmatite with unusual associates, as Cassiterite, Mispickel and Fluor Spar, and the more usual associate Topaz.

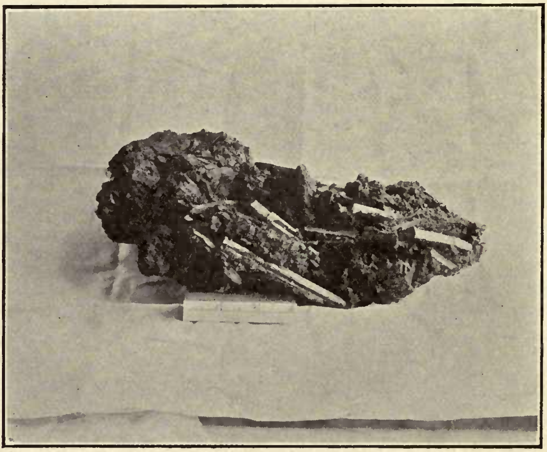

Fig. 22.—Beryl Crystals, partly coated with Limonite.

Fine varieties of Beryl are sometimes brilliant cut, the deeper coloured specimens requiring a rather shallow form, while the paler shades must be given a good depth to ensure a fine colour effect. More often a mixed cut is used, or a pure step cut. Good stones with fine colour may be mounted *à jour*, but stones of poorer colour are often improved by being mounted with foil in a closed setting.

In value an Emerald of best quality ranks nearly as high as the Ruby, a perfect stone of one carat often selling for £20; owing to the difficulty of obtaining Emeralds without imperfections in the larger sizes, the value of flawless stones increases very rapidly with size. Besides the frequently occurring flaws Emeralds often show inclusions, rendering the stone "mossy." The colour too may be irregularly distributed; sometimes only the extremity of a crystal is transparent. A fissured stone only increases in value in proportion to its size, and it may be worth about £2 10*s*. per carat. The other varieties of Beryl are often found in considerable quantity and in large pieces, hence the value is much lower and varies very closely with the weight.

There are numerous famous specimens of Emerald; two well known ones may be instanced: the Czar's Emerald, which measures ten inches in length and five in diameter, and the Emerald belonging to the Duke of Devonshire, which weighs 1,350 carats, and is an almost perfect specimen.

Owing to the range of colour shown by Beryl, there are a number of minerals which may have to be distinguished from it. Of these, all but Quartz are more dense. Yellow Quartz may be mistaken for Golden Beryl, but the Quartz is lighter and also shows less dichroism and is rather softer. Of the remainder, green Corundum may have to be distinguished from Emerald, yellow Corundum from yellow Beryl, and pale blue Corundum from Aquamarine. The Corundum is denser and of greater hardness. Green and pale blue Tourmaline may similarly be distinguished from Emerald and Aquamarine respectively by their greater density, and Tourmaline is never quite the same green as Emerald, usually showing a trace of blue. Topaz in its blue and yellow shades is also distinguished by a higher specific gravity; the same holds true with green and yellow Olivine, and in addition the green of the Olivine is rather yellow and the mineral is only feebly dichroic, Emerald showing a distinct difference in the two images under the dichroscope, one image usually being a yellow-green and the other a blue-green. Chrysoberyl in its variety Alexandrite is more strongly dichroic, is harder, and is denser than Emerald. Hiddenite, a variety of Spodumene, is denser. Dioptase and Diopside are of a rather different colour, the former of a deeper tint of green and the latter rather more of a glass green; both are heavier than Emerald, and Dioptase is also softer. Garnet is denser and is only singly refracting. Euclase is denser than Aquamarine. Aquamarine usually shows images of a very pale yellow-green and a pale blue-green under the dichroscope. Glass in all cases is softer, and is moreover only singly refracting.

353. CORDIERITE.

This mineral is also known, from its strong dichroism, as Dichroite; it is frequently called Iolite, the "violet-stone." The colour is characteristically some shade of blue, but on account of the marked dichroism the colour varies greatly, even in a given specimen. Thus a crystal from Arendal, in Norway, appeared dark blue when viewed along the longer horizontal axis of the crystal, a light blue along the shorter horizontal axis, and a yellowish white along the vertical axis. It is thus more correctly spoken of as pleochroic. It is transparent to translucent, and has a vitreous lustre on the crystal faces. It is doubly refracting, the greatest index for yellow light being 1·543, and the least 1·537. The dispersion is feeble. It is only fusible at high temperatures, and it is but slightly attacked by acids. The specific gravity varies from 2·60 to 2·72, depending largely on the amount of iron present. It has a conchoidal fracture, and a hardness of 7 to 7½. It has a distinct cleavage normal to the longer horizontal axis, and indistinct cleavages parallel to the other two axes. In crystalline form it is rhombic, but distinct crystals of any size are rare, and when they are found are usually rough. The general habit of the crystal is prismatic, and rather short. Twinned crystals sometimes give rise to a pseudo-hexagonal form (*see* Chrysoberyl). More often the mineral occurs in rolled fragments or massive. Occasionally completely developed crystals are found in granite, as in Bavaria, but usually it is only found in association with rocks which have undergone great metamorphism.

In chemical composition it is a silicate of aluminium, with magnesium and iron, and often with calcium, and containing water. The formula is possibly H_2O, 4 (Mg, FeO), 4 Al_2O_3, 10 SiO_2. The colour is probably due to ferrous iron. The most commonly associated minerals are Quartz, Orthoclase or Albite, Tourmaline, Garnet, Andalusite, Beryl, Topaz, etc. It occurs in many parts of Scandinavia, as at Arendal and Kragerö in Norway; at Åbo in Finland; at Tunaberg in Sweden; in Greenland, etc. But the chief gem qualities come from the gem gravels of Ceylon; there stones of both light and dark blue are found, specimens of a sky blue being known as Water Sapphire or Saphir d'Eau, while the darker indigo blue stones are called Lynx Sapphire. Fine specimens have been found at Haddam in Connecticut, in gneiss, associated with Tourmaline. The gem must be cut with the large exposed face parallel to the most perfect cleavage plane to bring out the best colour. It is usually step cut or table cut, but a variety showing asterism is cut *en cabochon;* and sometimes the mineral is cut in cubes, with the surfaces normal to the three axes of the crystal, to show the pleochroism. Its low specific gravity is usually sufficient to distinguish it from other blue stones, but in addition the strong pleochroism is of aid.

365. Lapis Lazuli.

Lapis Lazuli is only to be regarded as a mineral in so far as its beautiful colour, on which its use as a precious stone depends, is due to the presence of a disseminated mineral in a matrix. The term Lapis Lazuli thus refers rather to a rock, and the colouring mineral is now more often known scientifically as Lazurite. Nor is Lazurite the only coloured mineral present, for it has been shown that two other blue minerals, Haüyne and Sodalite, may also be in the matrix, as well as several substances whose colour does not affect the whole so much. Lapis Lazuli, which is also known as Azure Stone, was almost certainly the Sapphirus of Theophrastus and other ancient writers. It has been known from very remote times, being much used by the Egyptians, and to a lesser extent by the Assyrians. Epiphanius, Bishop of Salamis, says the Tables of the Law given to Moses were inscribed on Lapis Lazuli. The Romans used it to some extent as a material for engraving on.

Lazurite is practically always of a blue colour, the commonest shade being an azure blue, sometimes Berlin-blue, rarely of a violet tinge, sometimes greenish blue. Darker parts, merging to an indigo blue, are seen, and often white streaks and yellow metallic patches, due respectively to admixtures of Calcite and Iron Pyrites. As with other precious stones, the richer coloured kinds are known as "masculine," and the paler ones as "feminine." It is translucent to opaque. The streak is ultramarine. On heating to a dull red the pale blue shades are rather improved, for they often turn to a richer and deeper blue colour. But sometimes the effect of heating is to make the mineral greenish blue. At a higher temperature the blue colour is completely discharged, and the mineral finally fuses to a colourless glassy mass. The specific gravity varies from 2·38 to 2·45, hence it is one of the lightest precious stones. The fracture is uneven. The hardness is 5 to 5½. The crystalline form is cubic, but it is very rarely that crystals are seen. When they are found they are small, and in the form of the dodecahedron, parallel to the faces of which there is an imperfect cleavage. The substance known as Lapis Lazuli is really a mass of fine particles of this mineral, along with several others, in most cases embedded in Calcite. It is nearly always found in limestones that have been subjected to extensive metamorphism, either by proximity to a great plutonic mass or by dynamic changes. The chemical composition is complex, and by no means invariable; it may be expressed as essentially $3\ Na_2O$, $3\ Al_2O_3$, $6\ SiO_2$, $2\ Na_2S_3$—a sodium aluminium silicate with sodium sulphide. It is of some interest to note that Epiphanius recommends the use of powdered Lapis Lazuli as a dressing for pustules and boils, for it is possible it may have some antiseptic action when moistened. Since the mineral is imbedded in the carbonate of calcium, Calcite, it follows that on applying hydrochloric acid, effervescence is produced. Also the presence of the sulphide of iron would render it liable to decomposition if not kept dry. With regard to distribution, it seems more than likely that the localities mentioned by the old writers (Medea and Ethiopia) may have simply been trading localities, and not places where the stone was actually to be found. On the upper part of the river Oxus, to the north of the Hindu Kush, it is found in a limestone rock, and here it has been worked from very ancient times, and the method still adopted of winning it seems the same as it was then, namely, by heating the rock by a fire and then suddenly cooling it with water, and thus causing the rock to split up. Much of the Lapis Lazuli from this locality goes to the great annual fair at Nizhni Novgorod, in Russia.

At the western extremity of Lake Baikal it occurs to the south of Kultuk in a crystalline limestone near the meeting zone of granite and gneiss; and to the west of Kultuk in a granular limestone in granite a good deposit exists; and here an improvement in quality of the material is observed as the depth of the workings increases, so that the rich colour is probably not due to the effect of weathering. In the Andes, in Chile, it occurs in a metamorphosed limestone underlying a granite rock, and in the detritus of these rocks. It is associated with Ruby in Burma.

It is cut as a flat plaque, or *en cabochon;* more often it is worked into vases and other small ornamental objects, though now the solid material is not so often used as thin slices, which are veneered on. It is largely used, too, for mosaics and in the ornamentation of luxurious buildings such as the palaces of the Russian Czars. Formerly it was the sole source of the beautiful pigment ultramarine, which was greatly esteemed on account of the purity of its colour and permanence. Now, however, the pigment is made artificially, though the artificial product does not command nearly the same price. All the substances that Lapis Lazuli is likely to be mistaken for are of a higher specific gravity. Stained Agate is also harder, and the carbonate of copper, Azurite, is softer.

370. Garnet.

The term Garnet includes a series of isomorphous compounds, all of which have, besides a very closely related chemical composition, very similar physical properties.

The name seems to have been derived from "Grénat," which really referred to Hyacinth, a variety of Zircon. It was known in ancient times, for Theophrastus describes a mineral, that was almost certainly Garnet, as being used for mirrors. The "feminine Carbunculus" of Pliny probably included some of the Garnets, his Amethystizontes being probably Almandine Garnets.

The predominant colour of Garnet is some shade of red, but amongst the various kinds of the mineral, yellow, green, purple and brown are seen, and some are colourless and some are black; blue is never seen. The colours will be more particularly referred to when dealing with each kind separately; the lustre varies from a brilliant vitreous lustre to a resinous; transparent to opaque; normally singly refracting, hence not showing dichroism. The refractive index for yellow light varies from 1·747 to 1·814; the dispersion is small in all except Demantoid. Almandine shows absorption bands in the spectrum; some Garnets show asterism. Most Garnets fuse more or less easily, but Uvarovite is almost infusible. The specific gravity varies from 3·15 to 4·3 in the various kinds. The fracture is conchoidal to subconchoidal or uneven, and most specimens are brittle. The hardness is from 6½ to 7½. An indistinct cleavage parallel to the faces of the dodecahedron is sometimes present; the streak is white.

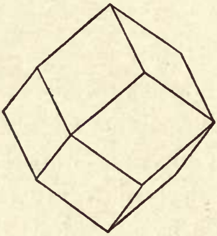
FIG. 23.—Garnet.

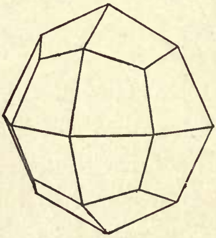
FIG. 24.—Garnet.

The crystalline form is in all Garnets cubic, and the commonest forms are the dodecahedron (Fig. 23), and trisoctahedron (Fig. 24). The crystals, when *in situ*, are more often found embedded in a matrix, and they are then usually idiomorphic; less often they are found attached at one point to the wall of a cavity. Garnets are usually of secondary origin, developed sometimes in metamorphosed calcareous rocks, more often in eruptive rocks (Figs. 25 and 26).

In chemical composition the Garnets are orthosilicates of the form $3\ R''O,\ R'''_2\ O_3,\ 3\ SiO_2$, where R'' may represent calcium, iron, magnesium, or less frequently manganese or chromium, and R''' represents aluminium, iron, or chromium. The Garnets are thus grouped—

Aluminium Garnet I.	A. Aluminium-Calcium Garnet—Hessonite.
	B. Aluminium-Magnesium Garnet—Pyrope.
	C. Aluminium-Iron Garnet—Almandine.
	D. Aluminium-Manganese Garnet—Spessartite.
Iron Garnet II.	E. Calcium-Iron Garnet—Andradite.
Chromium Garnet III.	F. Calcium-Chromium Garnet—Uvarovite.

Those Garnets which are rich in iron fuse more easily, and some of them show magnetic properties; most garnets resist all acids except hydrofluoric. Heat in most cases causes an alteration in colour, but the colour is usually restored on cooling. The colour depends on the chemical composition, and thus is uniformly distributed.

HESSONITE is also known as Essonite, Grossular, or Cinnamon-stone. The colour is usually some shade of reddish brown, but may be yellow-brown, honey yellow, pale green, or pale red; some specimens look more red at a distance and more yellow when close to the eye. The specific gravity is 3·44 to 3·62, and the hardness is 7¼.

Ceylon is the most important locality; in the extreme south of the island at Belligam it is found in a gneiss, while at Matura it occurs in the gravels. Most of the Hessonite used as a gem comes from this part.

In the Alps it is found in serpentine at the Mussa Alp in Piedmont with Alalite and Chlorite; this variety is sometimes spoken of as Succinite on account of its amber-colour. A group of crystals is shown in Fig. 27. In the Maigels-Thal it occurs in mica-schist with Epidote. It is also found in the Ural Mountains and elsewhere.

A variety of Hessonite, known more particularly as Grossular, of a greenish colour, is sometimes used as a gem, when it is called Gooseberry Stone; it is found in Siberia. A pale red variety from Mexico has also been cut; it is found in transparent crystals in a limestone.

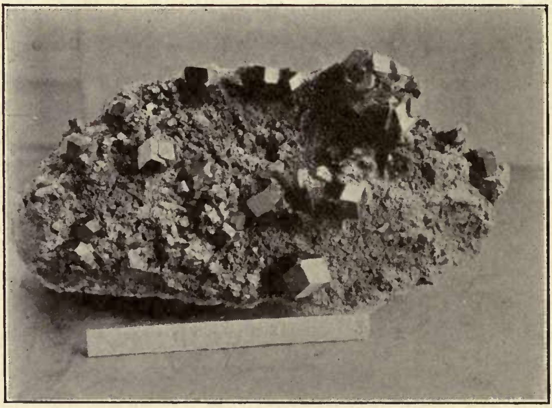

FIG. 25.—Garnet Crystals in the Matrix.

PYROPE, often called the Bohemian Garnet from its important occurrence in Bohemia, includes some Precious Garnet and Vermeille (*see* Almandine); sometimes it is known as Rock Ruby. The colour ranges from blood-red to hyacinth-red and yellow in one direction, and to black in the other. It practically always occurs in transparent fragments, each fragment, however, being free from flaws and of a very uniform quality. It is always derived from basic rocks. The specific gravity is 3·70 to 3·78; the hardness is 7¼. The refractive index for red light is 1·79, it never shows anomalous refraction, and it is very infusible.

FIG. 26.—A Group of Garnet Crystals.

The colour depends on the presence of iron and manganese, and perhaps chromium also. It is found in Bohemia in a decomposed basic rock and in detritus from this near Meronitz, Podsedlitz, and Budweis; in Saxony, at Zöblitz; in Scotland, at Elie in agglomerate; and in South Africa in the Diamond bearing agglomerates where both a paler red and blood-red colours (Cape Ruby) occur, associated with the minerals mentioned under "Diamond." In the United States it is found in Arizona (Arizona Ruby), in Colorado (Colorado Ruby) and in New Mexico. It also occurs in Mexico.

Almandine, which is known under the various names Precious Garnet, Common Garnet, and Oriental Garnet, was the Carbunculus Alabandicus of Pliny, being named after Alabanda in Caria, which, if not a locality where it occurs, was at any rate an important trading centre for it. The colour is red of a deep shade in the gem variety, sometimes inclining to a columbine red; the brownish red shades are used under the name of Vermeille (*see* Pyrope), but this kind is less valued. It often occurs transparent.

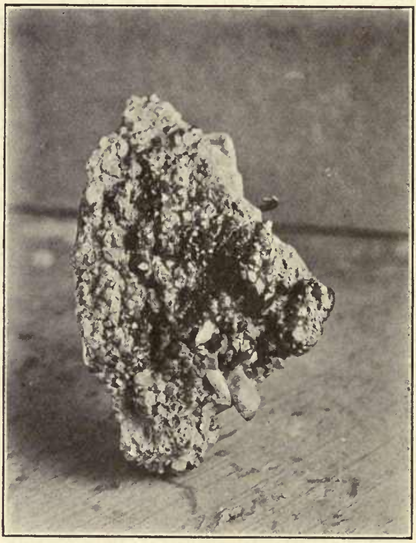

Fig.27.— Garnet with Alalite.

Its specific gravity is 3·95 to 4·29, its hardness is 7¼, its index of refraction for red light is 1·77, and it has the peculiarity of showing absorption bands in the spectrum. It fuses easily before the blowpipe, and is slightly magnetic.

It is a widely distributed form of Garnet; the principal localities for the gem qualities are in the East. In Ceylon it is found in fine crystals in mica-schist near Trincomali; it also occurs in the gravels; from this occurrence it is sometimes known as Ceylonese Ruby. The so-called "Syrian" Garnet was supposed to come from Suriam in Pegu (Lower Burma), but its occurrence is not authenticated here. The term refers now rather to Garnet of a violet shade than to material from any special place.

In India it is found at the Sarwar mines in Rajputana, near the Godivari river in gneiss, in Haiderabad, and at Kakoria in Jaipur.

In Brazil it is found in the Minas Novas district; in Australia a kind known as Adelaide Ruby is found in the north of South Australia; in the United States on the Columbia River; and in Europe in the Ziller Thal in the Tyrol, in schist.

SPESSARTITE is of a dark hyacinth-red colour with a specific gravity of 4·0 to 4·3. Transparent material suitable for gem use has been found at the Mica mine near Amelia Court House in Virginia, United States.

ANDRADITE, called also Common Garnet and Black Garnet, includes three varieties sometimes used as precious stones. In general Andradite occurs in many shades of yellow, green, brown and grey; some in black. The specific gravity is 3·83 to 3·90.

The variety Demantoid is found of a grass-green to emerald-green colour, or sometimes colourless. The emerald-green form contains chromium. It has a high lustre, almost adamantine; the refractive index is greater than in most Garnets, and the dispersion much more marked, hence there is some play of colour in a cut specimen. It occurs in transparent masses, rarely in crystals. It is softer than the other Garnets, being only equal to 6½. The mineral is more easily attacked by acids than other members of the group, but it is very infusible. It is found in the Ural Mountains (and so is sometimes called Uralian Emerald) at Nizhni Tagilsk in gold washings, and *in situ* in serpentine in the Sissersk district.

Topazolite, another variety of Andradite, is found at Ala in Piedmont; in colour it is a yellow inclining to green.

Melanite, a common black form of Andradite (Fig. 25), occurs at Frascati near Rome and in Baden. It is used sometimes in mourning jewellery.

UVAROVITE, a Garnet of brilliant emerald-green colour containing chromium, is found in the Urals in cavities in Chromic Iron; unfortunately the specimens are too small to use as gems.

Rhodolite, so called from the similarity of its colour to that of the rhododendron—a light red—is a Garnet found at the Corvee Creek Corundum mines in Macon County in North Carolina, United States. It has a very high lustre and a freedom from flaws which makes it very valuable as a gem. In composition it is intermediate between Pyrope and Almandine.

Garnet is largely used as an abrasive, often being made into garnet-paper similar to glass- and sand-paper. Many of the pivot bearings of good watches are made of Garnet also. It was to some extent used by the Greeks as a material for engraving on, much more so by the Romans. Barbot, in his inventory of the French jewels, made in 1791, mentions two cups made of Garnet of three inches in height, and several smaller ones. It is usually cut *en cabochon*, often in a meniscoid form so as to thin the material when the colour is too deep; such thin stones are often known as "Garnet Shells." Paler coloured stones are either mixed cut, step cut, or table cut. Pyrope is often cut with a convex upper surface facetted near the girdle, and step cut below; sometimes it is cut as a brilliant or a rose. Large specimens of Pyrope are very rare. Hessonite is usually cut with facets and mounted with foil in a closed setting; it is rarely cut *en cabochon;* sometimes it is sold as Hyacinth, more especially in the case of the deeper coloured varieties; it appears more brilliant in artificial light. The lighter varieties of Garnet are sometimes mounted in an open setting. The most valuable kinds are the finely coloured Almandine, a good specimen of which approaches the Sapphire in value, and the Pyrope, which in moderate sized specimens may be worth £10 per carat.

Most minerals with which Garnet may be confused are doubly refracting, thus Zircon, Corundum, Olivine, and Beryl are all distinguished by this property. Spinel, however, is singly refracting like Garnet, and is very near it in hardness and specific gravity and often in colour. The crystals are of a different habit, Spinel being usually octahedral, but this is of no help in a cut specimen, nor is chemical analysis. Ruby is lighter than Almandine and heavier than Pyrope, thus Almandine is also denser than Pyrope. Ruby may be distinguished from any Garnet by its dichroism; it is harder too. Olivine (Chrysolite) and Beryl (Emerald) are both lighter than Demantoid and are both doubly refracting, though Olivine is only feebly dichroic. Zircon (Hyacinth) is denser and harder than Hessonite and has a much higher lustre. Glass imitations in all cases are softer.

CHAPTER XIII.

376. OLIVINE—SPHENE.

Some of the minerals known to the ancients as Beryllus, Smaragdus, and Topazios may have been Olivine; but their Chrysolithus was our Topaz, although Olivine is now known sometimes as Chrysolite. When undecomposed, Olivine is some shade of green, usually olive-green or greyish-green, but on exposure to weathering it turns brown or red through the formation of ferric salts. It is transparent in the gem varieties, and has a vitreous lustre. It shows strong double refraction, the refractive indices in yellow light being, for the greatest 1·697, and for the least 1·661. Dispersion is weak, and it is only feebly dichroic. When heated it turns white, but does not fuse easily. The specific gravity is 3·33 to 3·44. The fracture is conchoidal, and the mineral is brittle. It has two cleavages, neither very perfect, normal to the two horizontal axes of the crystal. The hardness is 6½ to 7; the streak is usually white. It is orthorhombic in crystalline form, and commonly occurs in stout rhombic prisms (Fig. 28). Sometimes twinned forms are seen; more often it occurs as embedded grains, thus often allotriomorphic. It is practically always found, when *in situ*, in basic eruptive rocks as an original

Fig. 28.
Olivine.

constituent. In composition it is an orthosilicate of magnesium and iron, 2 (MgFe)O, SiO_2. Olivine is easily decomposed by the mineral acids, and, according to Max Bauer, this is the *rationale* of the mixing of sulphuric acid with the final polishing material instead of water.

Olivine of a pure olive-green colour, and transparent, suitable for gem cutting, is known as Noble Chrysolite or Peridot. Although Olivine is found in such abundance, most of it as it occurs in eruptive rocks is in such small grains, or so cloudy or fractured, as to be unsuitable for use; and it is a remarkable fact that there is hardly a locality known where Noble Chrysolite is now to be found, even in gravel deposits. Dr. Kunz is of the opinion that most now seen uncut, or roughly cut, is material derived from long lost deposits, and the only definite localities now known are in the United States, in Arizona, and New Mexico, and there gem material is very scarce. Of the stones for which Chrysolite may be mistaken Emerald, Prehnite, and Tourmaline are less dense; Topaz is of the same density, but harder, and Chrysoberyl and Corundum are denser; further, Emerald, Chrysoberyl, Corundum, and Tourmaline are harder. Glass imitations, and the so-called Bottle Stone, are singly refracting. Olivine is usually either step cut or mixed cut; as a pendant stone it may be cut as a double rosette. Its value is about equal to that of Topaz.

382. PHENAKITE.

Phenakite is a mineral that only occurs sparingly in Nature, and it is not very much used as a gem. It is found colourless, wine yellow, rose pink, and brown. The specimens used as gems are always transparent. It is doubly refractive, the indices for yellow light being 1·654 and 1·670. The dispersion is weak, and hence there is but little fire in the stone when cut. The lustre is vitreous, and the mineral is capable of taking a high degree of polish. The specific gravity is 2·95 to 3·00. It has a conchoidal fracture, and is brittle. There is a perfect cleavage parallel to the prism face, and an imperfect one parallel to the primary rhombohedron. It crystallises in rhombohedral forms, and the habit is either stoutly prismatic or rhombohedral. In composition it is a beryllium orthosilicate, $Be_2 SiO_4$. It is found in mica-schist with Emerald and Chrysoberyl, at Takovaya, in the Ural Mountains; also on the Ilmen Mountains with Amazonstone and Topaz. In America it is found 16 miles from Pike's Peak, in Colorado; at Topaz Butte, with Topaz and Amazonstone in granite; also at Mount Antero, in Colorado, with Quartz and Beryl. The chief demand for the gem is in the countries where it is mostly found—Russia and America. The colourless specimens are cut as brilliants, and mounted in an open setting, and the coloured ones may be treated in the same way if the shade is good.

383. Dioptase.

Dioptase and Malachite are of interest among gem stones on account of the large percentage of the common metal copper entering into their composition. One might almost call Dioptase a copper ore, and certainly Malachite is. In colour it is emerald-green, but of a deeper tint than the Emerald itself has; the lustre is vitreous; it is transparent to translucent and shows strong double refraction, the indices being 1·667 and 1·723. When heated it turns black, and water is given off. The specific gravity is 3·27 to 3·35, it has a conchoidal fracture and is brittle. The hardness is only equal to 5 of Mohs' scale; there is a perfect rhombohedral cleavage. The streak is green. Its crystalline form is rhombohedral and it usually occurs as stout prisms (Fig. 29). The crystals are small. It is formed by the decomposition of copper ores, and hence usually is associated with other copper compounds. In composition it is a basic silicate of copper, H_2O CuO SiO_2. It is found in druses in a limestone at the hill of Altyn-Tübe on the Altai Mountains, also on the Malaya River in Trans-Baikal; also in Hungary and Chile. Good crystals have more recently been obtained at Mindouli, east of Comba, in the French Congo, associated with Chrysocolla. Dioptase is not extensively used as a gem, largely on account of the difficulty of obtaining good specimens, but also because of its liability to damage; in colour it is undoubtedly very fine. It is readily distinguished from Emerald by the deeper colour, higher specific gravity and inferior hardness.

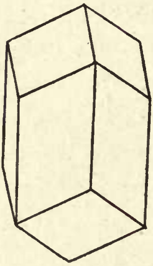

Fig. 29.
Dioptase.

393. Idocrase.

This mineral, which is also known as Vesuvian on account of its occurrence on Vesuvius, is not extensively used as a gem. The colour is usually brown, sometimes a clear green, and more rarely bright yellow or pale blue. The gem varieties are transparent, and the lustre is vitreous. The mineral is doubly refracting, both the ordinary and extraordinary rays being a good deal deflected, but in a nearly equal degree. The indices of a green crystal for yellow light were found to be 1·719 and 1·718. Dichroism is well marked, a green crystal showing images in the dichroscope respectively a pure green and a yellow-green. It fuses before the blowpipe. The specific gravity is 3·35 to 3·45. The fracture is subconchoidal, and the mineral is brittle. The hardness is 6½, and the streak white. The crystalline form is tetragonal and the crystals are usually short prisms, terminated by a pyramid and the basal face (Fig. 30). The crystals are often highly modified. Two cleavages are present, one a prismatic one and the other parallel to the basal plane. Idocrase is always found in calcareous rocks which have undergone thermo-metamorphism (Fig. 31). In chemical composition it is a basic calcium aluminium silicate, but the exact formula is not very certain, possibly $2\,H_2O$, $12\,CaO$, $3\,(AlFe)_2O_3$, $10\,SiO_2$. Iron, manganese and magnesium are sometimes present, and the two first elements may considerably modify the colour. It is a mineral of wide distribution, but many forms are opaque or only subtranslucent, and the only localities from which material has been obtained for gem use are in Italy, with the exception of the variety Xanthite, a brown Idocrase found near Amity in New York State. In Italy the brown crystals are found in the ejected blocks of Monte Somma, of which volcano Vesuvius is a later cone; at this locality the mineral is associated with a great number of interesting species. It also occurs in Piedmont, on the

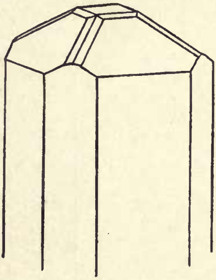

FIG. 30.—Idocrase.

Mussa Alp in the Ala Valley, the exact spot being called Testa Ciarva, a locality already mentioned in connection with Hessonite and Diopside. When used as a gem, Idocrase is either step cut or table cut. There are several minerals with which Idocrase may be confounded; of these Zircon and Demantoid Garnet are distinctly heavier, both are harder, and Garnet is singly refracting.

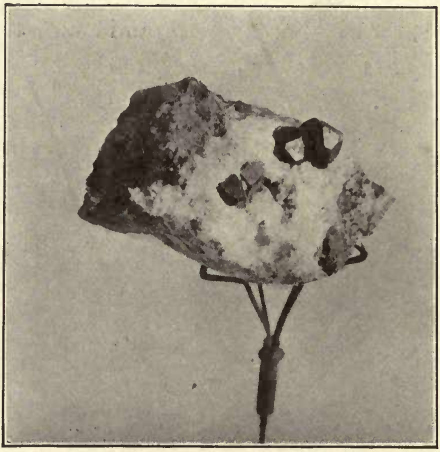

FIG. 31.—Idocrase in the Matrix.

Quartz (Cairngorm), Tourmaline and Diopside are lighter, Quartz and Tourmaline being harder and Diopside softer than Idocrase. Axinite is slightly less dense, slightly harder, and, more important, it shows violet, brown and green colours in different directions. Olivine is rather more yellow in colour, and is very feebly dichroic. Epidote is slightly denser than Idocrase, slightly softer and strongly pleochroic, showing green, yellow, and brown tints in different directions.

394. Zircon.

There has been much confusion about the relation to this species of some of the minerals spoken of by Pliny, but it seems well established that the Lyncurium of Theophrastus was our Zircon in part. It is supposed it was the seventh stone, the Ligure, of the Rationale of the High Priest. Zircon is usually found in some shade of brown, ranging from a pale yellowish-brown to a rich red-brown; only rarely is it colourless, green or violet. It varies from transparent to opaque, those varieties used as a gem being transparent or subtransparent. The lustre is distinctly adamantine. The mineral is doubly refracting in a marked degree, and the actual deviation is greater than in any other gem stone except the Diamond, the values of the indices for yellow light being 1·923 and 1·968. The dispersion, however, is feeble, so that the mineral when cut shows a lack of fire; the dichroism is very feeble; there is a marked phosphorescence on heating. Zircon is peculiar in showing

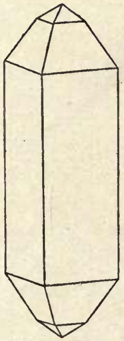

Fig. 32.—Zircon: Typical Form.

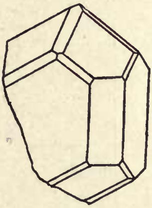

Fig. 33.—Zircon: Unequally developed Crystal.

absorption bands in the spectrum, as was indicated by Professor Church. The specific gravity is very variable, usually 4·6 to 4·7, but it may range from 4·2 to 4·86. The fracture is conchoidal, the mineral is brittle, and there are two cleavages, one prismatic and the other parallel to the faces of a pyramid, but neither are distinct. The hardness is $7\frac{1}{2}$; the streak is uncoloured. Zircon crystallises in the tetragonal system, and is usually found in rather elongated forms, as shown in Fig. 32. Some crystals are unequally developed and complex (Fig. 33); more rarely the prism faces are poorly developed or absent. Twinned forms occur, the component parts meeting one another in a form likened to the bent knee. Zircon is found as a secondary mineral

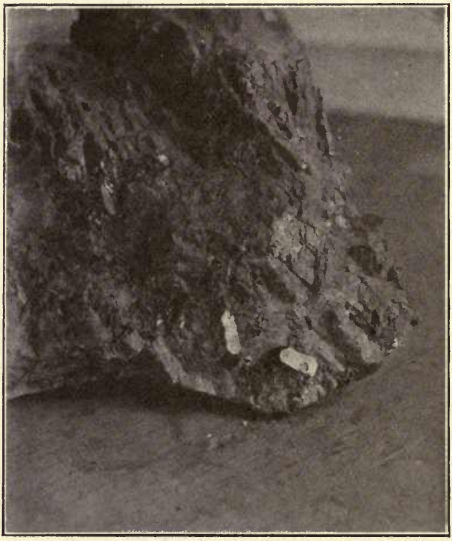

FIG. 34.—Zircon, in a Pegmatite Matrix.

chiefly in eruptive rocks that have undergone alteration, especially alteration by deformation. Crystals of Zircon in a pegmatite matrix are shown in Fig. 34. In composition it is a silicate of zirconium, $ZrSiO_4$. Some interesting changes are seen on heating the mineral; thus a deep red-brown specimen heated in the dark will be seen to phosphoresce suddenly, and it will then be found that the stone is changed to a very pale yellow colour, or has become colourless altogether; the specific gravity is increased, and the lustre is rendered greater. Some of these changes are supposed to be due to chemical alterations in the state of the iron contained in almost all specimens of the mineral. Even strong light may cause the stone to change, but the colour is to some extent restored by keeping the specimen in the dark for a time afterwards. With the ordinary variety of Zircon we are not much concerned. The gem variety occurs as Hyacinth, which includes the orange and red-brown transparent stones, and Jargon, comprising the colourless and pale yellow specimens.

Most of the stones suitable for use as gems are found in the gem gravels of Ceylon, which gravels are derived from the weathered crystalline rocks in which the Sapphires were developed. The chief localities are Ratua-pura and Matura, the latter locality giving its name to the "Matura Diamonds," which are very pale or colourless Zircons. Many other localities yield the mineral, but rarely in gem quality. Such are: Bohemia, where it occurs in gneiss; near Unask, in the Ural Mountains; at Friedriksvärn in Norway in the zircon-syenite; at Mudgee in New South Wales in the auriferous alluvium; and in the volcanic districts of France.

Zircon, besides its use as a gem, is now of great value as a source of the oxide Zirconia; and in North Carolina, in the United States, it is extensively mined, as well as in other parts.

Use is made of the effect of heat in discharging the colour of dark Zircon to produce colourless specimens, and such have been substituted for Diamond, which they much resemble, on account of their adamantine lustre, though they lack the fire of the Diamond. The great density of Zircon is of much help in its identification. The Garnets are distinguished by their single refraction, and so is Diamond, the latter also showing more "fire." Of the doubly refracting minerals, Corundum is the only one likely to be confused with Zircon that approaches it in density, and the Oriental Hyacinth, as it is called, is strongly dichroic.

397. Topaz.

What we know now as Topaz was not the Topazius of Pliny, which seems rather to have been our Olivine; it may have been included in part in Pliny's term Chrysolithus.

Topaz occurs colourless and more frequently of a straw or amber colour, or pale green or blue; more rarely pink.

The lustre is vitreous and especially bright on the prism faces; the cleavage plane shows a pearly lustre. The mineral in the kinds used as gems is transparent, though less clear forms are also found. It is doubly refracting, but the indices of refraction do not differ greatly from one another, and they are not of high value; nor is there much difference in the indices for differently coloured rays. Thus the greatest and least values for the B line in the red part of the spectrum are: for a crystal from Siberia, 1·619 and 1·610, while for the F line in the blue portion of the spectrum they are 1·628 and 1·619. Thus there is but little "fire" in a cut specimen of Topaz, but coloured varieties show distinct dichroism. Before the blowpipe it is infusible, but the effects of heat are nevertheless important in the case of Topaz. In 1755 a French jeweller named Dumelle found that on gradually heating a yellow Topaz the colour changed to a pink, and this effect has been made use of in the artificial production of a pink colour, a process now known as "pinking" or "burning," and one by which most of the pink stones now sold are produced. To effect this change the mineral must be heated and cooled again very gradually to avoid producing flaws; it may be heated in a sand bath, or packed with charcoal in a small crucible, or embedded in clay and then baked, or, finally, it may be wrapped in several layers of

FIG. 35.—Blue Topaz with Smoky Quartz.

amadou or German tinder, the whole bound with wire and the tinder lighted and allowed to smoulder away; if the heating is too great the stone will be completely decolorised. It is remarkable that a "burnt" Topaz shows more marked dichroism than the unaltered mineral, images of a cherry red and a pale yellow being seen in the dichroscope. The fact that Topaz may be so strongly heated without destroying the colour points to the colour not being due to organic matter; but in some Topaz organic matter does seem to account for the colour. Certain specimens of yellow and blue Topaz are found to change their tints on exposure to strong light, for instance. Topaz becomes strongly

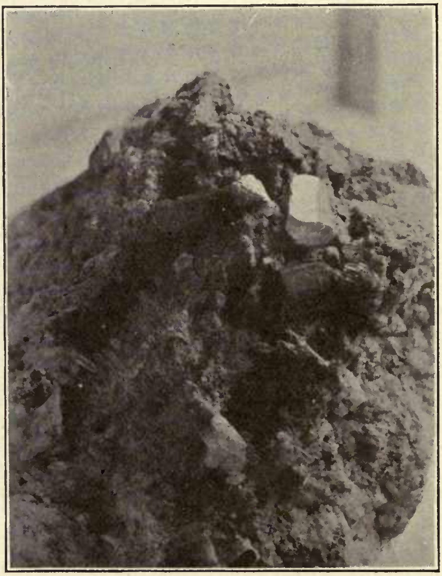

FIG. 36.—Topaz.

electrified when rubbed, or in some cases when pressed, and on heating.

The specific gravity of Topaz lies between 3·40 and 3·65. The fracture is subconchoidal; the mineral has a hardness of 8 of Mohs' scale, and is brittle. The streak is colourless. There is a highly perfect cleavage normal to the vertical axis of the crystal. The crystalline form is orthorhombic and the habit prismatic (Fig. 35), the prism usually showing the faces of two forms at least, and often being vertically striated, as is well shown in Fig. 36. Crystals often show an apparent want of symmetry (Fig. 37). Topaz is usually found, when *in situ*, in attached crystals in cavities in granite, in some dynamo-metamorphosed rocks (which have probably been acted on by thermo-metamorphism as well), and in some acid lavas known as liparites, though the last occurrence seems rare. It will be seen that Topaz is thus more often found in rocks rich in Quartz. It is also associated frequently with Beryl, Tourmaline, and Felspar, especially where these have separated from a granite magma in the later stages of consolidation. Other frequent associates are Apatite, Fluor Spar, Cassiterite, and Mica. Topaz is resistent to most forms of weathering and hence is often found in rolled pebbles in the detritus from such rocks as have been mentioned. In composition it is a fluo-silicate of aluminium, $[Al(O, F_2)]\,AlSiO_4$. Water is usually present in small quantity as an essential constituent, probably with the hydroxyl group (OH) replacing some of the fluorine.

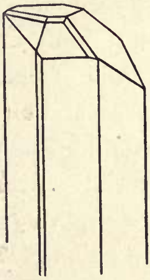

FIG. 37.—Topaz: An unequally developed Crystal.

Topaz is of very wide distribution; in England it is found with Cassiterite at St. Michael's Mount; in Scotland water-worn crystals of the pale blue (eau de nil) colour are found in gravels in Aberdeenshire; and bright though small crystals occur in the Mourne Mountain granite in Ireland. Some of the Scottish specimens have been cut into very beautiful stones, but these British occurrences are insignificant when compared to some of the foreign ones. In the Ural Mountains near Musinka blue crystals are found: these are sometimes known as Siberian or Tauridan Topaz. Colourless specimens are found near Miask in the Ilmen Mountains; while in the district of Nerchinsk, in the Adun-Chalon Mountains, very fine blue-green Topaz occurs; and on the Urulga River blue and yellow crystals are found, some of them of large size, one in the Russian Imperial collection weighing 22½ lbs. The Urulga specimens are very prone to change colour on exposure to a strong light. Topaz of various colours has been found in Kamshatka.

Brazil is perhaps the most important locality. Here, in the State of Minas Geraes, in the north-east, the gravels near Novas Minas afford colourless and variously coloured specimens; of these the richer blue ones are known as Brazilian Sapphire, and the deeper red ones, which are very rare, as Brazilian Ruby. In the south-west of Minas Geraes, near Curo Preto (Villa Rica), various shades of yellow are found in a clay slate. The golden yellow crystals are known as Brazilian Topaz from their abundant occurrence here.

In Ceylon the gem gravels yield very fine Topaz in various shades of yellow, and some colourless. The clear saffron yellow stones are known as Indian Topaz.

In Saxony, at Schneckenstein near Auerbach, Topaz is plentifully found, clear yellow crystals being called Saxon Topaz and the greenish yellow ones Saxon Chrysolite.

In the United States yellow crystals are found in Connecticut, blue ones in granite in Maine, colourless ones in Utah, and both colourless and pale blue occur with Amazonstone at Florissant in the Pike's Peak district of Colorado. Variously coloured Topaz is found with Cassiterite in Australia in Victoria, while in New South Wales colourless and yellow stones occur.

More recently blue Topaz is reported to have been found in Rhodesia.

Inferior forms of Topaz, known as "fallow" Topaz, are used as abrasives.

Topaz is one of the gems whose cleavage may be made use of in preparing the stone for cutting, but care has to be exercised during cutting to avoid damage through undesired cleavage taking place, flaws or "feathers" being very apt to form in this way. Topaz, when of large size, is often cut with a large table of generally elliptical form, and with numerous triangular facets between the table and the girdle, the lower part of the stone being cut in shallow steps. The ordinary step and table forms of cutting are also used, and for the colourless crystals (*gouttes d'eau*) the brilliant cut may be used. Most Topaz is mounted in a closed setting, often with foil at the back. Topaz is not worth nearly so much now as it was at one time, largely on account of change of fashion. A fine stone of 2 carats would now only be worth about £1.

Diamond and Spinel can be distinguished from Topaz, both being singly refracting; Diamond is, of course, much harder; coloured Spinels are not dichroic. Quartz, Phenakite and Tourmaline are less dense, and Aquamarine shows yellowish and sky blue images in the dichroscope, while blue Topaz shows colourless and green images. Corundum is more dense. Fluor Spar is very much softer and shows single refraction. Topaz when yellow shows pale yellow and yellow-red dichroscope images; burnt Topaz shows cherry red and honey yellow. Further, Topaz is easily electrified.

398. ANDALUSITE.

Andalusite, which is also known as Chiastolite, though this term is now rather confined to a variety, is a widely distributed mineral, occurring as a result of the metamorphism of argillaceous rocks by hydro-thermal action. The walls of the old farm house in Cumberland in which these words are penned are thickly studded with crystals of it, but they are *not* of gem quality. The only form used as a gem is found in Brazil in the district near Novas Minas, in gravel. These specimens are of green or yellow-brown colour. The mineral here is transparent, and has a rather poor vitreous lustre. It shows a weak double refraction, the greatest and least indices being 1·643 and 1·632. It, however, shows a very marked pleochroism; when viewed along the vertical axis the colour is a rich red, while in the direction of the horizontal axes the colour in both cases is green, but of slightly different tint. It is infusible before the blowpipe. Its specific gravity is 3·16 to 3·19. The mineral is brittle and shows a subconchoidal fracture, and has a hardness of 7½. There is a distinct cleavage parallel to the face of the rhombic prism. The streak is colourless.

In crystalline form it is orthorhombic, and the habit is usually prismatic, though in the variety Chiastolite it is more often acicular. In composition it is a silicate of aluminium, $Al_2O_3\ SiO_2$. The variety Chiastolite shows a cross when cut in a plane normal to the vertical axis, and when in large crystals is sometimes cut as a charm. Like all strongly pleochroic minerals, the colour effect must be kept in mind in cutting. A good specimen when cut resembles Alexandrite, but is softer and less dense.

400. CYANITE.

Cyanite, known also as Sapparé and Kyanite, is closely related to Andalusite, both in origin and composition; and, like Andalusite, though fairly widely distributed, is but rarely found in a form suitable for gem use. It is found in various shades of blue, green, and grey. The crystals often show a good colour in the centre, but are pale or white at the margins. The lustre is generally vitreous, but is pearly on the cleavage surfaces; transparent specimens are rare. The double refraction is rather strong, the mean index being given as 1·72. Pleochroism is well marked, and in the dichroscope images of two different depths of blue are seen. It is infusible; the specific gravity is 3·58 to 3·68. The hardness shows an unusual variation in the different directions, the least being between 4 and 5, and the greatest as much as 7¼. It is a rather tough mineral. There are two cleavages, one perfect, the other less so. In crystalline form it is triclinic, and it usually occurs in embedded and elongated forms, with no definite termination; the crystals are often bent. Most of the gem varieties are supposed to have come from India, but the exact locality is unknown. It is found in good specimens in Brazil near Villa Rica; in the Alps on Monte Campione in the St. Gothard district in schist; in the Tyrol; on Mount Greiner in the Zillerthal; and near Baskerville, in North Carolina, in the United States. The colours often resemble Sapphire, but Cyanite is softer and less dense.

403. EUCLASE.

Euclase is a rare mineral, occurring in crystals of a green or greenish blue colour, often transparent, and having a vitreous lustre. It is doubly refracting, though only in a feeble degree, the greatest and least indices for yellow light being 1·671 and 1·652. The dispersion is also small, but there is a distinct pleochroism. It is easily electrified by friction, and on strongly heating gives off water. The specific gravity is 3·05 to 3·10. It is brittle, shows a conchoidal fracture, and has three cleavages parallel to the three primary crystal forms. It occurs in short monosymmetric prisms vertically striated, the crystals often being highly modified.

In composition it is a hydrated beryllium aluminium silicate, H_2O, 2 BeO, Al_2O_3, 2 SiO_2.

It occurs in chlorite schist near Novas Minas, in Brazil, with yellow Topaz; also near the Sanárka River, in the Urals, in gold-bearing alluvium, with Topaz and Corundum. It has also been found in very small crystals in the Alps.

It may be distinguished from Beryl (variety Aquamarine) by being of higher specific gravity, and more strongly dichroic, and from blue Topaz by being less dense and more dichroic.

407. EPIDOTE.

Epidote, like Cyanite and Andalusite, is of wide distribution, but is rarely found of a kind suitable for use as a gem. The colour is characteristically pistachio-green, merging to a yellow-green and clear yellow, or to a brownish green or green-black; rarely colourless or red. It has a vitreous lustre, and when cut as a gem is very brilliant. The gem variety is transparent, but the common varieties are found quite opaque sometimes. It is strongly refracting, and the double refraction is very marked too, the greatest and least indices for red light being 1·768 and 1·730. Pleochroism is unusually well marked, showing tints of green, brown and yellow in three different directions. The specific gravity is 3·35 to 3·5. The mineral is brittle, and has an uneven fracture; it shows two cleavages, one perfect and the other imperfect. It crystallises in monosymmetric forms, usually prismatic, sometimes acicular. It is often found in attached crystals in cavities, usually in thermo-metamorphic rocks. Its common associates are Calcite, Apatite, Felspar, and Asbestos. In composition it is a silicate of calcium and aluminium, with iron, containing some water, H_2O, $4\ CaO$, $3\ (Al, Fe)_2O_3$, $6\ SiO_2$; the water is driven off on strongly heating. The chief locality is Knappenwand, in the Untersulzbachthal in Salzburg, where it occurs in an epidote-schist. It is also found in the United States at Haddam in Connecticut; at Roseville in Sussex County, New Jersey; and in Georgia. Some Epidote of gem quality has been found in Brazil, with green Tourmaline in Minas Geraes.

It is distinguished from most similarly coloured minerals by its greater density and more marked dichroism. Tourmaline, which is strongly dichroic, is much less dense.

410. AXINITE.

Axinite is but rarely used as a gem, although it has many properties making it suitable for such a use. In colour it varies from a pale sherry yellow to a deep brown or almost plum colour; the usual tint is clove brown. The lustre is vitreous, inclining to adamantine in some specimens, and the crystals are often transparent. It is doubly refracting, the indices in red light being, the greatest 1·681, and the least 1·672. It shows marked dichroism, yielding olive green and violet-blue, or cinnamon brown and violet-blue images in the dichroscope, according to the direction in which the crystal is viewed. It is pyro-

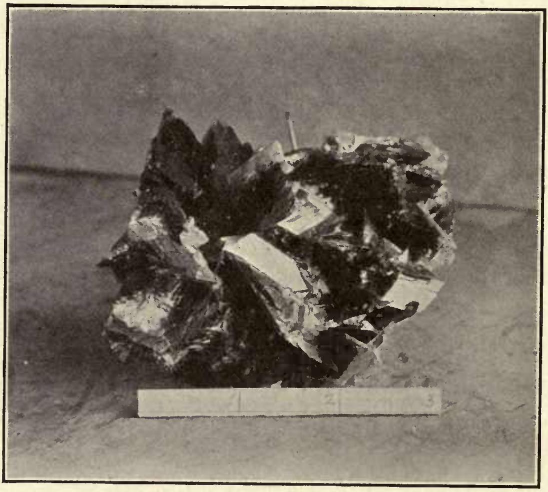

FIG. 38.—A Group of Axinite Crystals.

electric, and readily fuses. The specific gravity is 3·29 to 3·30. It is very brittle, has a hardness of 6½ to 7, and shows several planes of cleavage. The streak is colourless. It crystallises in thin triclinic prisms, having thin edges and being somewhat axe shaped (Fig. 38), hence the name (from ἀξινη). In chemical composition it is a boro-silicate of aluminium and calcium with iron and manganese, the latter metals probably accounting for the colour. It is found at St. Christophe, in Dauphiné, in gneiss, and in the east of Switzerland, near Dissentis, as well as in several less important localities. It may readily be distinguished by its colour and appearance in the dichroscope.

411. PREHNITE.

Prehnite, although not itself a Zeolite, is in many respects closely allied with the Zeolites in mode of formation and occurrence. It is found in a great range of colours, some of them very beautiful. Usually the colour is some tint of green, but occasionally it passes to a brilliant orange or a pale pink; other specimens are colourless. It is mostly subtransparent to translucent, with a vitreous lustre. It is doubly refracting, the mean index being 1·626, and shows rather strong dispersion; but individual crystals are rare, and usually small, the material used as a precious stone being a crystalline aggregate. It is pyro-electric; the specific gravity is 2·92 to 3·01, and the hardness is 6 to 6½. The crystalline form is orthorhombic. It usually occurs in aggregates of minute indistinct crystals strongly coherent, and is found sometimes in large masses, one in the Heddle collection in the Royal Scottish Museum measuring 3 feet in length. It is always found as a product of the decomposition of more or less basic eruptive rocks. It is an acid calcium aluminium orthosilicate, $H_2Ca_2Al_2Si_3O_{12}$. It is found in many parts of Scotland, as Dumbartonshire and Renfrewshire; also with the last mentioned species, Axinite, at St. Christophe in Dauphiné, at several places in the Alps, at Ala in Piedmont, and in Cape Colony ("Cape Chrysolite"). In the United States it is found in the Lake Superior copper region with Native Copper, at Farmington in Connecticut, and at Bergen Hill in New Jersey. Prehnite is rather apt to lose its colour on exposure.

426. Tourmaline.

Tourmaline is almost as remarkable as Corundum for the number of colour varieties which are used as gems, and as with Corundum, too, these gem varieties are rarely associated with the name of the mineralogical species to which they belong. Tourmaline most commonly occurs black, but such specimens are not used as gems. The various shades of red, blue and green, in which the mineral is found, are all to be seen in cut specimens; more rarely the colourless variety is cut. Only the transparent forms are used, and these have a vitreous lustre. The mineral is doubly refracting, but the indices are not high, though there is a relatively considerable difference between the ordinary and extraordinary rays, the values of the indices for yellow light being (in a colourless specimen) 1·637 and 1·619. The dichroism is, however, very marked, more so than in any other precious stone except Iolite. The images in the dichroscope are usually of nearly the same colour as the crystal, but they differ greatly in depth, and sometimes to some extent in tint; crystals of the green and blue shades of Tourmaline are particularly dichroic. The electrical properties are equally well marked; thus rubbing induces a difference of electric potential, and heat produces a marked difference, one end of the crystal becoming positive and the other negative, so that if a mixture of red lead and sulphur be dropped on to a heated crystal through a fine sieve the sulphur will be attracted to one end (the positive) and the red lead to the other (the negative); this readily distinguishes the two ends; the electrical properties are in some cases of value in identifying Tourmaline. The specific gravity varies from 2·98 to 3·20, but most of the gem varieties have a nearly constant density, as will be noted below. The mineral is brittle and has a subconchoidal fracture. Its hardness is 7 to 7½. There are two indefinite cleavages; the streak is colourless. In crystalline form it is rhombohedral and is hemimorphic, but as doubly terminated crystals are rare, this is not often seen in the ends, but in the prism faces it is usually apparent, for the crystal in section, instead of being hexagonal, has the form of a modified triangle through the predominance of alternate faces of the hexagonal prism (Fig. 39). Another peculiar feature of the crystals which throws light on the mode of origin of the mineral is the frequency with which the prism faces are well developed in comparison with the terminal planes. The crystals, too, are very frequently fractured and dislocated. It is a mineral of secondary origin usually found in association

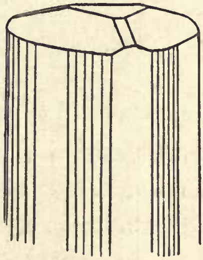

FIG. 39.—Characteristic Form of Tourmaline.

with rocks that have been subjected to dynamo- (and in many cases thermo-) metamorphism. Consistent with this we find the mineral often shows flaws or "feathers," though in other respects it is remarkably free from imperfection. The pink variety is very frequently flawed in this way (Fig. 40).

It is often found associated with Quartz, Albite, Lepidolite, Beryl, Idocrase, Garnet, Spinel, Cassiterite, Talc, Rutile, Chrysoberyl, etc.

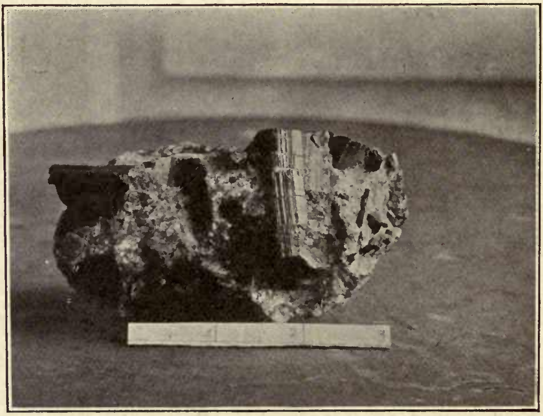

Fig. 40.—Tourmaline in the Matrix.

The varieties are mostly classified according to colour. The common black type is known as Schorl; a black variety from Kragerö in Norway is known as Aphrizite. The red colours are comprised under Rubellite, the violet-red specimens from Siberia being called Siberite. Rubellite has a specific gravity of 3·08. Indicolite (or Indigolite) includes the blue shades (density 3·16), the deeper Berlin-blue crystals from Brazil being called Brazilian Sapphire. The green forms include a bright green from Brazil called Brazilian Emerald, and a softer yellow-green type found in Ceylon and known as Ceylonese Chrysolite or Ceylonese Peridot. Green Tourmaline has a specific gravity of 3·107. The colourless variety is known as Achroite, and has a specific gravity of 3·022. Dravite is a brown Tourmaline from Carinthia.

In chemical composition Tourmaline is very varied, and in fact it may be regarded rather as an isomorphous series. It is essentially a silicate of boron and aluminium, but water and fluorine, as well as the alkali metals, and the elements titanium, iron, manganese, magnesium, and calcium may be present. No exact molecular formula has ever been arrived at; as with many other minerals, an increase in the percentage of iron present is accompanied by a greater depth of colour.

The localities where Tourmaline occurs are so numerous that only the places where material suitable for gem use, or where exceptionally coloured specimens are found, can be given.

In the Ural Mountains, in the neighbourhood of Mursinka, Rubellite is found in granite; the blue Indicolite also occurs here, and Rubellite in the Nerchinsk district of Trans-Baikalia.

In Brazil in the Novas Minas district and in the Ribeirão da Tolha green Tourmaline is found, some of it being the bright green known as Brazilian Emerald; the blue variety "Brazilian Sapphire," and a little Rubellite also are found here.

The gem gravels of Ceylon yield the yellow and yellow-green stones known as Ceylonese Chrysolite (or Peridot), and the brown Tourmaline occurs with them. In Bengal, and in the Sapphire deposits of Kashmir, Indicolite is found, and Rubellite occurs near Mainglon in Burma.

In the island of Elba, near San Piero, both the colourless Acroite and the red Rubellite are found in granite, and Rubellite is found at Penig in Saxony, with green and blue varieties. Dravite is named after its locality at the Unter-drauburg in the Drave district of Carinthia. It is also found at Crawford in New York State, while in the same State, in St. Lawrence County, fine Achroite occurs near De Kalb. In Maine at Paris the green variety as well as Rubellite and Indicolite occur; in Massachusets, Chesterfield and Goshen yield good Indicolite and green Tourmaline, and also a rose-red but opaque variety; in California, at Mesa Grande, both the red and green varieties occur.

The technical use of Tourmaline in the construction of plates for the polariscope should be mentioned; the slices are cut from the crystal parallel to the vertical axis.

In cutting Tourmaline as a gem due regard must be given to the colour effect from the pleocroism. Deep coloured stones are cut so as to have the table parallel to the vertical axis; but in the case of pale stones the table may be normal to this axis, for in this direction the mineral shows its darkest colour. Tourmaline is often parti-coloured, one end of a crystal may be green, and this may gradually merge into pink at the other end, being accompanied probably by a corresponding gradual change from a Tourmaline of one composition to one of another. The Rubellite from Paris in Maine often shows an outer green layer; a certain amount of Rubellite has crystallised first, and then the isomorphous green Tourmaline has been deposited in optical continuity with it; this may be compared with the well-known double growths of common alum and chrome-alum. Rubellite is apt to appear of a brown colour in artificial light. Coloured Tourmaline is usually cut in steps or as a table, and the appearance is often improved by the gem being set in a closed mount with foil.

Tourmaline, although in its various colours it so closely resembles in outward appearance so many other gems, may in most cases be identified by its specific gravity alone. Thus Aquamarine, Emerald, and Beryl generally, Quartz and Phenakite are all less dense. Hiddenite is slightly more dense, while Corundum in all its varieties, Garnet in its different forms, Olivine, Topaz, Spinel, Zircon, and Diamond are all of distinctly greater specific gravity. Further, the green and blue kinds of Tourmaline are very markedly dichroic, and this aids in the further differentiation of the green Hiddenite. The similarity of the coloured images seen in Tourmaline under the dichroscope, and its marked electrical properties are additional points of distinction.

428. STAUROLITE.

Staurolite suitable for gem use occurs but sparingly, and it is a mineral but little used for this purpose. What is so used is a reddish-brown, sometimes inclining to claret, and is transparent, though the ordinary forms are only translucent to opaque. The mineral shows double refraction (the greatest and least indices being 1·746 and 1·736) and is distinctly pleochroic, being hyacinth-red in one direction and yellow-red in the other two directions. The specific gravity is 3·73 to 3·75, and the hardness 7½. The fracture is sub-conchoidal; it shows two cleavages, neither very distinct. The crystals belong to the orthorhombic system, and are often twinned in crossed forms; hence the name. It occurs in crystalline rocks as a product of contact metamorphism, and is often associated with Garnet and Tourmaline. In chemical composition it is a complex silicate of iron, magnesium and aluminium. It occurs in schist at Monte Campione in Switzerland, and with Corundum in Macon County in North Carolina, in the United States. When used as a gem it is cut *en cabochon.*

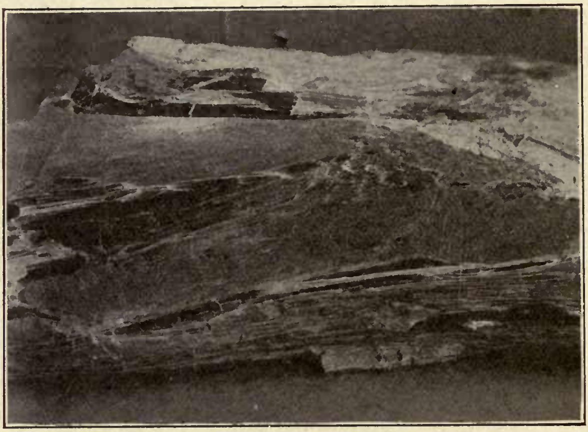

FIG. 41.—Precious Serpentine (Polished).

481. SERPENTINE.

It is rather questionable if the material used for the production of plaques, vases, and other similar ornamental objects should not be regarded rather as a rock than as a mineral, as it occurs in large masses and often includes other minerals. The form so used, however, has fairly definite physical and chemical properties, and contains a very large percentage of one compound. Such Precious or Noble Serpentine is of a rich oil green to pistachio green, markedly translucent, with a waxy lustre; its specific gravity is 2·5 to 2·6, and its hardness barely equal to 3. It is, however, capable of taking a high polish. It shows no crystalline form, being always massive (Fig. 41). It is usually a hydration product of ferro-magnesian silicates, and it is itself a hydrated silicate of magnesium, $H_4Mg_3Si_2O_9$. It is found in Cornwall, in the Isle of Man, and at Portsoy, in Britain; at Falun in Sweden; in Saxony, Siberia, etc.

510. SPHENE.

Sphene is only used as a gem when it occurs transparent, and of a good colour. The colour may be green, brown, yellow, or rose red; the lustre is adamantine. It shows double refraction, the greatest index being 2·01 for yellow light, and the dispersion is very large. It is markedly pleochroic, showing red, greenish-yellow, and almost colourless images, according to the direction in which it is examined. The specific gravity is 3·35 to 3·45, and the hardness 5 to 5½. It shows several cleavages, none very well marked. In crystalline form it is monosymmetric, and it is usually found in embedded idiomorphic crystals of a wedge shape, as an original constituent of granites and similar rocks, but it may occur as a product of thermometamorphism. Crystals suitable for gem use are usually attached to the sides of cavities in these rocks. In composition it is a titano-silicate of calcium, $CaTiSiO_5$.

Crystals up to 2½ inches long suitable for gem use have been found near Bridgewater Station, in Delaware County in Pennsylvania; good specimens are also obtained from the Alps. All the gem stones it may resemble are harder than Sphene.

CHAPTER XIV.

549. APATITE—JET.

Apatite occurs in a variety of colours that may give it, when cut, an appearance similar to several other minerals used as gems. The usual colour is a pale green, but blue, violet, red, yellow, and brown are sometimes seen in this species. It is transparent to opaque, but the transparent kinds are the only ones used for cutting. The lustre is vitreous, and the mineral shows weak double refraction, the indices for yellow light being 1·646 and 1·642; it shows pleochroism in the more deeply coloured specimens. Sometimes a chatoyant reflection is seen on the basal plane. The specific gravity is 3·16 to 3·22; the mineral is brittle, shows a conchoidal fracture, and has two imperfect cleavages, one parallel to the basal plane, and the other a prismatic cleavage. It occurs in crystals, often highly modified, belonging to the hexagonal system. It is a calcium phosphate, with fluorine or chlorine, $[Ca(F,Cl)]Ca_4P_3O_{12}$. It is found in good specimens at Ehrenfriedersdorf in Saxony; pale yellow and pale green crystals occur in the Zillerthal, and in Mosedale in Cumberland; the deep green variety is found at Arendal in Norway, in Siberia, and in Canada. Canada also yields a rose red type at St. Roch; and red and green crystals are found at Auburn in Maine in the United States. Its specific gravity and softness distinguish it from most minerals with which it may be confused. The double refraction differentiates it from Fluor Spar.

642. TURQUOIS.

This may have been the Callais of Pliny, but King refers Pliny's Callina to the coarser forms of Olivine. It seems, too, to have been much used by the ancient Persians as one of the stones known as Smaragdus; there were many curious superstitions connected with it, such as its power of preserving the bones of the human body from fracture due to a fall, if the person who fell was wearing one of these gems; it was the gem which broke instead of the bone.

It occurs in various shades of green and blue, sometimes rather grey or white. The most valued colours among Western races are the rich sky blue, but among many of the Eastern people the more abundant green shades are preferred. It is feebly translucent, and in very thin slices may be transparent. Its lustre is vitreous to waxy, and dull. Although always massive it may show double refraction, and hence is not amorphous; it is more likely that it is cryptocrystalline like Chalcedony. The specific gravity is 2·62 to 3·0, the fracture subconchoidal, and the hardness equal to 6. There is, of course, no cleavage; the streak is white or pale green. It always occurs as a deposition from percolating water, thus usually in crevices and cavities in rocks that are somewhat decomposed. It may fill the crevice, or may form a thin layer on the sides only. It seems often to result from the weathering of Felspar and Apatite, and has been found pseudomorphous after both these minerals, after Felspar in Persia, and after Apatite in California.

In composition it is a hydrous phosphate of aluminium, iron and copper, and the formula $[Al(OH)_2, Fe(OH)_2 Cu(OH)H]_3PO_4$ has been suggested by Penfield, who believes the copper and iron to be essential constituents. The colour is probably due to these metals in varying proportion. It is infusible before the blowpipe, but on heating it decrepitates and gives off water. Most varieties are soluble in the mineral acids. Many specimens are found to lose their colour after a time, possibly owing to a spontaneous dehydration.

The most important locality is Persia, where it occurs in volcanic rocks intrusive into various sedimentary rocks in the Khorassan province, at the village of Maden, associated with Limonite. These mines were mentioned by Ben Mansur (1300), who also gives as localities for Turquois, Ghasna, Kerman and Irak. The material is not only found *in situ*, but also in detritus derived from these volcanic rocks, and in this *débris* some of the finest specimens are found. In addition it occurs at several other places in Persia.

In the Sinai Peninsula it is found in the Wadi Meghara in mines that have been worked, it is supposed, since 3000 B.C. In the Kirghiz Steppes it is found of a greenish blue colour. Also in the Kara-Tube Mountains in a siliceous rock, with Limonite. In the United States it is found at several places in New Mexico, and in all of these it seems to have been worked in remote times by the ancient Mexican races; one of the principal places there is Mount Chalchuitl in the Los Cerillos Mountains; another is in the Burro Mountains. In Nevada it is found north of Columbus; also in Arizona and California.

Most of the searching for the material is now done in open workings, but when the Persian mines were under the government of that country systematic working underground was carried out, and there are extensive underground workings in New Mexico as well as huge heaps of *débris* on the surface.

When cut as a gem, it is either *en cabochon* or in a flat elliptical plate. The colour is sometimes artificially intensified by Berlin-blue. Turquois shows its colour well at night, while most of its imitations appear less beautiful in artificial light. The best specimens are known as Oriental Turquois or "stones of the old rock." The value now is not so great as it was at one time, but good specimens find a ready market, and on account of the difficulty in obtaining large perfect pieces the value rises rapidly with the increase of weight.

746. GYPSUM.

Gypsum is only used in its finely fibrous variety, Satin Spar, and massive variety Alabaster. Alabaster does not seem to have been included in Pliny's Alabastrites, though the fibrous and the stalactitic varieties of carbonate of lime were. King identifies the Lygdinus with compact Gypsum or Alabaster.

Gypsum occurs colourless, white, pink, blue, brown and yellow. Some forms show banding of different colours. It is transparent to subtranslucent; the lustre is vitreous to pearly; in Satin Spar it is silky. On heating, water is given off and the mineral becomes opaque. The specific gravity is 2·28 to 2·33, the hardness 2. The mineral crystallises in monosymmetric forms, and there is one distinct cleavage and two indistinct ones. In chemical composition it is a hydrous sulphate of calcium, $CaSO_4, 2H_2O$. It occurs frequently in connection with sedimentary deposits laid down in closed areas of water; Alabaster is often found in irregular beds, and Satin Spar in veins, in marls with such a history, as in those in Cumberland, Westmorland and Nottingham. Very fine massive Gypsum is found at Castelino, 35 miles from Leghorn. Fig. 42 shows a vein of Satin Spar.

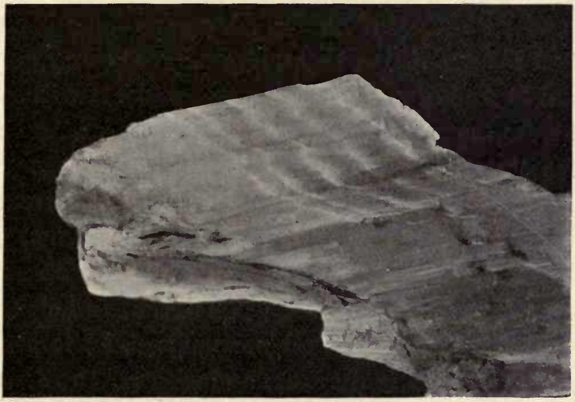

FIG. 42.—Gypsum; variety Satin Spar.

AMBER.

Amber is not strictly speaking a mineral, being of organic origin.

It is found in irregular masses of a yellow brown or reddish shade, showing a conchoidal fracture but no cleavage. It is transparent to translucent and opaque, with a specific gravity of 1·05 to 1·10, and a hardness of 2 to $2\frac{1}{2}$; the lustre is resinous. On heating it softens and then melts. The ancients, who called Amber Electrum, noticed the property it had of attracting small bodies to itself when rubbed. From this property of Amber our word Electricity is derived. The substance was also known as Succinum and Lyncurium in Pliny's time, and is still spoken of as Succinite. The electrical charge is negative.

In origin Amber is the fossilised resin of certain plants; at the time when it was viscous flies often became attached to it, and in their endeavours to escape have sometimes damaged themselves, so that a leg of a fly may be found enclosed in Amber a little distance from where the fly is. Apart from these inclusions most varieties of Amber—all but the "water-clear" in fact—show numerous minute bubbles; the smaller the bubbles the more numerous they are, and thus the more cloudy the specimen seems. Such cloudy material may be clarified by gradually heating the Amber in an oil of nearly the same refractive index, which is about 1·53. Rape seed oil is usually used; it gradually permeates all the minute pores and removes the disturbing cause very largely.

In composition Amber is an oxygenated hydrocarbon having the empirical formula $C_{10}H_{16}O$.

Amber is chiefly found on the seaboard of the Baltic, where after storms it is picked up on the shore; it is also dredged for in the sands of the shallows. It is found, too, along the coasts of Jutland and Schleswig-Holstein. In the south and east of England, in Western Russia, in parts of Poland, in Spain and Sicily, Amber is found in sandy deposits. One piece in the Imperial Museum in Berlin weighs eighteen pounds.

Amber of inferior quality is used in the manufacture of some varnishes, and small pieces are now hydraulically compressed when soft into flat pieces known as Spiller imitations; it then shows several peculiarities, such as streaks, a sharp demarcation between clear and cloudy portions, and microscopically the cavities show signs of deformation.

Amber is largely worked into beads, mouth-pieces for pipes and cigarette-holders, walking stick knobs, and the like. Sometimes it is cut and polished to mount in a brooch. It can be easily worked in a lathe and can be rendered temporarily flexible by heat.

Celluloid imitations (Ambre antique) show the sharp demarcation between clear and cloudy parts as in pressed amber; the smell of camphor may be elicited on rubbing. Celluloid is rather sectile.

JET.

Jet is a dense compact variety of coal, near Cannel Coal and Lignite. It shows no microscopic vegetable structure, and for the purposes of cutting it must be free from Iron Pyrites. It is a dense black in colour, and opaque. When polished it has a brilliant lustre, but an unpolished surface is glistening or even rather greasy in lustre. The fracture is conchoidal. The specific gravity is 1·35 and the hardness 3 to 4. On heating it burns readily, with a sooty flame. It is found in flat pieces in Liassic rocks at Robin Hood's Bay, near Whitby, in England, and in other parts of East Yorkshire; in France in the province of Languedoc; in Asturia in Spain; in Hesse; the Erzgeberg, Bavaria, and other parts of Central Europe. In America fine material is found in Colorado.

It is largely used for mourning ornaments and for the manufacture of articles such as beads, trays, small boxes, etc. It can be fashioned in much the same way as hardwood or ivory, but the final polishing is done by hand. Much of the working of Jet is carried on at Whitby.

GLOSSARY.

Absorption Bands.—The absorption bands of a substance are dark bands seen in the spectroscope when the substance is interposed between a source of white light and the instrument.

Agglomerate.—A rock filling the vent of a volcano and composed of large fragments ejected by the volcano.

Allotriomorphic Minerals.—Minerals with forms other than their own proper form. Due to pressure of surrounding bodies.

Allotropism.—An element is allotropic when it occurs in several distinct forms without change of chemical composition: for instance, red and yellow phosphorus, or carbon as Graphite and Diamond.

Anhydrous.—Without water.

Aqueous Theory.—A theory which maintains that all minerals were deposited from a simple solution, comparable to the deposition of crystals of saltpetre from a solution in water.

Asterism.—The property of exhibiting a star-like light.

Basal Plane.—A plane on the termination of a crystal, cutting the principal axis at unit length and lying parallel to the other axes.

Basic Rocks.—Rocks containing a low proportion of silica.

Biaxial Crystals show three directions of optical elasticity, and hence have three indices of refraction. All crystals of the orthorhombic, monosymmetric and triclinic systems are biaxial. There are two directions in which light travels with equal velocity.

Botryoidal.—Like a bunch of grapes.

Carat.—The unit of weight for gems; from κερατίον, one of the vetches, the seeds of which were used as weights in ancient times, on account of their uniform size. It is equivalent to 3·16̇ grains, about ·2055 gram.

Coefficient of Expansion.—The increment by which a substance of unit size increases its size (at 0° C.) for an increase of one degree of temperature.

Colloid.—A substance having no crystalline structure; on account of difficulty of absolutely determining this a colloid is now often regarded as a substance having a molecular weight greater than a certain figure.

Conductivity of Heat.—The conductivity of a substance is the amount of heat that will pass through a unit area of that substance of unit thickness in unit time, when the difference of temperature of the surfaces is 1° C.

Contact Twins.—Crystals showing a form as if a single crystal had been divided in two halves and one half rotated through 180°.

Crystal.—A substance of definite chemical composition having a definite internal molecular arrangement and a definite external form, bounded by plane surfaces, systematically arranged and meeting in angles of fixed and definite value.

Crystalline.—Showing the internal structure of a crystal but not the external form.

D line.—A brilliant double line seen in the yellow portion of the spectrum, characteristic of the metal sodium.

Decrepitation.—A crackling of a substance when heated, due to the sudden separation of particles.

Dendritic.—In tree-like forms.

Detritus.—Material resulting from the breaking down of a rock from natural causes.

Diffraction Grating.—A piece of smooth glass or metal ruled with fine lines of equal width and equidistant from one another so as to form a series of minute rectangles. The lines may be up to 43,000 to an inch, usually about 30,000. Such a grating modifies light so as to produce a spectrum.

Dihedral Angle.—The angle formed by the meeting of two planes in an edge.

Divided Arcs.—Portions of a circle, usually made in brass, graduated into units and fractions of angular measurement.

Dodecahedron.—A form of the cubic system having twelve faces each the shape of a rhomb. This is the rhombic dodecahedron (Fig. 23). Other twelve-faced forms also occur.

Druse.—A cavity lined with crystals.

Dynamo-metamorphism.—Change induced in a rock as a result of mechanical movement. Since this movement usually occurs under great pressure it is usually accompanied by great heat.

Electroscope.—An instrument for detecting an electrical charge.

Epigene Minerals.—Minerals formed from others by the slow downward percolation of water at a relatively low temperature.

Eruptive Rocks.—Volcanic rocks which have been poured out on the surface of the land or in the sea.

Facet.—An artificially produced plane surface on a gem stone.

Fault.—A surface or fissure in a rock mass where a differential gliding movement has occurred.

Fault Breccia.— A mass of angular fragments of rocks lying in a fault fissure.

Ferromagnesian Silicate.—A mineral consisting largely of silicate of iron and magnesium; usually found in rocks containing a low percentage of silica.

Fritting.—The caking of the ingredients in the making of glass.

Fumaroles.—Small vents around a volcano from which gases, and sometimes mud, escape; often found on volcanoes of declining activity.

Geode.—The same as Druse (q. v.).

Gurgulho.—A deposit of angular rock fragments in which Diamonds are found.

Habit (of a crystal).—A term used to indicate the general form of a crystal; thus one of a "prismatic" habit is of the general form of a prism, that is, more or less elongated.

HEMIHEDRAL.—Having only half the full number of crystal faces developed.

HEMIMORPHIC.—Having the opposite ends of the crystal terminated by dissimilar faces.

HALOGEN COMPOUND.—A chemical compound of a base with chlorine, bromine, iodine or fluorine.

HIGH POTENTIAL.—Having a great electrical pressure or electromotive force.

HYDROUS.—Containing water.

HYDRO-THERMAL MINERAL.—One whose formation is due to the action of heated water, usually acting under great pressure.

HYPOGENE MINERALS.—Minerals arising by forces acting from within the earth outwards.

IDIOMORPHIC.—Having the form proper to the particular substance. Most minerals in crystalline rocks that are idiomorphic have crystallised out from the rock magma at an early stage in its consolidation.

INTERFERENCE OF LIGHT.—A change in light due to its waves being altered.

INTERPENETRATION TWINS.—Twinned crystals appearing to have much of their substance in common, but with the solid and dihedral angles of both members fully developed.

INTRUSIVE SHEET.—A mass of volcanic rock lying in a flat bed, surrounded by, and often replacing, other rocks.

ISOMORPHOUS.—Having the same form. Chemical substances and minerals which are isomorphous are not only similar in crystalline form but also in composition, and molecules of isomorphous substances are often found to replace one another. The Felspar group affords a good example.

ISOTROPIC.—Substances which have but one index of refraction of light. All cubic crystals and all colloid substances that transmit light are isotropic.

LENTICULAR.—Having the shape of a bi-convex lens.

LITHOSPHERE.—The region of land, as distinguished from air and water.

MAGMA.—The rock-bulk. Crystals separating from the Magma are those that crystallise out while the bulk of the rock is in a fluid or semi-fluid condition.

MAMMILATED.—Having the rounded form of the mamma or breast.

MENISCUS.—A solid contained between two surfaces of different curvatures, or between two such surfaces and the surface of a cylinder; the former is thicker in the centre than at the edges, while the reverse is the case in the latter form.

MILLING CUTTER.—A wheel armed with cutting edges arranged like the teeth of a circular saw and so mounted that it can be made to move in a required direction while rotating.

MINERAL.—A homogeneous substance formed without the agency of organic life; it is of definite composition and usually of definite form.

MINERAL VEINS.—Fault fissures which have been filled with mineral matter, usually that deposited from uprising heated water.

MOLECULE.—The smallest amount of a chemical substance that can exist by itself.

MONOCHROMATIC.—Of one colour.

NEWTON'S RINGS.—Rings of coloured light seen when a thin film of air, or other matter, is left between two surfaces separated by a very small distance from one another.

NORMAL.—At right angles. Thus, a plane normal to an axis of a crystal is so placed that any line in the plane is at right angles to that axis.

OPTICALLY DENSER MEDIUM.—A substance through which light waves travel with less rapidity than they do through the standard substance.

OPTICALLY RARER MEDIUM.—A substance through which light waves travel with greater rapidity.

OSMOSIS.—A force which impels a solvent through a semi-permeable medium, from a less concentrated solution to a more concentrated.

PHOSPHORESCENCE.—The emission of light by a substance after being heated, rubbed or exposed to light or other forms of radiant energy. So called from the marked presence of the phenomenon in phosphorus.

PLANE OF INCIDENCE.—The plane containing an incident ray of light and the normal to the surface on which the light falls.

PLUTONIC ROCKS.—Rocks which have consolidated at great depths and hence under great pressure.

POLYSYNTHETIC TWINNING.—Repeated twinning parallel to one plane.

PSEUDOMORPH.—Having the external form of another substance; thus, Turquois which has no external crystalline form of its own may be found in the form of a crystal of Felspar through a gradual decomposition of the Felspar with formation of Turquois.

RE-ENTERING ANGLE.—A hollow angle contained between two planes, similar to the under surface of the roof of a house.

REFLECTION OF LIGHT.—The turning back of light when it strikes a polished surface. The angles of incidence and of reflection are equal and in the same plane.

REFRACTION.—The retardation or acceleration of light waves on entering a more or less dense medium, bending the ray.

REFRACTION, SINGLE.—The simple bending of the light ray that occurs equally in all directions in a transparent amorphous or cubic substance.

REFRACTION, DOUBLE.—The bending of a light ray in two directions that occurs in all transparent substances not either amorphous or cubic.

RHOMBOHEDRA.—Solid figures contained by six planes, opposite pairs of planes being parallel, and the three upper planes all inclined to the vertical axis at equal angles. The form may be conceived by the extension of alternate faces of the double hexagonal pyramid, six faces instead of twelve being present; were the other six faces of a similar pyramid developed, the two forms would be positive and negative rhombohedra of the same order.

SALIENT ANGLE.—The outward projecting angle formed by the meeting of two planes.

SHAK.—A cavity in a limestone rock.

SILICA.—The dioxide of silicon; often used as a term to include all the naturally occurring forms of this oxide.

SOLFATARA.—A small vent in the neighbourhood of a volcano, emitting sulphurous vapours.

SOLID ANGLE.—The corner formed by the meeting in a point of three or more planes.

SPECIFIC GRAVITY.—The ratio of the weight of a substance in air to the weight of an equal volume of water at its maximum density.

STRASS.—The glass used for the production of artificial gems.

SURFACE CHARGE OF ELECTRICITY.—A charge of electricity on a surface, the potential or electrical tension varying at different points on the surface, as at the two ends of a Tourmaline crystal.

SURFACE TENSION.—A force acting between a surface and a medium with which it is in contact. The total force in a given case is proportional to the area of the surface.

THERMAL SPRINGS.—Springs of uprising heated water.

THERMO-METAMORPHISM.—A change induced in rocks as the result of the action of heat, and probably of heated water.

TRACE (OF A PLANE).—The line along which the plane cuts another plane.

TRANSLUCENT.—Allowing light to pass; distinguished from transparent in not allowing objects to be definitely seen.

TRANSPARENT.—Allowing light to pass so freely that definite images of the objects reflecting or emitting the light are formed on the retina.

TRISOCTAHEDRON.—A generally octohedral form of the cubic system in which each face of the octahedron is replaced by three planes; when each of these planes has three angles the form is a trigonal trisoctahedron; when each of the planes has four angles the form is a tetragonal trisoctahedron (Fig. 24).

UNCONFORMITY.—The relation between two rocks when the newer has been deposited on the eroded surface of the older.

UNDULATIONS OF LIGHT.—The waves in the ether which give rise to the phenomenon of light.

UNIAXIAL CRYSTALS.—Those having one direction, and one only, in which light suffers no double refraction; crystals belonging to the tetragonal and hexagonal systems are uniaxial.

UNIT RHOMBOHEDRON.—The rhombohedron which may be regarded as developed from the extension of alternate faces of a hexagonal pyramid, each face of which pyramid would cut the vertical axis at unit length and two of the horizontal axes at unit length.

VACUUM TUBE.—A closed tube which contains two electrical terminals and which has been exhausted to a high degree; on passing a current of electricity of high potential through the tube, emanations, whose properties differ widely from ordinary light waves, are produced.

VIBRATIONS OF LIGHT.—*See* "Undulations."

ZEOLITE.—A Zeolite may be regarded as a mineral consisting of hydrous non-magnesian silicates, of epigene origin, which froths up before the blow-pipe.

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BRADBURY, AGNEW, & CO. LD., PRINTERS, LONDON AND TONBRIDGE.

THE "WESTMINSTER" SERIES

Coal. By James Tonge, M.I.M.E., F.G.S., etc. (Lecturer on Mining at Victoria University, Manchester). With 46 Illustrations, many of them showing the Fossils found in the Coal Measures.

List of Contents: History. Occurrence. Mode of Formation of Coal Seams. Fossils of the Coal Measures. Botany of the Coal-Measure Plants. Coalfields of the British Isles. Foreign Coalfields. The Classification of Coals. The Valuation of Coal. Foreign Coals and their Values. Uses of Coal. The Production of Heat from Coal. Waste of Coal. The Preparation of Coal for the Market. Coaling Stations of the World. Index.

This book on a momentous subject is provided for the general reader who wishes accurate knowledge of Coal, its origin, position and extent, and its economical utilization and application.

Iron and Steel. By J. H. Stansbie, B.Sc. (Lond.), F.I.C. With 86 Illustrations.

List of Contents: Introductory. Iron Ores. Combustible and other materials used in Iron and Steel Manufacture. Primitive Methods of Iron and Steel Production. Pig Iron and its Manufacture. The Refining of Pig Iron in Small Charges. Crucible and Weld Steel. The Bessemer Process. The Open Hearth Process. Mechanical Treatment of Iron and Steel. Physical and Mechanical Properties of Iron and Steel. Iron and Steel under the Microscope. Heat Treatment of Iron and Steel. Electric Smelting. Special Steels. Index.

The aim of this book is to give a comprehensive view of the modern aspects of iron and steel, together with a sufficient account of its history to enable the reader to follow its march of progress. The methods of producing varieties of the metal suitable to the requirements of the engineer, foundryman and mechanician are described so that the worker may learn the history of the material he is handling.

Natural Sources of Power. By Robert S. Ball, B.Sc., A.M.Inst.C.E. With 104 Diagrams and Illustrations.

Contents: Preface. Units with Metric Equivalents and Abbreviations. Length and Distance. Surface and Area. Volumes. Weights or Measures. Pressures. Linear Velocities, Angular Velocities. Acceleration. Energy. Power. Introductory Water Power and Methods of Measuring. Application of Water Power to the Propulsion of Machinery. The Hydraulic Turbine. Various Types of Turbine. Construction of Water Power Plants. Water Power Installations. The Regulation of Turbines. Wind Pressure, Velocity, and Methods of Measuring. The Application of Wind Power to Industry. The Modern Windmill. Constructional Details. Power of Modern Windmills. Appendices A, B, C. Index.

Two departments of Engineering and their applications to industry form the subject of this volume: the "natural" sources of water and wind power which supply mechanical energy without any intermediate stage of transformation. Most people will be surprised at the extent to which these natural power producers are used. The widespread application of water power is generally known, but it is interesting to learn that the demand for windmills was never so great as it is to-day, and there are signs of abnormal expansion in the direction of their useful application in the great agricultural countries of the world. Though primarily of importance to the engineer, this work will be of great interest to every manufacturer who in economizing his means of power production can take the natural forces that lie to his hand and harness them in his service. The author is the son of Sir Robert Ball, the eminent mathematician and astronomer.

Liquid and Gaseous Fuels, and the Part they play in Modern Power Production. By Professor VIVIAN B. LEWES, F.I.C., F.C.S., Prof. of Chemistry, Royal Naval College, Greenwich. With 54 Illustrations.

LIST OF CONTENTS: Lavoisier's Discovery of the Nature of Combustion, etc. The Cycle of Animal and Vegetable Life. Method of determining Calorific Value. The Discovery of Petroleum in America. Oil Lamps, etc. The History of Coal Gas. Calorific Value of Coal Gas and its Constituents. The History of Water Gas. Incomplete Combustion. Comparison of the Thermal Values of our Fuels, etc. Appendix. Bibliography. Index.

The subject of this book has, during the last decade, assumed such importance that it is hoped this account of the history and development of the use of various forms of combustible liquids and gases for the generation of energy may do some service in its advancement.

Electric Power and Traction. By F. H. DAVIES, A.M.I.E.E. With 66 Illustrations.

LIST OF CONTENTS: Introduction. The Generation and Distribution of Power. The Electric Motor. The Application of Electric Power. Electric Power in Collieries. Electric Power in Engineering Workshops. Electric Power in Textile Factories. Electric Power in the Printing Trade. Electric Power at Sea. Electric Power on Canals. Electric Traction. The Overhead System and Track Work. The Conduit System. The Surface Contact System. Car Building and Equipment. Electric Railways. Glossary. Index.

The majority of the allied trades that cluster round the business of electrical engineering are connected in some way or other with its power and traction branches. To members of such trades and callings, to whom some knowledge of applied electrical engineering is desirable if not strictly essential, the book is particularly intended to appeal. It deals almost entirely with practical matters, and enters to some extent into those commercial considerations which in the long run must overrule all others.

Town Gas and its Uses for the Production of Light, Heat, and Motive Power. By W. H. Y. Webber, C.E. With 71 Illustrations.

List of Contents: The Nature and Properties of Town Gas. The History and Manufacture of Town Gas. The Bye-Products of Coal Gas Manufacture. Gas Lights and Lighting. Practical Gas Lighting. The Cost of Gas Lighting. Heating and Warming by Gas. Cooking by Gas. The Healthfulness and Safety of Gas in all its uses. Town Gas for Power Generation, including Private Electricity Supply. The Legal Relations of Gas Suppliers, Consumers, and the Public. Index.

The "country," as opposed to the "town," has been defined as "the parts beyond the gas lamps." This book provides accurate knowledge regarding the manufacture and supply of town gas and its uses for domestic and industrial purposes. Few people realize the extent to which this great industry can be utilized. The author has produced a volume which will instruct and interest the generally well informed but not technically instructed reader.

Electro-Metallurgy. By J. B. C. Kershaw, F.I.C. With 61 Illustrations.

Contents: Introduction and Historical Survey. Aluminium. Production. Details of Processes and Works. Costs. Utilization. Future of the Metal. Bullion and Gold. Silver Refining Process. Gold Refining Processes. Gold Extraction Processes. Calcium Carbide and Acetylene Gas. The Carbide Furnace and Process. Production. Utilization. Carborundum. Details of Manufacture. Properties and Uses. Copper. Copper Refining. Descriptions of Refineries. Costs. Properties and Utilization. The Elmore and similar Processes. Electrolytic Extraction Processes. Electro-Metallurgical Concentration Processes. Ferro-alloys. Descriptions of Works. Utilization. Glass and Quartz Glass. Graphite. Details of Process. Utilization. Iron and Steel. Descriptions of Furnaces and Processes. Yields and Costs. Comparative Costs. Lead. The Salom Process. The Betts Refining Process. The Betts Reduction Process. White Lead Processes. Miscellaneous Products. Calcium. Carbon Bisulphide. Carbon Tetra-Chloride. Diamantine. Magnesium. Phosphorus. Silicon and its Compounds. Nickel. Wet Processes. Dry Processes. Sodium. Descriptions of Cells and Processes. Tin. Alkaline Processes for Tin Stripping. Acid Processes for Tin Stripping. Salt Processes for Tin Stripping. Zinc. Wet Processes. Dry Processes. Electro-Thermal Processes. Electro-Galvanizing. Glossary. Name Index.

The subject of this volume, the branch of metallurgy which deals with the extraction and refining of metals by aid of electricity, is becoming of great importance. The author gives a brief and clear account of the industrial developments of electro-metallurgy, in language that can be understood by those whose acquaintance with either chemical or electrical science may be but slight. It is a thoroughly practical work descriptive of apparatus and processes, and commends itself to all practical men engaged in metallurgical operations, as well as to business men, financiers, and investors.

Radio-Telegraphy. By C. C. F. Monckton, M.I.E.E. With 173 Diagrams and Illustrations.

Contents: Preface. Electric Phenomena. Electric Vibrations. Electro-Magnetic Waves. Modified Hertz Waves used in Radio-Telegraphy. Apparatus used for Charging the Oscillator. The Electric Oscillator: Methods of Arrangement, Practical Details. The Receiver: Methods of Arrangement, The Detecting Apparatus, and other details. Measurements in Radio-Telegraphy. The Experimental Station at Elmers End: Lodge-Muirhead System. Radio-Telegraph Station at Nauen: Telefunken System. Station at Lyngby: Poulsen System. The Lodge-Muirhead System, the Marconi System, Telefunken System, and Poulsen System. Portable Stations. Radio-Telephony. Appendices: The Morse Alphabet. Electrical Units used in this Book. International Control of Radio-Telegraphy. Index.

The startling discovery twelve years ago of what is popularly known as Wireless Telegraphy has received many no less startling additions since then. The official name now given to this branch of electrical practice is Radio-Telegraphy. The subject has now reached a thoroughly practicable stage, and this book presents it in clear, concise form. The various services for which Radio-Telegraphy is or may be used are indicated by the author. Every stage of the subject is illustrated by diagrams or photographs of apparatus, so that, while an elementary knowledge of electricity is presupposed, the bearings of the subject can be grasped by every reader. No subject is fraught with so many possibilities of development for the future relationships of the peoples of the world.

India-Rubber and its Manufacture, with Chapters on Gutta-Percha and Balata. By H. L. Terry, F.I.C., Assoc.Inst.M.M. With Illustrations.

List of Contents: Preface. Introduction: Historical and General. Raw Rubber. Botanical Origin. Tapping the Trees. Coagulation. Principal Raw Rubbers of Commerce. Pseudo-Rubbers. Congo Rubber. General Considerations. Chemical and Physical Properties. Vulcanization. India-rubber Plantations. India-rubber Substitutes. Reclaimed Rubber. Washing and Drying of Raw Rubber. Compounding of Rubber. Rubber Solvents and their Recovery. Rubber Solution. Fine Cut Sheet and Articles made therefrom. Elastic Thread. Mechanical Rubber Goods. Sundry Rubber Articles. India-rubber Proofed Textures. Tyres. India-rubber Boots and Shoes. Rubber for Insulated Wires. Vulcanite Contracts for India-rubber Goods.

The Testing of Rubber Goods. Gutta-Percha. Balata. Bibliography. Index.

Tells all about a material which has grown immensely in commercial importance in recent years. It has been expressly written for the general reader and for the technologist in other branches of industry.

Glass Manufacture. By WALTER ROSENHAIN, Superintendent of the Department of Metallurgy in the National Physical Laboratory, late Scientific Adviser in the Glass Works of Messrs. Chance Bros. and Co. With Illustrations.

CONTENTS: Preface. Definitions. Physical and Chemical Qualities. Mechanical, Thermal, and Electrical Properties. Transparency and Colour. Raw materials of manufacture. Crucibles and Furnaces for Fusion. Process of Fusion. Processes used in Working of Glass. Bottle. Blown and Pressed. Rolled or Plate. Sheet and Crown. Coloured. Optical Glass: Nature and Properties, Manufacture. Miscellaneous Products. Appendix. Bibliography of Glass Manufacture. Index.

This volume is for users of glass, and makes no claim to be an adequate guide or help to those engaged in glass manufacture itself. For this reason the account of manufacturing processes has been kept as non-technical as possible. In describing each process the object in view has been to give an insight into the rationale of each step, so far as it is known or understood, from the point of view of principles and methods rather than as mere rule of thumb description of manufacturing manipulations. The processes described are, with the exception of those described as obsolete, to the author's definite knowledge, in commercial use at the present time.

Precious Stones. By W. GOODCHILD, M.B., B.Ch. With 42 Illustrations. **With a Chapter on Artificial Stones.** By ROBERT DYKES.

LIST OF CONTENTS: Introductory and Historical. Genesis of Precious Stones. Physical Properties. The Cutting and Polishing of Gems. Imitation Gems and the Artificial Production of Precious Stones. The Diamond. Fluor Spar and the Forms of Silica. Corundum, including Ruby and Sapphire. Spinel and Chrysoberyl. The Carbonates and the Felspars. The Pyroxene and Amphibole Groups. Beryl, Cordierite, Lapis Lazuli and the Garnets. Olivine, Topaz, Tourmaline and other Silicates. Phosphates, Sulphates, and Carbon Compounds.

An admirable guide to a fascinating subject.

Patents, Designs and Trade Marks: The Law and Commercial Usage.

By **Kenneth R. Swan**, B.A. (Oxon.), of the Inner Temple, Barrister-at-Law.

CONTENTS: Table of Cases Cited—*Part I.—Letters Patent.* Introduction. General. Historical. I., II., III. Invention, Novelty, Subject Matter, and Utility the Essentials of Patentable Invention. IV. Specification. V. Construction of Specification. VI. Who May Apply for a Patent. VII. Application and Grant. VIII. Opposition. IX. Patent Rights. Legal Value. Commercial Value. X. Amendment. XI. Infringement of Patent. XII. Action for Infringement. XIII. Action to Restrain Threats. XIV. Negotiation of Patents by Sale and Licence. XV. Limitations on Patent Right. XVI. Revocation. XVII. Prolongation. XVIII. Miscellaneous. XIX. Foreign Patents. XX. Foreign Patent Laws: United States of America. Germany. France. Table of Cost, etc., of Foreign Patents. APPENDIX A.—1. Table of Forms and Fees. 2. Cost of Obtaining a British Patent. 3. Convention Countries. *Part II.—Copyright in Design.* Introduction. I. Registrable Designs. II. Registration. III. Marking. IV. Infringement. APPENDIX B.—1. Table of Forms and Fees. 2. Classification of Goods. *Part III.—Trade Marks.* Introduction. I. Meaning of Trade Mark. II. Qualification for Registration. III. Restrictions on Registration. IV. Registration. V. Effect of Registration. VI. Miscellaneous. APPENDIX C.—Table of Forms and Fees. INDICES. 1. Patents. 2. Designs. 3. Trade Marks.

This is the first book on the subject since the New Patents Act. Its aim is not only to present the existing law accurately and as fully as possible, but also to cast it in a form readily comprehensible to the layman unfamiliar with legal phraseology. It will be of value to those engaged in trades and industries where a knowledge of the patenting of inventions and the registration of trade marks is important. Full information is given regarding patents in foreign countries.

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By **Cyril Davenport**, V.D., F.S.A. With 7 Plates and 126 Figures in the text.

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