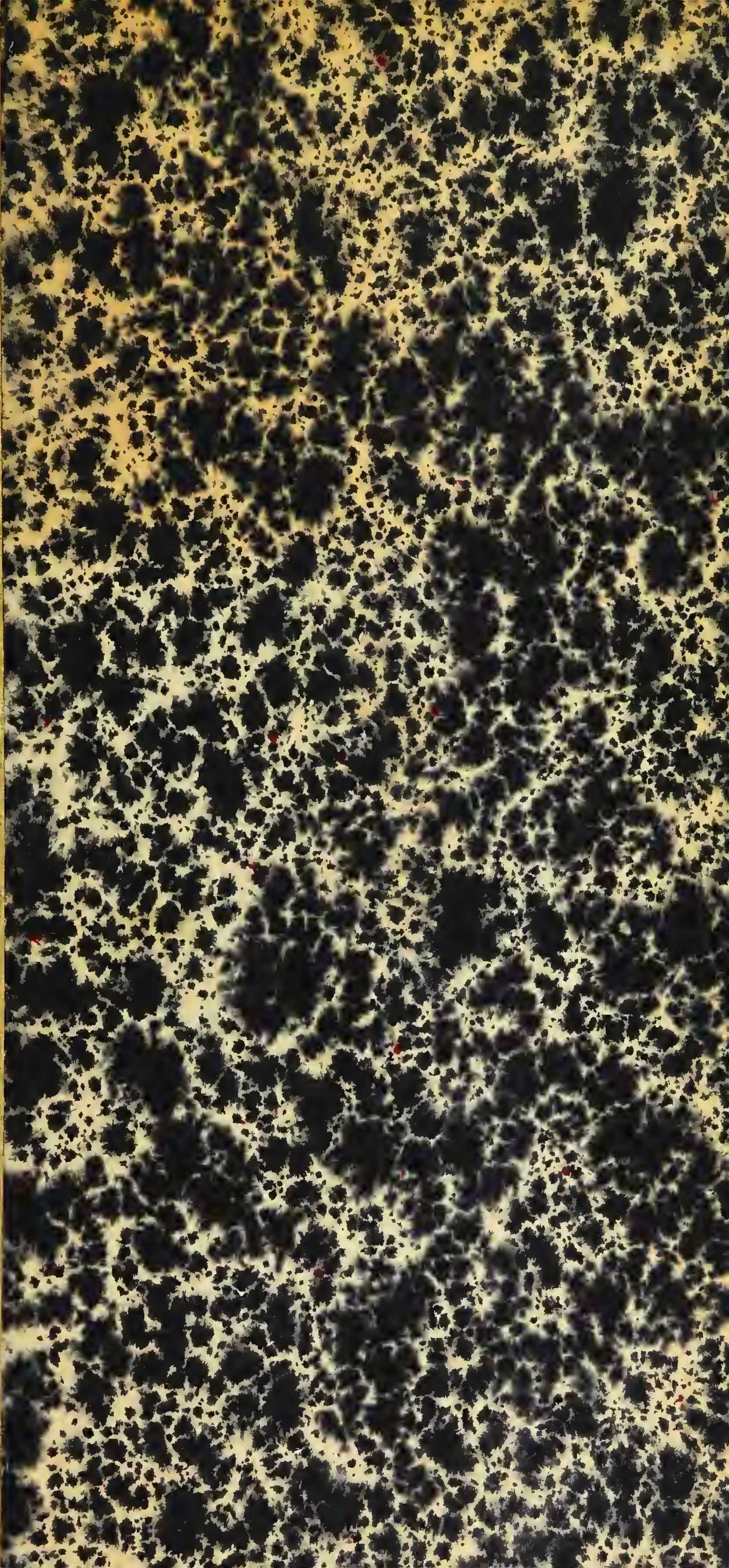

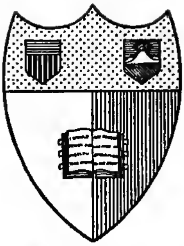

GUIDE

TO THE

COLLECTION OF GEMSTONES

IN THE

MUSEUM OF PRACTICAL GEOLOGY.

BY

W. F. P. McLINTOCK, B.Sc.

LONDON:
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INTRODUCTION.

The minerals in the Museum of Practical Geology are arranged for the most part according to their commercial applications and, in consequence, the ores, *i.e.*, minerals used for the extraction of metals, are separated from the so-called non-metallic minerals or those which, in general, are not applied to such a purpose. This arrangement has, of course, no scientific basis and fails to bring out the relationships between the various species, but it possesses the advantage of showing in a compact and readily accessible way those minerals which concern commercial and mining men.

The non-metallic minerals are arranged in cases, marked A—X. The term *non-metallic* is somewhat misleading, as nearly all the minerals to which it is applied contain a metal or metals. These, however, are usually the light metals, *e.g.*, aluminium, calcium, magnesium, potassium, sodium, as distinguished from the heavy metals of commerce, such as copper, tin, silver, gold, lead, &c.

Amongst the non-metallic minerals gemstones occupy an important place from the point of view of commercial and general interest. They have not been separated from the rest of the minerals of this class, and the visitor will find them distributed throughout the various divisions. The reason for this is that in the majority of cases gemstones show no natural relationships with one another, the only feature which unites them into a class being their suitability for purposes of adornment. This suitability depends mainly on *beauty* and *durability*, but all minerals possessing these qualifications would not be reckoned as gemstones by a dealer. Many stones possessing these qualities in a high degree have little or no value at the present time, for there is a wide distinction between a stone naturally fitted for the purposes of the jeweller, and one for which there is a demand.

From the commercial point of view the really precious stones are *diamond*, *ruby*, *sapphire*, *emerald*, and, perhaps, *opal* and *turquois*. (The *pearl*, although probably the most valuable gem at the present time, is excluded, as it can hardly be termed a mineral.) The demand for the first four of these is fairly constant and the value is always high for good specimens. The fashion of the moment dictates the value of the other minerals which legitimately claim a place amongst gemstones. At one time it may be *tourmaline*, at another, *chrysolite*, at another, *cat's-eye*, or *aquamarine*, or *topaz*, or *zircon*, which is in vogue; the favoured gem consequently rises in value until some new whim relegates it to comparative obscurity. To such stones the term "semi-precious" is sometimes applied.

The element of *rarity* plays, perhaps, the most important part in determining the value of a gemstone and outweighs, by what often seems a disproportionate amount, considerations of beauty and of durability. In this respect it must be noted that, although a particular mineral may be fairly abundant, yet pieces suitable for cutting are usually rare. A striking example is afforded by the *emerald* which, despite its comparative softness and consequent lack of durability, is one of the costliest stones at the present time. Crystals of emerald are not uncommon, but those possessing the correct colour combined with transparency and freedom from flaws are exceedingly rare and practically any price can be obtained for a cut stone of a few carats in weight answering to the above description.

A curious and instructive instance of the influence exerted by rarity on the value of a precious stone has been afforded in recent years by the ruby. As will be described later (p. 30) it is now possible to manufacture this stone in clear, transparent, finely-coloured masses which, when cut and polished, yield very effective gems. Such *synthetic rubies*, as they are called, are identical for all practical purposes with the natural stone from which they can be distinguished only by very special examination, yet the difference in value between the two is enormous. The artificial stone can be purchased for about 4*s.* per carat, whilst a Burmese stone of similar colour and transparency would fetch, because of its rarity, £40 per carat, or even more.

The diamond, superior to all other stones in hardness, lustre, and "fire," is popularly supposed to stand first in value, yet, on account of the comparative abundance of good specimens, it is outstripped by the emerald and the ruby. To put the matter briefly we may say that the possession of beauty and durability entitle a mineral to rank as a precious stone, whilst rarity, combined with these two characteristics, settles its position in the series.

Various classifications of precious stones have been adopted from time to time, but all are more or less unsatisfactory. In Chapter IV. of this guide-book the stones are considered in the order in which they occur in the cases starting from Case A. Chapter I. deals with the properties of precious stones with special reference to their discrimination; in Chapter II. the principal styles of cutting are touched upon; whilst Chapter III. deals shortly with the imitation, artificial treatment and formation of precious stones.

In order to facilitate the determination of cut specimens, the principal stones have been tabulated according to colour and other physical properties, and the tables will be found at the end of the book.

The literature relating to gemstones is wide and scattered, but most of the important information has been collected by Prof. Max Bauer in his "Edelsteinkunde." This book is in German, but an admirable English translation of the first edition has been made by Mr. L. J. Spencer, of the British Museum (Natural History). Since the appearance of that translation a new and enlarged edition of the German work has been brought out, and it has been largely consulted in the preparation of this Guide. Other books dealing with the subject are:—

"Precious Stones," by A. H. Church. 1908.

"The Gemcutter's Craft," by Leopold Claremont. 1906.

"Das Radium und die Farben," by C. Doelter. 1910. (This book contains the latest information regarding the pigments of gemstones.)

"Diamants et Pierres Précieuses," by E. Jannettaz. 1881.

"Precious Stones," Cantor Lectures, by H. A. Miers. 1896.

"The Diamond Mines of South Africa," by G. F. Williams. 1902.

G. F. Kunz has a book on the "Gems and Precious Stones of North America," 1890; and he is also the author of a bulletin on the "Gems and Jewellers' Materials of California," 1905.

Dealing specially with the artificial formation of gemstones there are:—

"Synthèse des Minéraux," by F. Fouqué and M. Lévy. 1882.

"La Synthèse du Rubis," by E. Frémy. 1891.

"Mémoire sur la reproduction du rubis par fusion," by A. Verneuil. *Annales de Chimie et de Physique,* 1904.

"La Synthèse des pierres précieuses," by J. Boyer. 1909.

CHAPTER I.

The Properties of Gemstones.

By long practice it is possible to train the eye to recognise with some precision the various members of this series of minerals; but anyone who inspects a collection of cut gems must be struck at once with the resemblance between different species and the bewildering ranges of colour presented by one and the same stone. It frequently happens, too, that even the expert eye is at a loss and, in such cases, recourse must be had to those tests which will settle the identity of the specimen. The knowledge necessary to carry out such an examination is easily acquired and the requisite apparatus is of a modest description; it is consequently a matter of surprise that dealers and people in the habit of buying precious stones frequently find themselves in the possession of specimens which they cannot identify with certainty.

An acquaintance with the properties of gemstones is also essential for a correct and intelligent appreciation of their beauty. To understand why stones should be facetted in certain ways; to know the best directions in which particular stones must be cut in order to get the maximum effect; to realise why, for instance, the diamond should be so incomparably superior to all other white stones in " fire " and " life "; these, and many other points, are made clear once the knowledge of a few fundamental facts is acquired.

The following is the order in which the properties will be considered:—Crystalline Form; Hardness; Cleavage; Specific Gravity; Optical Properties; Chemical Properties.

Crystalline Form.

A study of the substances in the mineral kingdom discloses the fact that the majority of them occur in definite forms, or *crystals,* which are bounded by a series of planes known as *faces.* Investigation of the various kinds of crystals has resulted in their being divided into seven orders, or *systems,* called, respectively, the *Cubic,* the *Tetragonal,* the *Rhombic,* the *Hexagonal,* the *Rhombohedral,* the *Monoclinic,* and the *Triclinic* system. In each of these the faces are referred to directions or lines, known as *axes,* which, in the different systems, are differently related to one another. For an account of *crystallography,* or the science of crystals, the reader is referred to any of the numerous books on the subject. It must, however, be pointed out here that the external form of a crystal is simply an expression of the definite internal structure or arrangement of the particles which build up the whole. Gemstones, as a rule, are well crystallised and many of the interesting properties displayed by them—notably the effects which they produce on light—can be directly traced to their crystalline structure.

Hardness.

This may be defined as the power of resisting abrasion and is possessed by most precious stones in a high degree; to their hardness they owe their durability and their power to take and to retain a high polish. Hardness is measured by comparison with certain minerals arbitarily chosen, a stone being harder than those which it can scratch and softer than those to which it yields. The scale generally adopted is that drawn up by Mohs and consists of the following ten minerals arranged in ascending order of hardness:—

1. Talc.
2. Gypsum.
3. Calcite.
4. Fluor-spar.
5. Apatite.
6. Felspar.
7. Quartz.
8. Topaz.
9. Corundum.
10. Diamond.

In practice only the last five of this scale need be used, as all the important gemstones possess a hardness of at least 6. Crystals or sharp fragments of the minerals 6-10 can be mounted on brass rods and used as " hardness points " for testing specimens. If the stones are in the rough state the tests are easily made, but, if they are cut, great care is needed to prevent injury to any of the facets. The girdle is the most convenient place to use, as any mark made there is of no importance and will be subsequently hidden by the mount. Successive trials are made with the test minerals until a scratch is made on the stone, and from this an idea of the hardness is obtained. Thus, if the specimen resists quartz but yields to topaz, its hardness lies between 7 and 8, and would be designated as about 7½. A common error in making this examination is to mistake for a scratch the streak left when a softer mineral is rubbed over a harder one; to avoid this, one should always rub the mark and then examine the place with a lens.

A more convenient way in which to test hardness, especially when dealing with cut stones, is to have a set of polished surfaces of the minerals 6 to 9 and to rub the gem successively over them, beginning with number 6, until no scratch is obtained.

It must not be imagined that the intervals between members on Mohs' scale are of equal value and that, for instance, the difference between talc and gypsum is the same as that between corundum and diamond. As a matter of fact diamond is so superior to all other minerals in this respect that the difference between it and corundum is very much greater than that between any other consecutive minerals on the scale.

Ordinary window-glass has a hardness of about 5 and can be readily scratched by all true gemstones as well as by a steel file, so that it is a simple matter to determine in this way whether a specimen is genuine or merely an imitation in glass.

As a general rule, it is a difficult matter to determine accurately the hardness of a cut stone without injury to the facets, but much can be learned regarding its identity by the use of the four polished surfaces mentioned above.

The following is a list of the principal stones arranged in order of hardness. It will be noted that in several cases the value varies between limits. This is due to the fact that crystals possess different degrees of hardness in different directions, but the differences in most cases are so slight that they cannot be detected by the methods of testing described above. The mineral, *kyanite*, however, is exceptional, for here the difference is so great that it is quite observable by ordinary tests (p. 66):—

Table of Hardness.

Diamond	10	Spodumene..	7–6½
Ruby	9	Kyanite	7–5
Sapphire		Idocrase	6½
Chrysoberyl	8½	Chrysolite	6½
Spinel	8	Epidote	6½
Topaz	8	Chalcedony	6½
Phenacite	7¾	Benitoite	6½
Beryl: Emerald	7¾	Demantoid	6½
Aquamarine, etc.		Felspar	6
Zircon	7½	Diopside	6
Euclase	7½	Turquois	6
Andalusite	7½	Beryllonite...	6
Garnet	7½–7	Opal	6
Iolite	7½–7	Jade	6–5½
Tourmaline	7¼	Obsidian	5½
Quartz	7	Sphene	5½
Jadeite	7–6½	Lapis-lazuli	5½
Axinite	7–6½	Fluor-spar	4

Cleavage.

Crystals possess different cohesion in different directions and, in consequence, frequently show a tendency to split or cleave along certain planes when subjected to a blow. Thus the diamond splits very easily parallel to the faces of the octohedron; topaz, parallel to the basal plane; fluor-spar, parallel to the octahedral faces, as in diamond; and so on. Many gemstones, however, *e.g.*, tourmaline, spinel, garnet, corundum, &c., show little or no trace of cleavage, and, when broken with a hammer, present a conchoidal fracture.

Cleavage is not a property by which facetted stones may be identified, but it is of great importance in the process of cutting and renders the operation in the case of the diamond much easier than it otherwise would be. The commonest and most effective form for this stone is that known as the *brilliant* (p. 22), which can be readily obtained when the rough crystal has been reduced by cleavage to the octahedral shape.

Specific Gravity.

The ratio of the weight of a body to that of an equal volume of pure water is termed the *specific gravity*, and, as this number is constant and definite for any one stone, its determination offers a sure and ready means of identifying cut specimens without injury to them. Thus any piece of ruby is found to weigh roughly four times as much as an equal volume of water, and this is expressed by saying that the specific gravity of ruby is 4. By a well-known principle, a body, when immersed in water, loses in weight by an amount equal to the weight of the water displaced, and, as the volume of water displaced is clearly equal to that of the immersed body, a ready means of determining specific gravity at once presents itself. This consists in weighing the body in air and then in water; the loss gives the weight of water displaced, *i.e.*, the weight of a volume of water occupying the same space as the body, and this, divided into the weight in air, gives the specific gravity of the body.

Thus, if the weight in air = 4·2 grams, and the
weight in water = 3·0 grams,
then the loss = 1·2 grams,
and the specific gravity $= \frac{4\cdot2}{1\cdot2} = 3\cdot5.$

The Westphal balance, of which an illustration is given (Fig. 1), is an exceedingly simple and accurate instrument for making such a determination.

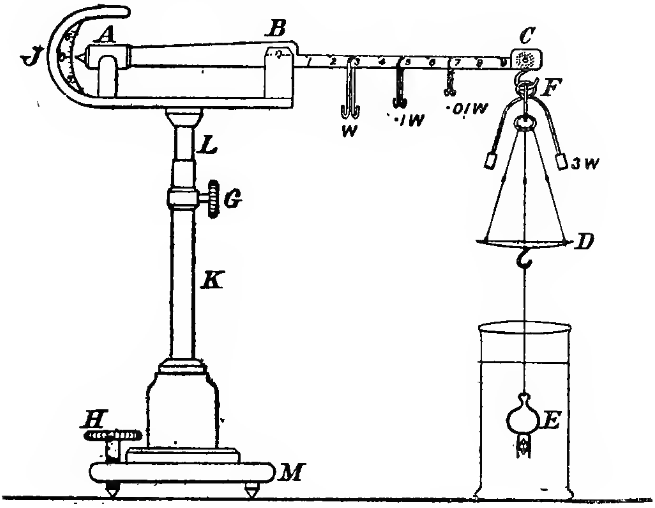


Fig. 1.—*The Westphal balance.*

The balance consists essentially of a horizontal beam A B C, mounted at B on knife-edges. At one end of the beam there is a brass counterpoise A, provided with a pointer which swings opposite the scale J; the portion of the beam from B to C is divided into ten equal divisions, these being marked by grooves in which weights may be placed without fear of slipping. The whole is attached to the rod L, which slips into the hollow case K, and can be clamped in suitable position by the screw G. The plate M, on which the balance rests, is provided with a screw H, for levelling. From the hook F is suspended the pan D and the clip E. The weights employed are arbitrary, but are all multiples and sub-multiples of some weight W.

The method of using the balance is as follows:—(1) The clip E is immersed in water and weights added to the beam until the pointer comes to rest at zero on the scale. (2) These weights are then removed, the stone is placed in the pan D and weights again added until counterpoise is obtained, the clip E still remaining in the water. (3) The operation is repeated with the stone enclosed in the clip E and immersed in water as in the figure.

Let the weight (1) = 3·613 W,
and the weight (2) = 3·260 W
then ·353 W = weight of stone in air.
Let the weight (3) = 3·357 W.
Then loss in weight = 3·357 — 3·260 W = ·097 W
and specific gravity of stone = $\frac{\cdot 353\ \mathrm{W}}{\cdot 097\ \mathrm{W}} = 3{\cdot}639$.

From the above it will be seen that it is unnecessary to know the factor W.

The results obtained with this balance are quite accurate to the second place of decimals even when the weight of the stone is only ·1016 gm. (= $\frac{1}{2}$ carat). Care must, however, be taken that all air-bubbles are removed from the clip and the stone, of which neither must touch the sides of the vessel during the weighing.

Another method of finding the specific gravity of a stone consists in the use of heavy solutions. A body floats in a liquid of higher specific gravity than itself and sinks in one of lower specific gravity; in a liquid of the same specific gravity it neither floats nor sinks but simply remains suspended. The liquids most generally utilised are (1) a saturated solution of *potassium-mercuric iodide*, having a specific gravity of 3·18 at ordinary temperatures; (2) a saturated solution of *cadmium boro-tungstate* having a specific gravity of 3·28 at ordinary temperatures; (3) *methylene iodide* having a specific gravity of 3·32 at 15° C.

The specific gravity of solutions (1) and (2) may be lowered by dilution with water, whilst that of (3) may be lowered by dilution with benzene, and heightened by the addition of iodoform and iodine to as high as 3·6. In practice it is often sufficient to know that the specific gravity of a stone lies between certain limits, and for this purpose the following set of solutions has been recommended:—

(1) Methylene iodide saturated with iodine and iodoform, sp. G. = 3·6
(2) Methylene iodide... ... ... „ = 3·3
(3) „ „ diluted with benzene ... ... „ = 3·0
(4) „ „ further „ „ ... ... „ = 2·65

By observing the behaviour of a stone in these solutions, starting with the one of lowest specific gravity, one can often identify it without further trouble. If, however, the specific gravity has to be determined exactly, the first solution in which the stone floats is carefully diluted until the latter just remains suspended. The specific gravity of the solution, and also of the stone, can then be obtained by an examination of the behaviour in it of test fragments of minerals of known specific gravity.

For stones like *zircon, corundum, garnet*, &c., which have a specific gravity above 3·6, *thallium-silver nitrate* may be used. This salt is solid at ordinary temperatures, but melts at 70° C. to a clear liquid having a specific gravity of 4·8 in which the heaviest precious stones will float. Dilution with water rapidly reduces the specific gravity and the solution may thus be employed in the same way as those described above. The drawbacks to the use of this salt are its high cost, and the necessity of working at elevated temperatures. When the specific gravity of the stone is above 3·6, it is always better to determine the value directly by means of the Westphal balance.

The following is a list of the principal stones arranged in order of specific gravity.

Table of Specific Gravities.

Zircon	4·7–4·0
Almandine	4·3–4·0
Ruby	4·0
Sapphire	4·0
Demantoid	3·86–3·83
Pyrope	3·8–3·7
Chrysoberyl	3·8–3·64
Kyanite	3·68–3·60
Benitoite	3·65–3·64
Essonite	3·65–3·63
Spinel	3·65–3·60
Topaz	3·56–3·50
Diamond	3·53–3·52
Epidote	3·5–3·36
Sphene	3·45–3·35
Idocrase	3·4–3·3
Chrysolite	3·4–3·3
Jadeite	3·33
Axinite	3·30
Diopside	3·30
Spodumene	3·20–3·15
Fluor-spar	3·19–3·02
Andalusite	3·18
Tourmaline	3·15–3·0
Euclase	3·1–3·05
Jade	3·0
Phenacite	2·96
Beryllonite	2·84
Turquois	2·8–2·6
Beryl	2·71–2·68
Labradorite	2·70
Quartz	2·65
Iolite	2·65–2·60
Chalcedony	2·60
Obsidian	2·60–2·4
Moonstone	2·58
Moldavite	2·4
Lapis-lazuli	2·4
Opal	2·2

Optical Properties.

Lustre, brilliancy, fire, colour, in fact, all the qualities which go to make up the beauty of precious stones are directly due to the powerful influences which they exert upon reflected and transmitted light. Stones seldom occur in nature in a form suitable for showing such properties to advantage, and it is the business of the cutter to treat the rough specimen in the manner best calculated to display its latent beauties. To do this in an intelligent way a knowledge of the optical properties is essential, whilst, as will be indicated later, such knowledge often affords a sure and ready means of identifying cut stones without injuring them in any way. The optical properties characteristic of gemstones are conveniently classed as follows:—

Transparency, lustre, refraction, dispersion, colour and *dichroism, spectroscopic properties*; a few stones, such as *opal, moonstone, cat's-eye,* &c., depend for their beauty on special optical effects which will be noted under a separate heading.

Transparency.—Stones, in accordance with the amount of light which penetrates them, are called *transparent, semi-transparent, translucent* and *opaque*. When an object is viewed through a transparent stone its outlines are clear and sharp, when through a semi-transparent one, blurred and indistinct. Translucent stones allow a certain amount of light to pass through but no image of an object can be obtained, whilst opaque stones allow no light to pass at all. Most gemstones are transparent in the highest degree except when marred by flaws which greatly impair this property and cause a large reduction in value. Chalcedony (Case M_4) may be mentioned as an example of a semi-transparent stone, whilst opal (Case N) is translucent and turquois (Case X) opaque. It must, of course, be understood that these terms apply to cut specimens of ordinary thickness and that most minerals are transparent or, at least, translucent when in sufficiently thin pieces.

The behaviour of gemstones towards the Röntgen rays has received some attention lately, and it has been found that different stones show different degrees of transparency to these radiations. Thus *diamond* and *phenacite* are quite transparent; *corundum* (including *ruby* and *sapphire*) is transparent, but not to the same extent as the two stones previously mentioned; *chrysoberyl* and *opal* are still less transparent; *quartz, topaz, felspar, diopside,* and *spodumene* are translucent; *turquois, tourmaline, chrysolite,* and *sphene* are almost opaque; whilst *almandine, beryl, hyacinth, epidote,* and *glass* are opaque.

A stone can be tested by photographing it with the Röntgen rays, when, if it be transparent, no shadow is cast, whilst if it be opaque a shadow with sharp outlines is obtained.

Lustre.—This is essentially a surface effect and is due to the reflection which always takes place when light impinges on a bright surface. The highest kind of lustre is that shown by polished metal and hence known as *metallic lustre,* but it is possessed by no gemstone of importance. The other kinds of lustre recognised are *adamantine,* as in the *diamond*; *vitreous,* as in *ruby, sapphire,* and most precious stones; *resinous,* as in some kinds of *garnet*; *silky,* as in the *cat's-eye, satin-spar,* and several minerals showing a fibrous structure; *pearly,* as shown by the cleavage faces of *topaz* and *felspar*; *waxy,* as in the *turquois.*

Rough specimens rarely show a high degree of lustre, and this quality is always best seen on a polished surface. To appreciate this it is only necessary to compare the greasy appearance of the crystals of diamond in Case A with the brilliant aspect of the cut specimens also exhibited there. In general, the harder the stone is, the higher is the polish to which it is susceptible, and the more intense is the lustre of the cut specimen. Refractive index (*see* below), however, seems to have some effect as it is a fact that minerals which refract light strongly have a high degree of lustre; examples of this are afforded by *zircon* (Case P) and *sphene* (Case O).

Refraction.—When light from outside impinges on the surface of a transparent body a certain amount is reflected whilst a certain amount penetrates the substance. The light in the latter case does not preserve its original path, but is bent or *refracted,* as it is called, and proceeds on its way in a new direction. The power of refracting light is strong in many gemstones, and to it can be traced several of the beautiful effects for which they are noted. As these effects are never seen in rough specimens but are only brought out by cutting and facetting, it is clear that the principles of that process must be governed to a large extent by the laws of refraction.

Figure 2 represents what takes place when a ray of light A O travels from air into a transparent precious stone. If $X O X^1$ is drawn perpendicular to the surface of separation, then O B represents the path of the ray in the stone; it has been bent towards the perpendicular line and lies in the plane containing O A and $X O X^1$. If a circle is described with O as centre and the lines $a\,a^1$ and $b\,b^1$ drawn perpendicular to $X O X^1$ then $\frac{a\,a^1}{b\,b^1}$ is a measure of the refracting power of the stone and is called the *refractive index.* The refractive index is independent of the size of the angle X O A. This angle is called the angle of incidence, and in such a case as the one in question, where the light is travelling from air into an optically denser medium, is always greater than the angle of refraction, $X^1 O B$, from which it follows that $a\,a^1$ is always greater than $b\,b^1$, *i.e.*, the refractive index is always greater than I.

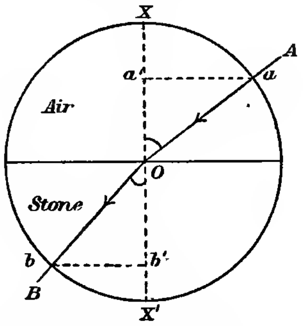


Fig. 2.—*Refraction of light in a stone.*

If, now, light emerges from a stone into air (Fig. 3) the ray is again deviated, but, in this case, it is bent away from the perpendicular, *i.e.*, the angle X O A is less than the angle X^1 O B.

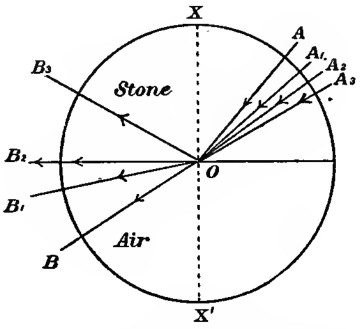


Fig. 3.—*Total internal reflection of light in a stone.*

If, as shown in the figure, the angle X O A is increased, a point is reached—represented by X O A_2—when the emergent light just grazes the surface of the stone, and if the angle X O A is increased by ever so little beyond this—represented by X O A_3—

no light emerges into the air, but all is thrown back into the stone. This phenomena is called *total internal reflection* and the angle X O A_2, *i.e.*, the angle of incidence for which the emergent light grazes the bounding surface, is called the *critical angle.* This angle may also be defined as the angle of incidence at which total internal reflection begins, and it varies with the refracting power of the medium in which the light is travelling; thus, the greater the refractive index of a stone the smaller is the critical angle, and *vice versa.* Figures 4 and 5 illustrate this point. In the case of diamond (Fig. 4) all rays which strike the bounding surface at an angle of incidence greater than 24° 21′ are reflected back into the stone. If, then, there were a whole series of rays travelling in the quadrant X O Y and incident at O on the boundary at all possible angles, a very large proportion of them, represented by the shaded area, would not escape into the air. With quartz (Fig. 5) light in order to suffer total reflection must be incident at an angle greater than 40° 8′ so that if there were, as before, a series of rays travelling in the quadrant X O Y, a proportion of them, much smaller than in the previous case, would be totally reflected.

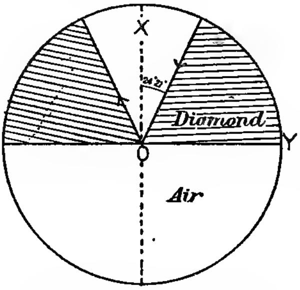


Fig. 4.—*All rays incident at an angle greater than* 24° 21′ *suffer total internal reflection.*

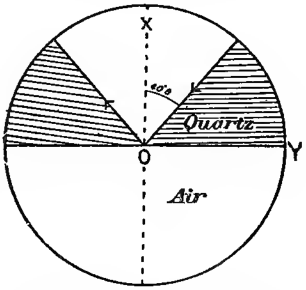


Fig. 5.—*All rays incident at an angle greater than* 40° 8′ *suffer total internal reflection.*

The brilliancy and life of a diamond cut in the brilliant-style, especially when viewed by top light, are due in great measure to total internal reflection. Owing to the high refractive index, and consequent small critical angle of this stone, a beam of light,

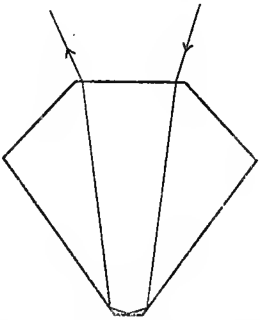


Fig. 6.—*Path of a ray in a brilliant.*

once it has entered, experiences several reflections before it can emerge. Figure 6 represents this diagrammatically. Light entering by the top facets is refracted and proceeds to the bottom ones which are steep; the angle of incidence of the beam is greater than the critical angle, and hence no light escapes into the air, but all is thrown back on to another facet when the process is repeated, and so on until the beam finally emerges by one of the top facets. The result of these reflections is that the stone is filled with light and the bottom facets appear like flashing mirrors.

Dispersion.—White light is really composite, being made up of rays of the different colours seen in the spectrum. These colours are violet, indigo, blue, green, yellow, orange, red, and the rays to which they correspond are refracted to different extents. Thus it is found that for any one stone the refractive index for blue light is greater than the refractive index for green light, which in turn is greater than that for yellow light, and so on. If, as shown in Fig. 7, a beam of white light is passed through a prism of a transparent substance it is split up into its component parts owing to the rays of different colours being deviated to different amounts; the blue rays are more strongly refracted and deviated than the yellow ones, and these are more strongly deviated than the red ones, with the result that a series of colours is obtained if the emergent rays are thrown upon a white screen. This phenomenon is known as *dispersion,* and the power of so splitting up light is called *dispersive power,* which of course varies in different stones. It is strongest in the diamond which, with a refractive index of 2·465 for violet light, and 2·407 for red light, has a dispersion of ·058. Thus when white light enters a diamond its component rays are widely separated and so the beautiful play of prismatic hues, known as *fire,* is obtained. In this respect diamond is superior to all other stones, for not only is the dispersive power stronger, but, owing to the high refractive index, the path of a beam of light emitted by a cut specimen is, as we have seen, a very long one, and the separation of the rays is consequently increased. Figure 8 illustrates this point.

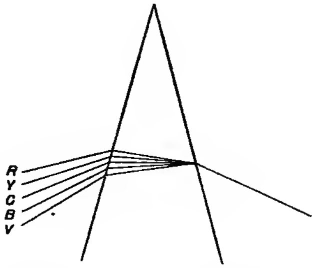


Fig. 7.—*Dispersion of white light by a transparent prism.*

Other stones possessing strong dispersion are sphene (p. 67) and green garnet (p. 75).

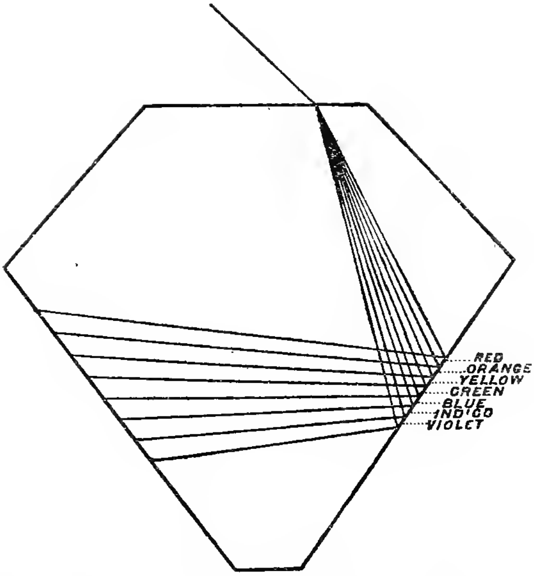


Fig. 8.—*Dispersion and total internal reflection of light in a brilliant.*

Double Refraction.—The foregoing remarks on refraction apply to substances like glass, and to precious stones like diamond, garnet, and spinel which crystallise in the cubic system. A ray of light entering any of these is refracted and emerges as a single ray, and consequently any object such as a black spot or a candle flame when viewed through them appears single. Such substances are therefore said to be *singly refracting.*

In minerals belonging to the other six crystallographic systems the incident ray is, in general, split up into two rays which take different paths and for which the refractive indices are different; a black spot or a flame when viewed through them appears double, and they are said to be *doubly refracting.*

This phenomenon must not be confused with dispersion, and the distinction between the two can be best explained in this way. If a ray of light of single colour, *i.e.*, monochromatic light, is allowed to pass through a singly refracting substance it travels as a single ray and finally emerges as a single ray; in a doubly refracting substance the single ray is in general split up into two rays which have different paths and for which the refractive indices are different.

It has already been pointed out that, when white light is refracted through a prism of a transparent substance, it is split up into its component colours, so that if, for example, a candle is viewed through such a prism, the image is fringed with colour. Now if the prism consists of a singly refracting substance, *one* such coloured image is obtained, but if the substance is doubly refracting, *two* such coloured images are obtained.

The mineral calcite (Case I_1) offers the best illustration of double refraction as the separation of the two rays in this case is exceedingly wide and consequently the images are far apart. In most gemstones the images are not so widely separated and it is sometimes a matter of difficulty to decide by the eye alone whether a specimen is doubly refracting or not. A good way is to examine through the stone either a candle-flame or the small spike at the bottom of an ordinary ground-glass electric lamp, when the current is on, and to see whether the images are double or single.

This method works quite well for large specimens, but for smaller ones, a *polariscope* is usually necessary. This instrument in its simplest form consists of two tubes mounted vertically on a column with a rotating stage placed between them. In each of these tubes is placed a *Nicol's prism*—so called after the inventor—which is mounted so as to allow of complete rotation. These Nicol's prisms are cut from calcite (Case I_1) and possess the property of polarising light. A complete account of this phenomenon cannot be attempted here, but it is sufficient to say that if two Nicol's prisms are held before the eye, and the one next to the observer is rotated, whilst the other is kept stationary, in two positions during a complete rotation darkness ensues. The light going through the first prism has been so affected or *polarised* that it cannot go through the second prism when it occupies one or other of the two positions mentioned above. These positions lie at 180° from each other and in them the prisms are said to be *crossed*. Now when a singly refracting specimen is interposed between crossed Nicol's prisms and rotated, the field of view always remains dark; if, however, a doubly refracting stone is interposed darkness ensues in four positions only during a complete rotation. These four positions occur at intervals of 90°, and in all intermediate positions light gets through. Two points must be mentioned, however. In the first place glass and singly refracting minerals may show "anomalous double-refraction" due to strains existing internally. In such cases, however, the positions of light and darkness are not nearly so well defined as in a true, doubly-refracting specimen.

In the second place doubly refracting stones all possess certain directions known as *optic axes*, and light travelling along these is not doubly refracted. Minerals belonging to the tetragonal, hexagonal, and rhombohedral systems have one such direction and are hence called *uniaxial*, whilst those belonging to the orthorhombic, monoclinic, and triclinic systems have two such directions, and are in consequence called *biaxial*.

Before concluding that a specimen is singly refracting, one must always examine it in several directions as an entirely wrong conclusion may be arrived at through a doubly refracting stone being viewed along an optic axis.

Singly refracting stones have one definite refractive index, whilst doubly refracting stones have a series of refractive indices depending on the direction in which the light is travelling in them. It is found that these refractive indices vary between a maximum and a minimum value, both of which are given in this book.

The determination of the refractive index is a valuable method of identifying a cut specimen, and for this purpose an instrument called a *refractometer* is used. An exceedingly handy type has been devised by Dr. Herbert Smith, of the British Museum (Natural History), by means of which the refractive index can be read off directly from a scale inserted in the instrument. The principle of the instrument depends on the fact that once the critical angle of a substance is known, the refractive index can be calculated immediately.

The following is a list of gemstones arranged according to their refractive indices:—

Table of Refractive Indices.

Singly refracting Stones.

Diamond	2·43	Essonite	1·76
Demantoid	1·90	Spinel	1·72
Pyrope	1·80	Opal	1·46
Almandine	1·77	Fluor-spar	1·44

Doubly refracting Stones.

	Maximum.	Minimum.
Sphene	2·06	1·91
Zircon	1·97	1·92
Benitoite	1·80	1·76
Ruby Sapphire	1·77	1·76
Epidote	1·77	1·73
Chrysoberyl	1·76	1·75
Kyanite	1·73	1·72
Idocrase	1·720	1·718
Diopside	1·70	1·67
Chrysolite	1·70	1·66
Axinite	1·69	1·68
Phenacite	1·68	1·66
Spodumene	1·68	1·65
Euclase	1·67	1·65
Andalusite	1·64	1·63
Tourmaline	1·64	1·62
Topaz	1·63	1·62
Beryl Emerald Aquamarine, etc.	1·58	1·57
Quartz Amethyst Cairngorm Rock Crystal	1·56	1·55
Beryllonite	1·56	1·55
Iolite	1·55	1 54

Colour and Dichroism.—With the exception of diamond, most precious stones like ruby, sapphire, emerald, spinel, &c., are prized largely on account of the beautiful colours which they display. The quality of colour is a most uncertain means of identifying cut stones, as it usually happens that a whole range of tints is shown by specimens of one and the same stone, whilst specimens of different stones are often so similar in colour that it is impossible for any but the most practised eye to distinguish them. This fact is impressed forcibly on anyone who inspects for the first time a series similar to that exhibited in the Horseshoe Case.

Of the substances which cause the tints in precious stones, very little is yet known, a circumstance which is due partly to the very small amounts in which they are present in the specimens, and the consequent difficulty in detecting them by chemical methods, and partly to the high cost of the material necessary for such analysis. The colouring matters, or pigments, are distributed throughout the mass in a homogeneous manner and are in such a fine state of division that they cannot be detected by the most powerful microscope. Some have supposed that the pigments and the stone form a solid solution, others that it is merely a case of mechanical mixture, whilst the Viennese mineralogist, Doelter, who has given much attention to this subject, has suggested that in some cases the pigment may be in the colloidal state. In this way he explained the alteration which often takes place in the colour of a stone when it is subjected to heat or other agencies, *e.g.*, radium emanations. Such agencies might possibly convert the colloidal pigment into a crystalline one which would possess a different colour. An example of this is yellow topaz which, on being heated, assumes a beautiful pink shade. Doelter has also examined the behaviour of many gemstones towards the emanations of radium and has discovered a number of interesting facts which have, however, not yet been completely explained. Thus he found that a yellow diamond remained unaltered; a brown diamond was tinged with violet; smoky quartz of pale-brown colour, was coloured very dark-brown; wine-yellow topaz was coloured dark-orange; a blue sapphire was coloured brown; emerald was practically unaltered, as also was ruby.

In Case O will be found a sapphire which, originally colourless, has been tinged with brown by exposure to radium emanations. It may be remarked that this specimen has become much paler during its sojourn in the case. As a result of his study of the influence exerted by heat and radium emanations on the colour of minerals, Doelter has divided the pigments into two classes, (a) stable pigments which are present in ruby, diamond and deeply-coloured sapphires, and which are almost insensitive to heat and to radium-emanations, and (b) "labile" pigments, which are present in pale sapphires, smoky quartz, fluor-spar, topaz, zircon, &c., which are altered in some way by heat and radium emanations. He found that, when such stones were decolourised by heat, exposure to radium usually imparted the original colour to the stone. The whole subject is yet in its infancy and for more information the student should consult "Das Radium und die Farben" by Professor C. Doelter, in which a compact summary is given of the results so far obtained.

An interesting point about several coloured, doubly refracting stones is that they show distinctly different colours according to the direction in which they are viewed. This phenomenon is called *dichroism*, and is well seen in such a mineral as green tourmaline which appears almost black when viewed along the prism edge, whilst across the prism edge it appears light-green. In many cases, however, the dichroism is so feeble that it cannot be observed by the naked eye, and an instrument called a *dichroscope* is then utilised. This, as shown in Fig. 9, consists of a hollow tube A, in which is mounted a rhomb of calcite R. One end of the tube is closed by a cap in which is cut a slit S, whilst at the other end is inserted the tube B, fitted with a lens L, which can be focussed on the slit by sliding the tube B in and out.

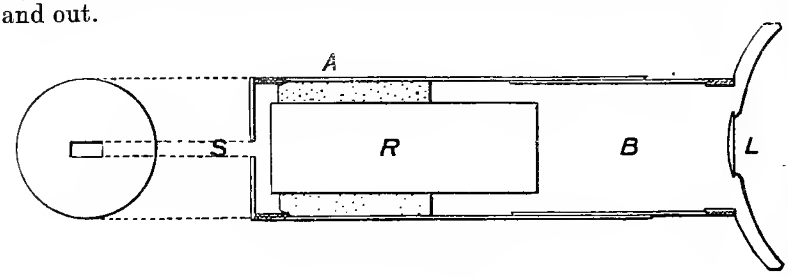


Fig. 9.—*The dichroscope.*

On looking at the sky through the instrument we see two images of the slit owing to the double refraction of the calcite. When a dichroic stone is placed in front of the slit, and either the instrument or the stone is rotated, the following facts may be observed. In four positions at 90° from each other, the images of the slit are identical in colour, but if the rotation from any such position is continued, a difference in colour can be noted which reaches a maximum at 45°; the difference then decreases until the next position at which identity of tint occurs is reached, and so on, until the rotation is completed.

Dichroism is due to double refraction and is never observed in singly refracting stones like garnet and spinel, nor in any coloured glass. Coloured, doubly refracting stones are sometimes so feebly dichroic that no difference in the tints of the images can be observed, whilst dichroic stones do not exhibit the property if they are viewed along an optic axis. To eliminate errors arising from this latter fact one should always examine the stone in several directions. It is therefore clear that, whilst presence of dichroism is a sure indication that the specimen is doubly refracting, absence of it does not imply that a stone is singly refracting.

The following is a list of the dichroic gemstones.

Table of Dichroic Gemstones.

Stone.	Colour.	Colours seen in Dichroscope.	
Ruby	red	pale, yellowish-red ...	deep-red.
Sapphire	blue	pale, greenish-blue ...	deep-blue.
Oriental Amethyst	purple... ...	almost colourless ...	violet.
„ Emerald...	green	green	brown.
Aquamarine ...	bluish-green ...	pale, yellowish-green	pale-blue.
Emerald	green	yellowish-green ...	bluish-green.
Alexandrite ...	„	green	yellow to red.
Topaz	yellow ...	pale-pink or colourless	yellow.
„	pink	pale-yellow or colourless.	pinkish-red.
„	blue	colourless	blue.

Stone.	Colour.	Colours seen in Dichroscope.	
Tourmaline	green	pale-green	dark-green.
„	red	pink	dark-red.
„	blue	pale-blue	dark-blue.
„	brown	yellowish-brown	deep-brown.
Epidote	„	yellowish-green	deep-brown.
Andalusite	green or brown	green or yellowish-green.	brownish-red.
Sphene	brownish-yellow	greenish-yellow	reddish-yellow.
Cordierite	blue	yellowish-grey	deep-blue.
Axinite	brown	blue	brown to yellowish-green.
Smoky Quartz	„	pale-yellow	yellowish-brown.
Amethyst	purple	pale-purple to yellow	deep-purple.
Kunzite	pink or lilac	pale-pink to colourless.	purple to pink.
Hiddenite	green	pale-green	dark-green.
Chrysolite	„	yellowish-green	green.
Kyanite	blue	pale-blue	dark-blue.
Euclase	pale green	pale-green to colourless.	green.

Spectroscopic Properties.—When light which has penetrated certain minerals—usually those containing rare earths—is examined with an ordinary pocket spectroscope certain dark absorption bands are seen. Two gemstones, *zircon* and *almandine*, show this property so well that it can be used for their identification. In the case of zircon, dark bands can be seen in the red, yellow and blue parts of the spectrum, whilst in almandine the absorption bands appear in the yellow, green and blue areas. The illustration from Sir A. H. Church's book on precious stones, exhibited at Case P, shows the spectra obtained in these two instances. To make the test it is only necessary to view through a spectroscope the light reflected from a polished surface. By this means zircon can be identified at once, and almandine can be differentiated from ruby, other varieties of garnet and from red spinel.

Special Optical Appearances.—Several stones, *e.g.*, *moonstone, cat's eye, labradorite,* and one or two others, owe their beauty to none of the optical properties already described, but to the peculiar effects which are seen when light strikes their surface. Such stones are usually translucent and are never facetted, but are cut either with a rounded surface, *i.e.*, *en cabochon*, or simply as flat polished plates.

The phenomenon known as *adularescence* is well seen in the moonstone (Case Q), a variety of the potash-felspar, adularia, from which the appearance takes its name. The peculiar delicate play of light is confined to certain crystallographic planes along which the crystal shows a tendency to part. The sheen is due to the reflection of the light from numerous platy inclusions arranged parallel to these planes. A similar explanation holds good for labradorite (Case Q) and for the variety of chrysoberyl known as cat's-eye, which latter stone when cut *en cabochon* often shows a broad band of white light which moves across the surface of the specimen as its position with respect to the observer is changed.

A variety of quartz, known in consequence as *cat's-eye quartz,* shows a somewhat similar appearance, which here, however, is due to the fibrous structure of the stone; the name *chatoyancy* has been given to this effect.

Asterism is shown by some sapphires and rubies—called, in consequence, *star-sapphires* and *star-rubies* (Case N)—which exhibit a more or less well defined six-rayed star when cut *en cabochon,* and in such a way that the greatest thickness of the specimen lies parallel to the vertical axis of the crystal. This appearance is caused by a series of microscopic canals lying in the crystal and arranged in directions which make angles of 60° with one another.

Sometimes internal flaws give rise to a play of prismatic colours, and a good example of this is afforded by the specimen of rock-crystal in Case M_1. The colours in such cases result from the interference of light which is occasioned by the thin film within the specimen. *Precious opal* owes its remarkable play of colours to a similar cause, though doubt exists as to the character of the flaws which give rise to the interference of the light.

Thermal and Electrical Properties.

Precious stones conduct heat well and always feel much colder than imitations in glass; by simply touching a specimen with the tip of the tongue, one is able, after a little practice, to distinguish readily between paste and a genuine stone. If the specimen is small it is best to hold it in a pair of pincers, as, if held in the hand, it may get so heated up that the test can no longer be applied.

Most gemstones when rubbed with some such material as flannel acquire an electric charge which they retain for longer or shorter periods. Before the discovery of many of the interesting optical properties already described, electrical properties were sometimes used to discriminate between stones, but nowadays little use is made of them.

Some minerals acquire a charge on heating, and in consequence are called *pyro-electric,* and this property is exhibited in such a marked degree by *tourmaline* and *topaz* that it can be used to identify them.

Chemical Properties.

The simple substances or *elements,* which enter into the composition of gemstones are usually of the commonest description. Thus, the metal aluminium, which is one of the most widely distributed elements in the earth's crust, is found in one form or another in the majority of precious stones. Combined with oxygen alone, it forms the *ruby* and the *sapphire,* and it is an essential constituent in many of the silicates, *e.g., topaz, tourmaline, beryl* (including emerald), several of the *garnets,* &c., which are used for ornamental purposes. In the *spinel,* oxide of aluminium is united to that of magnesium, whilst in the *chrysoberyl* it is combined with the oxide of beryllium which is a somewhat rarer element. *Turquois*, again, consists largely of aluminium phosphate and is the only gemstone of importance which contains the element phosphorus.

Silicon is the most widely distributed of all the elements, with the exception of oxygen, and occurs as a constituent of many gemstones. In combination with oxygen, as silicon dioxide, or *silica*, it forms *rock-crystal*, *cairngorm*, *amethyst*, *chalcedony*, and *agate*, whilst it is of course present as an essential constituent in the silicates mentioned above.

Diamond, unique in many respects amongst precious stones, is composed of pure carbon, and is the only stone consisting of a single element. *Tourmaline*, on the other hand, may be cited as an example of complex composition, for it may contain as many as twelve elements.

The process of determining the constituents of a substance and the percentages in which they are present is known as *chemical analysis*, and is the most certain means of identifying a specimen. It demands, however, the sacrifice of a considerable amount of material, and is on that account, inapplicable to valuable cut stones. Such an operation is rarely necessary as the identity of a stone can be definitely established by means of the physical tests already described.

CHAPTER II.

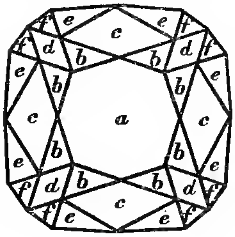
THE CUTTING OF PRECIOUS STONES.

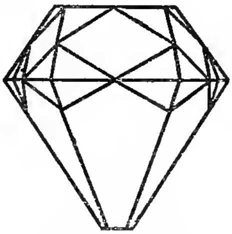
Precious stones as they occur in nature do not display in a prominent manner any of the beautiful qualities which have been referred to in the previous chapter. Some of them, it is true, are found in well formed crystals with the faces showing a good lustre, but many of them occur in the sands and gravels of rivers as water-worn pebbles, which present by no means the attractive appearance popularly associated with this class of minerals. Even when, as in the case of the emerald, the stone is normally found as crystals in the mother-rock, it rarely happens that a specimen shows sufficient freedom from internal and external blemishes to warrant its being mounted without further treatment.

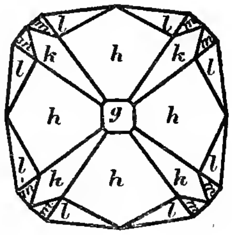
Such qualities as *transparency, lustre, fire, chatoyancy, asterism,* &c., can only be observed when a specimen has been cut and polished, and even that is insufficient, for the cutting must be directed towards bringing out the effect or effects for which the stone is noted. Oriental lapidaries, when cutting a stone, are dominated by the idea of making the finished article as large as possible, with the result that it does not show the optical properties to advantage, and is in no respect comparable to one cut according to European methods, where the end kept in view is not so much to conserve weight as to bring out the latent beauties of the rough material.

Transparent stones are usually cut with plane faces, or *facets,* as they are called, while translucent or opaque stones, especially those showing any of the special optical effects mentioned in the last chapter, are cut *en cabochon, i.e.,* with a rounded surface. According to the arrangement of the facets there are four main styles of cutting, which are known respectively as (1) the *Brilliant,* (2) the *Step Cut,* (3) the *Rose* or *Rosette,* and (4) the *Table Cut.*

(1.) The *Brilliant.*—Figures 10, 11, and 12 represent a stone cut in this manner. The greatest circumference, or *girdle,* divides the specimen into an upper part, or *crown,* and a lower part, or







THE BRILLIANT.

Fig. 10.—*Upper part or crown.*

Fig. 11.—*View of side.*

Fig. 12.—*Lower part or culasse.*

culasse. In the crown (Fig. 10) there are 33 facets made up as follows:—

Table (*a*)	1
Star facets (*b*)	8
Templets or bezels (*c*)	4
Quoins or lozenges (*d*)	4
Cross facets or Skew facets (*e*)	8
Skill facets (*f*)	8
Total	33

In the culasse (Fig. 12) there are 25 facets made up as follows:—

Culet or Collet (*g*)	1
Pavilion facets (*h*)	4
Quoins (*k*)	4
Cross facets (*l*)	8
Skill facets (*m*)	8
Total	25

In the newer style of cutting, represented in Figs. 13, 14, and 15, the facets are made more nearly equal in size and the girdle approaches a circle in outline. There are thus 58 facets in the typical brilliant, but this number may vary somewhat, and is sometimes increased to 66 by the grinding of 8 small facets round the culet.

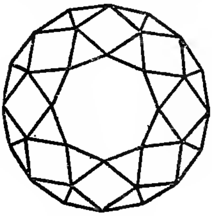


Fig. 13.—*Crown.*

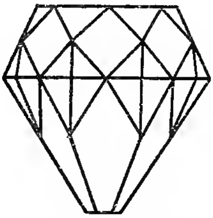


Fig. 14.—*View of side.*

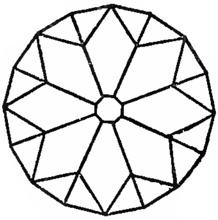


Fig. 15.—*Culasse.*

This form of cutting is by far the most important, as it is employed on all the best diamonds and on many other stones, both coloured and colourless. In the case of diamond there is a certain proportion about the finished brilliant which gives the maximum of "fire" and "life." Of the total thickness of the stone, *i.e.*, the distance between the table and the culet, one-third should be occupied by the crown, and two-thirds by the culasse, whilst the diameter of the culet should be one-ninth that of the girdle, and one-fifth that of the table.

The octahedron lends itself very readily to this style of cutting, and it has already been pointed out how much labour is saved to the cutter by the fact that diamond splits parallel to the octahedral planes. Figure 16 illustrates the first process in the treatment of the octahedron. The opposite apices are ground away to the extent indicated and form the table and the culet. The octahedral planes form the bezels of the crown, and the pavilions of the culasse, whilst the quoins are obtained by truncating the angles between them.

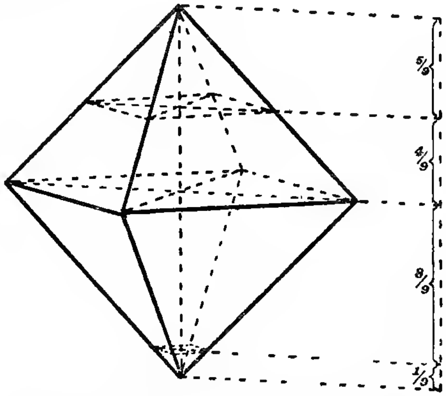
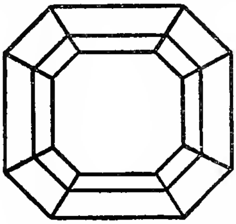
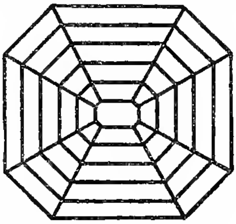


Fig. 16.—*Derivation of brilliant from octahedron.*

(2.) The *Step Cut.*—Figures 17 and 18 represent respectively the upper and lower parts of a stone cut in this manner. In the upper part there is a table with a series of rows of facets sloping down towards the girdle, whilst in the under part the rows of facets slope away from the girdle to the culet. There is considerable variation in the number of rows of facets, and also in the outline of the girdle, which may be square, eight-sided, as in the illustration, or six-sided.





THE STEP CUT.

Fig. 17.—*Upper part.* Fig. 18.—*Lower part.*

This style of cutting, sometimes known as the *trap cut,* is much employed in the treatment of coloured stones, and is usually preferred in the case of the emerald. Sometimes a specimen is fashioned with the upper part as a brilliant, and the lower part cut in steps, and such a stone is said to be *mixed cut.*

(3.) The *Rose* or *Rosette.*—The upper part of a stone cut in this way is shown in Fig. 19. It consists of six low triangular facets *a,* from the base of which the six triangular facets *b* slope down to the girdle. The spaces between the facets *b* are occupied by twelve facets *c,* which meet the girdle in an edge. There are thus in this part of the stone twenty-four facets, which are divided into the six star facets *a,* known as the *crown,* and eighteen cross facets *b* and *c,* to which the name *dentelle* is given. The under part of the stone consists usually of a broad flat face, which in the case of the diamond is usually a cleavage plane. Sometimes, however, the under part is simply a repetition of the upper, in which case the name *double rosette* is applied.

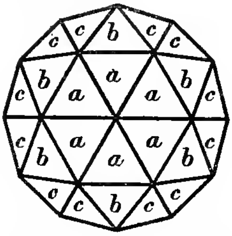


Fig. 19.—*Rose or rosette, upper part.*

There are several types of rose in which the number of facets may be greater or smaller, but the one described above finds the most extended application. Diamonds which are unsuited for the brilliant cut are usually fashioned as roses, and this form stands next to the brilliant in importance.

(4.) The *Table Cut*.—This form is unimportant nowadays although it was a favourite way of treating diamonds in the early history of gem-cutting. In its simplest form the *table* may be

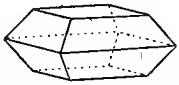


Fig. 20.—*The table.*

considered as an octahedron whose opposite apices (Fig. 20) have been ground away to an equal extent. It thus has ten facets, but a few additional ones may be cut.

The rounded forms call for little explanation. They, as mentioned above, are usually employed for translucent and opaque stones, although transparent stones, especially garnets, are sometimes treated in this way. The *simple cabochon* (Fig. 21) has a flat base, which may be oval or circular, whilst in the *double cabochon* the under part also consists of a dome, which is, however, usually flatter than that of the upper part (Fig. 22).

Fig. 21.—*Simple cabochon.*

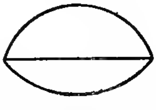


Fig. 22.—*Double cabochon.*

Fig. 23.—*Hollow cabochon.*

In the *hollowed cabochon* (Fig. 23) the interior of the stone has been ground away, thus giving it a shell-like form; several of the garnets shown in Case P have been treated in this way, and their transparency greatly increased in consequence.

When the rounded surface of the cabochon is very much flattened, the stone is called *tallow topped*.

The actual process of cutting is carried out on a metal disc which is provided with the powder of some hard substance to act as grinding material. The metal disc—about one foot in diameter—is mounted on a vertical axis and rotates horizontally at a high velocity. The material of which it is made varies with the hardness of the stone to be treated and it may consist of iron, brass, copper, tin, or lead.

The grinding material also varies according to the stone which is being cut. Diamond is the hardest of all substances and can only be abraded by its own powder. Samples of diamond powder are shown in Case A, and also in a case in the Hall devoted to abrasives. Stones like ruby and sapphire are also cut with diamond powder which, despite its high cost, is employed because it allows of the work being done quickly.

Powdered *emery*, an impure form of corundum, is extensively used for the softer stones and, in recent years, the artificial *carborundum*, a carbide of silicon, which is harder than corundum, has also been employed.

The abrasive is made into a paste with olive oil or water and spread on the outer part of the disc into which it gradually works its way, thus providing a circular file which cuts out the facet. After the stone has been given the required shape it has to be polished, and this is usually accomplished on a disc of softer material with some such polishing agent as tripolite, putty powder, rouge, bole, &c., applied to the wheel in a paste.

Diamond, on account of its great hardness, is treated in a different way from any other stone. If the rough stone is to be cut as a brilliant, and its natural shape is not suitable to that style of cutting, advantage is taken of the cleavage to reduce it to the octahedral form. The diamond splitter mounts the stone in cement at the end of a rod and makes an incision in the proper direction by means of another diamond similarly mounted. He then inserts a chisel into the cut, gives it a smart tap with a hammer and splits off the unnecessary portion. This is repeated until the stone is in the desired shape and ready for *bruting*, as it is called. The stone is mounted as before in cement and rubbed against another diamond similarly mounted, and in this manner the principal facets are roughly formed. These facets as well as the smaller ones, which have not been put upon the specimen during the bruting, are then ground and polished on an iron wheel covered with a paste of olive oil and diamond powder.

The manner in which a stone is held against the grinding disc is interesting. The holder consists of a copper cup attached to a small rod, and is known as a *dop*. The copper cup is filled with a fusible alloy of lead and tin in which the stone is imbedded with the part which is to be ground left exposed. The dop is then clamped by means of the small rod to a horizontal bar in such a position that the cup hangs downwards and the stone rests on the grinding disc. By means of weights placed on the horizontal support the pressure on the disc is increased, and the grinding is thus effected. There may be as many as four different stones on the one disc. There are many technical details concerned with the cutting of gemstones, and for an account of them the visitor is referred to any of the larger books treating of the subject.

CHAPTER III.

THE IMITATION, TREATMENT, AND ARTIFICIAL FORMATION OF GEMSTONES.

The more valuable gemstones or precious stones, as they are often called, have from the earliest times been highly esteemed, and it is not surprising that much ingenuity should have been expended in making imitations which resemble, at least in outward appearance, the natural product. Glass at once suggests itself as being suitable for the purpose and, since glass-making is an industry of very great antiquity, counterfeits in this substance were well known to the ancients who attained considerable skill in their manufacture. Again, it sometimes happens that very slight differences in the tints of specimens of the same stone make very considerable differences in value and various devices have been employed for treating the less valuable variety so that it may resemble for a time at least the more costly one. Such artifices may be intended solely to deceive the purchaser, but some are well recognised processes of treatment for permanently altering the appearance of a stone. A few typical instances will be cited here and others will be referred to when the particular gems come to be described.

Until a comparatively recent date all that the collector had to fear was the glass imitation mentioned above, but, within the last few years, *corundum*, including its varieties *ruby* and *sapphire*, has been successfully manufactured, and the stones cut from this artificial material are identical with the natural ones in optical and other physical properties. As we shall see later on, differences do exist between the two, but a microscope is often required to make them out and, owing to the enormous difference in value between the natural and the artificial stone, the advent of the latter has caused no small amount of perturbation in the precious stone trade.

Keeping these facts in mind, the collector will do well to observe the rule of buying specimens unmounted whenever that is possible. When a stone is mounted, flaws are easily hidden, devices for improving its appearance are difficult to detect, hardness, specific gravity, double refraction, presence or absence of dichroism cannot be determined, and microscopic examination is impossible.

The Imitation of Precious Stones.

Various kinds of glass, technically known as *paste* or *strass*, are employed for this purpose, the colour, when it is desired to counterfeit such stones as ruby, sapphire, emerald, topaz, &c., being obtained by the addition of small quantities of suitable metallic oxides. The glass used for imitating such a stone as diamond must possess a high refractive index, a high lustre, and strong dispersive power, qualities which are attained by the addition of lead, and, less commonly, thallium. The use of such ingredients, however, not only diminishes the hardness of the product but also renders it liable to alteration and, consequently, after some time it becomes cloudy and loses much of its initial brilliancy.

The making of a good paste is by no means a simple matter. The ingredients must be of extreme purity if accidental colouring is to be avoided, whilst the cooling of the molten material must be carried out slowly and carefully in order to produce a transparent mass free from air-bubbles and striae, blemishes which would render it unfit for making good imitations. The constituents are usually pure quartz, carbonate or nitrate of potash, and red lead, the proportions of these varying according to the purposes for which the paste is intended. The substances are powdered, mixed, and, with the addition of a little borax, fused up in a crucible. The mass is then allowed to cool very slowly, after which the clear transparent product is ready for cutting. Such a glass is colourless but, by the addition of very small proportions of various metallic oxides, it can be made to assume any tint. A blue colour is produced by cobalt oxide, red by cuprous oxide, ruby-red by the addition of some gold compound such as purple of Cassius, green by either cupric or chromic oxide, violet by manganese oxide, and so on.

Reference has already been made to the fact that glass is warmer to the touch than a natural stone, and the test mentioned on p. 20 is usually quite sufficient for anyone who has had any practice in this kind of work.

Again a paste imitation yields to the file whilst a genuine stone does not, and, if still further confirmation be required, it is only necessary to remember that a glass is singly refracting, lacks dichroism, and under the microscope often shows air-bubbles and striæ.

A cut specimen may sometimes be made with an upper part, or crown, of genuine stone whilst the lower part, or culasse, consists of paste. Such devices are known as *doublets*, of which there exist several varieties. Thus the doublet may consist of two pieces of natural stone cemented together, or the upper part may be of a valuable stone like diamond, whilst the lower part consist of a cheaper stone like white corundum.

In the *triplet* a layer of glass is intercalated between two pieces of genuine material.

The doublet and triplet are difficult to detect when mounted, but if the specimen be dismounted and immersed in hot water the cement softens and the parts fall asunder.

The Artificial Treatment of Precious Stones.

The most valuable kind of diamond is that known as the "blue-white," which is rather rare as the majority of stones possess a yellowish tinge, faint, it is true, but still quite visible to the practised eye. When blue wax or varnish is rubbed over the back of a yellow stone the tint is "corrected" and the specimen appears quite white. The device, however, is only temporary, as the colouring matter is bound to go sooner or later and the true colour then makes its appearance. The trick can always be detected by washing the stone in alcohol when the pigment is dissolved off.

Many stones alter their colour when heated and this fact is made use of in the case of topaz, zircon, and quartz.

At the present time the most valuable kind of topaz is that possessing a pink colour but such stones are rarely if ever found in nature. The yellow topaz is, however, readily changed to pink by heating, and it is no exaggeration to say that all the pink stones in the market to-day have been produced in this way. The topaz is packed in a crucible with some such material as magnesia and heated carefully. The stone goes nearly white, but, on cooling, assumes the beautiful rose-pink colour seen in Case O.

Some kinds of zircon when heated not only become colourless but also show a considerable increase in lustre. The refractive index of this stone is high, and colourless zircons obtained by " burning " have frequently been passed off as diamonds. The fraud is difficult to detect in a mounted specimen but, if the stone be dismounted, the lack of hardness combined with the strong double refraction, and the high specific gravity of the zircon, or *jargoon*, as it is sometimes called, suffice to distinguish it from the diamond.

The dark variety of quartz, known as *morion*, owes its colour to volatile organic compounds which are discharged by heating. If, however, the stone is raised to a moderate temperature the colour changes from almost black to a rich brown, and in this form the material is frequently sold as " Spanish topaz."

The colourless variety of quartz is sometimes treated in a peculiar manner. The stone is heated to a fairly high temperature and then plunged into a solution of dye. Numerous cracks are developed in this way, and the dye soaks along them. Such stones can be detected at a glance as the colouring is not uniform but is confined to the fissures produced by the sudden cooling.

Examples of the above method of artificial treatment will be found in the cases devoted to the minerals mentioned and other instances of staining and colouring will be referred to when the particular stones are described.

The Artificial Formation of Precious Stones.

It has already been pointed out how unsatisfactory the glass imitation is as compared with the natural stone, and how easily it can be detected. With the advance in the knowledge of the composition of minerals, however, chemists began to direct their attention towards producing them in the laboratory. As was to be expected, much labour and ingenuity was expended on precious stones and many attempts were made to produce a substance answering in all respects to the natural one. This branch of the subject has attracted the French chemists, in particular, but the results obtained by them, whilst of great scientific value, are, with one or two exceptions, of no commercial importance. Many minerals have been formed and amongst them are a few gemstones, but it is one thing to produce a stone and quite another to manufacture it in pieces large and transparent enough for cutting and by a process which can compete successfully with the natural gem.

The only stones which, up till now, have been successfully manufactured are *corundum* (including *ruby* and *sapphire*), *spinel* and *turquois*; diamond, beryl, and one or two others have been formed in recognizable pieces, but in no case have the products been fit for cutting.

Corundum consists of crystallised oxide of aluminium, or alumina, and includes several varieties which have different names depending on their colour. Thus, *ruby* is transparent red corundum, *sapphire* is transparent blue corundum, *oriental topaz*, transparent yellow corundum, and so on (p. 54).

As usually prepared in the laboratory, alumina is a white amorphous powder and the problem to be solved consisted either in producing this substance under conditions which would make it assume the crystallised state, or, given the white powdery alumina, to convert it into the hard, crystallised corundum.

The first attempts were made as early as 1837 by the French chemist, Gaudin, but, although he succeeded in forming a crystalline product, it was quite unfit for the uses of the jeweller.

Somewhat similar remarks apply to his attempts, made in 1857, and again in 1869, as well as to those of the other chemists, Sainte-Claire Deville, Caron, Ebelmen, and Hautefeuille, who had been become interested in the question about the same time. The crystals obtained by these investigators were usually small, and the processes by which they were obtained could not be applied commercially.

In 1877 Frémy and Feil succeeded in forming crystals of ruby by quite a new method which consisted in calcining a mixture of alumina, red oxide of lead, and potassium bichromate for several hours in a clay crucible. The oxide of lead combined with the alumina to form lead aluminate and this, acting on the silica of the crucible, produced lead silicate, and alumina which crystallised out as ruby; the red colour was imparted by the chromium of the potassium bichromate. The crystals so obtained were in the form of thin plates and quite unfit for cutting.

Frémy continued his researches and, in collaboration with Verneuil, succeeded in making rubies by another process. They employed an open crucible and calcined in it at a high temperature a mixture of pure alumina, potassium carbonate, barium fluoride and, as before, potassium bichromate. The reactions which take place with such a mixture are rather complicated, but the chief result is the formation of aluminium fluoride which decomposes under the influence of heat and the moisture of the furnace gases into hydrofluoric acid and alumina which, however, assumes the crystallised state; the chromium of the bichromate imparts, as before, the red colour. The rubies obtained by this method were large enough to be cut in the rose-form, but they were still too small for general use in jewellery. Examples of them are shown in Case N.

In 1885, or thereabouts, a number of very perfect rubies appeared on the market in Geneva. They possessed all the characters of the natural mineral, but were seen to contain a number of rounded air-bubbles. They were sold at a high price and the secret of their manufacture was well kept, but it seems to be practically certain that they were made by fusing up a number of smaller rubies in the oxy-hydrogen blowpipe and letting the mass so obtained cool and crystallise out. This process is known as *reconstruction* and was applied with some success in 1895 and during the succeeding years.

Nowadays artificial rubies are not reconstructed from fragments of the natural stone, but are made from pure alumina, prepared from ammonium alum, to which oxide of chromium is added to produce the red colour. There are two ways of preparing the material:—(1) By calcining at a red heat ammonium alum, *i.e.*, a double sulphate of ammonium and aluminium, to which some potassium bichromate has been added. This method is the one employed commercially. (2) By adding ammonia to a solution of the above alum to which chromium alum has been added. The precipitate so obtained is washed and calcined. The amount of the salt of chromium added in either case is sufficient to give 2·5 per cent. of chromium oxide in the mixed oxides. The mixture is fused by a blowpipe fed with coal gas and oxygen, and, with certain precautions, a clear transparent mass of ruby is obtained. It had been known for a long time that alumina could be fused by an oxygen blowpipe, and Gaudin had actually prepared some crystallised material by this method as early as 1869, but all his attempts to produce a large transparent mass had failed.

The matter remained pretty much in this state until Verneuil took it up, and in a series of brilliant researches succeeded in solving the problem. The following is a short account of his results which were published in 1904.

He found that, to obtain a clear transparent product from the fusion of alumina, these three conditions had to be observed:—

(1.) The fusion must be carried out in that part of the flame which, whilst capable of melting alumina, is richest in hydrogen and carbon.

(2.) The mass must grow upwards in regular layers superposed to each other.

(3.) The cooling surface, *i.e.*, the contact of the fused mass with the support, must be as small as possible.

Verneuil designed a most ingenious piece of apparatus (Fig. 24) embodying these principles and by its means was able to produce large transparent masses of ruby.

It consists essentially of a vertical blowpipe whose upper part is in the form of a fairly large chamber C, in which is suspended a sieve P containing the finely powdered mixture of alumina and chromium oxide. The wire by which the sieve is suspended penetrates the lid of the chamber and terminates in a small disc E.

The oxygen enters the blowpipe by an opening O in the lid of the upper chamber so that when the disc is tapped the powder is shaken out of the sieve and carried along to the flame in the current of oxygen. The support R, on which the molten mass grows, consists of a cylinder of alumina enclosed in a collar of platinum, the whole being fastened to an iron arm S which can be moved in a vertical direction and in two horizontal directions at right angles to each other thus ensuring that the mass is in the most favourable part of the flame. The coal gas enters by the opening H.

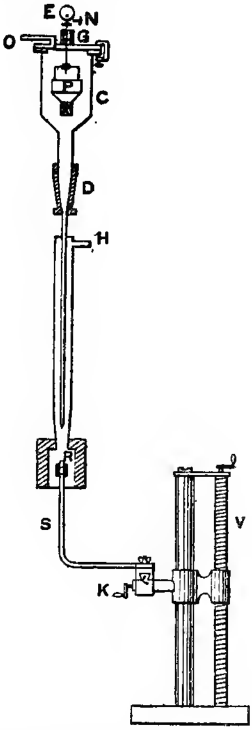


Fig. 24.—*Verneuil's apparatus for making corundum.*

The first particles of powder which fall upon the support form a conical mass which gradually grows upwards until the apex reaches a part of the flame sufficiently hot to liquefy the alumina and the powder which arrives after that melts and forms a fine thread. As this thread grows upwards it gradually reaches a hotter region of the flame and a little sphere is formed on the summit. The support is then lowered a little, the sphere increases in size and the final product is a pear-shaped mass or *boule* of ruby. The remarkable thing about these *boules* is that, although possessing no crystal faces, yet they have the internal crystalline structure of the natural ruby and are identical with it in hardness, specific gravity, refractive index, double refraction and dichroism. The long axis of the pear corresponds roughly to the vertical (and optic) axis of the natural crystals, whilst on the broad end there is a series of lines intersecting at 60° which correspond in position to the rhombohedral faces. A very good series of stones made by this process and presented to the Museum by Mr. E. Hopkins of Hatton Garden is shown in Case N. The shape of the product is well seen, whilst one specimen shows the *boule* growing on the apex of the cone of alumina which fell first on to the support. As indicating the size which the masses sometimes attain it may be mentioned that the largest of the *boules* shewn here measures $1^4/_5$ in. in length, and weighs $94\frac{1}{2}$ carats.

The production of the sapphire proved a more difficult problem. Oxide of cobalt was added to the pure alumina, but all attempts to get a clear, transparent mass with the characteristic blue colour failed. It was found that by adding some magnesia to the mixture a transparent, blue flux resulted and this was cut and put on the market as " Hope sapphire." On examination, however, these stones proved by their hardness, specific gravity, absence of dichroism, &c., to be *spinel.* Examples of them are shown in the series.

By adding small quantities of magnetic oxide of iron and of titanic acid to the alumina, Verneuil at last succeeded in preparing a clear transparent, blue product answering in all respects to the natural sapphire; examples of these are shown.

The green stones are produced by the addition of vanadium. They possess the interesting property of appearing red by lamplight and have been wrongly called " reconstructed alexandrites." The pale pink stone is, in like manner, often wrongly designated " reconstructed " or " scientific topaz," whilst the colourless artificial corundum has sometimes been sold as " synthetic diamond." The yellow colour seen in some of the *boules* is got by adding 3 per cent. of nickel oxide to the alumina; these stones are also called " scientific topaz."

From the above remarks it will be seen that none of the tests mentioned in Chapter I. serves to distinguish the artificial from the natural corundum. As at present manufactured, however, the former usually shows rounded air-bubbles and curved striæ which can be seen in most cases with a lens, but are sometimes visible only under the microscope. In the larger specimens the striæ and bubbles are often quite prominent and can be detected readily, but with the smaller ones recourse must usually be had to microscopic examination. This is carried out most readily when the stone is immersed in a cell filled with a liquid of high refractive index and the whole placed on the microscopic stage. In this way the flaws referred to above can be readily detected. Natural rubies also show striæ and cavities but the former are straight lines whilst the latter are not rounded but possess definite crystal-outlines.

Artificial rubies are now manufactured in large numbers and stones of good quality can be purchased for 4*s.* per carat.

Turquois, a hydrous phosphate of aluminium and copper, is another stone which has been successfully manufactured, but little is known regarding the details of the process. It appears to consist in subjecting to great pressure a chemical precipitate having the same composition as the natural mineral. The stones formed in this way bear a strong resemblance to the natural ones, but they differ in their behaviour when heated. The natural turquois decrepitates and falls to powder, whilst the artificial one fuses quietly; this test can only be applied to rough fragments. The artificial stone, further, when moistened shows a series of intersecting cracks on the surface.

In contrast to the success attained in the artificial production of the ruby, all the efforts made to produce the *diamond* in a form fit for jewellery have so far proved abortive.

The diamond consists of pure, *crystallised* carbon, and the pressure and temperature necessary to convert the black amorphous carbon, or charcoal, into the beautiful crystallised variety are so difficult to realize in the laboratory that, after many attempts, the only result has been a few microscopic, badly-formed crystals which are utterly unfit for any of the purposes to which the diamond is applied.

The first experiments in the formation of this stone which had any semblance of success were carried out by J. B. Hannay, a Glasgow chemist. His method depended on the fact that metals such as sodium, potassium, or lithium are capable of uniting with the oxygen and hydrogen of carbon compounds and of setting free the carbon. Hannay also found that when an element was set free from a gaseous compound it tended to assume the crystalline form. Accordingly he took a mixture of lithium, bone-oil, and paraffin, sealed it up in a stout iron tube and heated it for several hours in a furnace. The lithium united with the hydrogen and oxygen of the hydrocarbons and liberated the carbon under great pressure. The tube, after being allowed to cool, was opened and found to contain a hard black mass in which were imbedded minute crystals having all the properties of diamond. These experiments were carried out in 1880 and of the eighty attempts made only three were successful; the rest failed owing usually to the bursting of the tube under the enormous pressure, or to leakage due to defective sealing.

In 1893 the French chemist, Moissan, succeeded in making diamonds by quite a different method. He made use of the fact that iron, liquefied at a high temperature such as that produced by the electric furnace, is capable of dissolving carbon which separates out when the mass is cooled. Moissan employed a crucible of carbon in which he placed a mixture of pure iron and pure carbon and the whole was then subjected to the heat of the electric furnace. After being kept at this high temperature (about 4,000° C.) for a short time the crucible with its solution of carbon in iron was plunged into water and rapidly cooled. Now, iron expands when it passes from the liquid into the solid form, so that the sudden cooling caused a solid crust of iron to form round the liquid and expanding interior. The pressure so produced was enormous and some of the carbon which was thrown out of solution assumed the form of diamond. The crystals obtained in this way were very small, measuring at the most about ·7 millimetres in length, and the work of separating them from the iron and the carbon in the crucible was exceedingly long and tedious. The method, in short, is of no commercial importance, but it is interesting as throwing light on the probable mode of origin of diamonds in meteoric iron (p. 41).

Still more recently Friedländer fused up olivine and stirred it with a rod of graphite which, when cooled, was found to be encrusted with small crystals of diamond.

CHAPTER IV.

THE DESCRIPTION OF GEMSTONES CONTAINED IN THE COLLECTION.

In this Chapter the minerals are described in the order in which they are arranged in the cases.

DIAMOND (Case A).

Hardness, 10.	Specific Gravity, 3·53-3·52.
Singly refracting.	Refractive Index, 2·43.

In many respects diamond occupies a unique position amongst precious stones. It is the gemstone *par excellence* in popular estimation and is the one most generally employed by jewellers. To the mineralogist it appeals strongly on account of its many singular properties; thus, it is the hardest known substance; it consists of a single element; it is combustible; its refraction and dispersion are extraordinarily powerful; whilst its crystals are usually complex and have many of the faces rounded in a curious manner. Finally, in the commercial world, diamond is the most important gemstone, for more capital is sunk in its exploitation than in that of any other member of the series.

The fact that diamond consists of pure carbon was first demonstrated by Smithson Tennant in 1797. It had been shown by two Florentine Academicians as early as 1695 that a crystal of this mineral disappeared when sunlight was focussed upon it through a powerful burning-glass, whilst the French chemist, Lavoisier, in 1772 and during the succeeding years, proved that, besides strong heat, air was necessary to make the diamond disappear. He examined the gas obtained in the experiment and found it similar to that obtained by the burning of pure carbon, or charcoal in air; he hesitated, however, to say that diamond and carbon were one and the same substance and it remained for Tennant to prove their identity. His method depended on the fact that, when potassium nitrate is fused up with carbon, potassium carbonate is formed. He put a weighed quantity of diamond into a gold tube along with potassium nitrate and heated the mixture strongly for about one hour. After the tube had cooled he dissolved the residue in water and then added lime water to this solution. A white precipitate (carbonate of lime) was formed which was carefully separated from the liquid and then treated with hydrochloric acid. By this means Tennant obtained a volume of carbon dioxide equal to that which he would have obtained had he conducted his experiments with an equal amount of carbon or charcoal. From this consideration he concluded that diamond and carbon were identical in composition, and his results have since been repeatedly verified.

It is possible to convert diamond into graphite (Case B) by subjecting it to a high temperature and excluding air.

The crystals of diamond belong to the cubic system, and the faces, as already mentioned are very frequently rounded. The common forms are the octahedron (Fig. 25) and the dodecahedron

(Fig. 26) whilst crystals of cubical form (Fig. 27) are much rarer. The octahedral planes are sometimes replaced by three- or six-faced pyramids, thus giving rise to trikis-octahedral and hexakis-octahedral forms. A set of models illustrating these shapes is exhibited.

Another point of interest well brought out by the octahedral crystals from South Africa is that the edges of the octahedron are replaced by striated grooves which show that what appears to be a simple crystal is in reality a compound or twin form (Fig. 25).

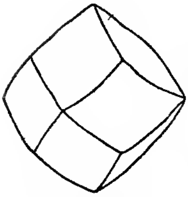


Fig. 26.—*Dodecahedral crystal of diamond.*

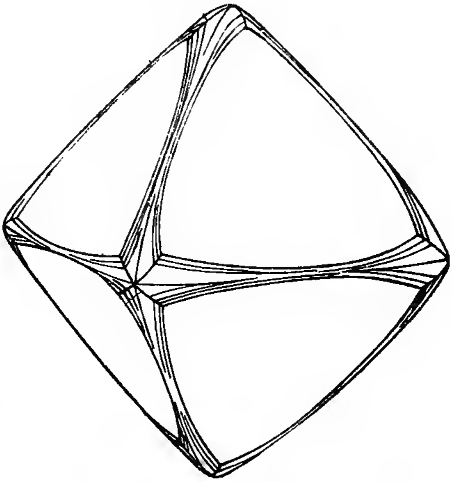


Fig. 25.—*Octahedral crystal of diamond shewing striation at edges.*

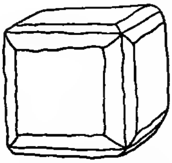


Fig. 27.—*Cubical crystal of diamond.*

Diamond cleaves very readily parallel to the octahedral planes, a fact which renders it brittle and easily reduced to powder. The extraordinary hardness of the diamond has often been confused with the quality of toughness or tenacity, *i.e.*, the power of resisting a blow, and it is said that an old way of "testing" a doubtful specimen consisted in laying it on an anvil and striking it with a hammer. If the stone broke, then it was pronounced spurious. Needless to say, many diamonds failed to resist such treatment.

Absolutely colourless diamonds, *i.e.*, "blue-white" stones, or diamonds "of the first water," are rather uncommon and are the most highly prized. Faint tinges of yellow, green, and brown are frequently met with and are shown by several of the specimens in the case; a black diamond from Brazil is also exhibited. Various shades of yellow are characteristic of the Cape diamonds, but the colour is often so faint that it can be detected only by placing the stone side by side with a colourless one. Deeply-coloured diamonds are rare and, when flawless, command very high prices. The colour of diamonds is very stable and is influenced but slightly by heat or by the emanations of radium. Many attempts have been made to eliminate the faint colours which are so prevalent and so to enhance the value of the specimens, but no successful process has, as yet, been discovered.

Very little is known regarding the nature of the pigment or pigments and iron, chromium and titanium have all been suggested with more or less plausibility.

When diamond is exposed to the action of radium in a dark room it becomes phosphorescent and, as the only other gemstone which resembles it in this respect is kunzite (p. 82), this property can be utilised to discriminate between diamond and any other stone such as white sapphire, topaz, zircon, or rock-crystal, to which it bears a superficial resemblance. In this stone, however, the hardness. lustre, refraction and dispersion are so characteristic that there should be no confusion between it and the minerals mentioned above. Diamond (hardness 10) scratches corundum easily and a very ready means of testing a doubtful specimen is to try its effect on a polished plate of that mineral.

The styles in which diamond is cut have been already described (p. 22).

Stones are sold by weight and the unit employed is the *carat*[*] which, unfortunately, is not a definite standard but varies according to the country in which it is used. The origin of the carat can, no doubt, be traced to the seeds of the locust tree, *ceratonia siliqua*, which are remarkably constant in weight and average about 3·04 grains or 197 milligrams. The English carat, however, as defined by the Board of Trade, is 3·1683 grains or 205·310 milligrams, whilst some makers have used the value 205·410 milligrams which is often given as the metric equivalent of the English carat. In foreign countries the value varies from as high as 213·5 milligrams to 188·6 milligrams. The fractions of a carat which are used in weighing are $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, and $\frac{1}{64}$; and if a specimen does not weigh an exact number of carats its weight is expressed by the aid of these somewhat clumsy fractions. There can be no doubt that the general adoption of the *metric carat* of 200 milligrams—the use of which in France has been made compulsory by law—would prove of great advantage to dealers in precious stones, and would prevent the confusion arising from the use of different units of weight to which the same name has been given.

Specimens of cut diamonds are shown here, whilst in Case II. will be found a beautiful gold snuff-box set with sixteen large brilliant cut stones and numerous other small ones. It was presented by Nicholas I., Emperor of Russia, to Sir Roderick Murchison, who bequeathed it to the museum.

The best known localities for diamonds are India, Brazil, and South Africa; Borneo, British Guiana, Australia, the United States, British Columbia, and one or two other places have yielded stones, but they are comparatively unimportant as sources of the mineral.

India.—This is the oldest locality and is famous as having been the source of many of the celebrated stones which are illustrated here by models. The mines were at one time very productive and the prejudice in favour of Indian diamonds was so

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[*] Mineralogical Magazine, vol. xv., No. 71, "Notes on the Weight of the 'Cullinan' diamond, and on the value of carat-weight," by L. J. Spencer.

strong that, on the discovery of the Brazilian deposits in 1728, the stones were sent to India and exported from there as Indian diamonds. Nowadays India is unimportant as a diamond-producer. Many of the mines are exhausted and the yield from those now being worked does not exceed a few thousands of pounds in annual value.

The diamond-bearing deposits are confined to the eastern slope of the Deccan and are found scattered over the area extending from the Penner River in the south almost to the Ganges in the north. The mines occur in groups of which those situated 200 miles east of the fortress of Golconda—hence known as the Golconda Mines—are the most famous. The diamonds occurred in loose alluvium lying close to the banks of the Kistna River. From this locality the famous "Koh-i-Noor," and the "Hope Blue" were obtained.

Samples of the diamond-bearing alluvium from Cuddapah, on the Penner River are shown here. A group of mines was situated in this neighbourhood and west of it at Wajra Karur a pipe of blue rock similar to the famous *blue ground* of the Kimberley mines was discovered but unfortunately it carried no diamonds. A sample of this rock will be found in Wall Case 39.

There are numerous other groups of mines, but they all possess similar features, the source of the diamond being a sandstone, a conglomerate, or loose alluvium.

Brazil is represented by a good series of specimens. In this country diamonds are found over a wide area, but the two most productive states are Minas Geraes and Bahia; Parana, Matto Grosso, and Goyaz have, however, yielded a large number of crystals. The diamond-bearing regions are characterized by the presence of a laminated micaceous sandstone, called *itacolumite* which sometimes exhibits flexibility. The diamonds are found in the débris resulting from the disentegration of this rock. This débris occurs as rounded fragments in the beds of the river, in the valleys above the present water-level where the fragments are not so water-worn and in the plateaus as quite angular masses.

The river-deposits are the richest and a sample of the material known as *cascalho* is exhibited. It consists of rounded fragments of sandstone, quartz, rutile, brookite, anatase, tourmaline, talc, &c., and its excavation is carried out during the dry season. On the advent of the rainy reason it is washed and the diamonds are picked out by hand. The method of treatment of the other deposits is similar, though of course they can be mined all the year round.

The richest mines in Minas Geraes are situated in the Diamantina district, whilst in Bahia the Sincura mines have been very productive. It is from the latter locality that the valuable *carbonado*—often called *carbonate*—is obtained. It occurs in nodules and consists of an aggregate of small crystals of diamond intermingled with various impurities. It has no cleavage and, on account of its extraordinary hardness, is in great demand for mounting the crowns of rock-drills. Specimens of carbonado are shown here.

Brazil produces annually about 50,000 carats of diamonds.

South Africa.—This locality far outstrips in importance any other which has hitherto been discovered. Here the deposits are of extraordinary richness and, so far, appear to be inexhaustible. The majority of them are owned by the powerful De Beers Company, who have applied the most approved methods of mining and winning the diamonds and, in consequence, exercise a large controlling influence in the diamond market of the world.

There are two sources of the diamond in South Africa, known respectively as the *river diggings* and the *dry diggings*. The former are situated on the banks of the Vaal in the neighbourhood of Barkly West, where the diamonds are found in the gravels of the river-bed and in the adjacent alluvial terraces. The material, as can be seen from the specimens shown here, consists largely of siliceous pebbles. It is excavated, washed and passed through a sieve and from the concentrate so obtained the diamonds are picked out by hand. They are of superior quality and fetch more per carat than the produce of the *dry diggings*, but the yield is small and rarely exceeds 20,000 carats annually.

The *dry diggings* were discovered in 1870 and have proved the richest source of diamond in the world. The first deposits were found at Jagersfontein, near Fauresmith, in the Orange River Colony, and, shortly afterwards, the mines in the neighbourhood of what is now the town of Kimberley were discovered. Since that time new finds have been made at various other places and, as recently as 1902, an exceedingly rich mine—The Premier Mine—was found near Pretoria.

In character all the mines are similar. They consist of vertical pipes cutting through shales, quartzite and igneous rock and extending downwards to an unknown depth. The pipes have a diameter at the surface varying from 200 to 700 yards and sometimes, as shown in the diagram on Wall Case 42, the sides tend to converge as greater depths are reached. The material filling them consists of a soft but tenacious blue rock known as *blue ground* which is soapy to the touch and which alters at the surface to a yellow friable earth, the *yellow ground* of the miners. Samples of these carrying diamonds are shown in the case.

The *blue ground* consists essentially of a finely divided serpentinous matrix in which are embedded boulders and angular fragments of rock besides various minerals. The enclosed fragments and boulders may be divided into three classes:—(1) those having essentially the same composition as the matrix; (2) pieces of shale, quartzite, and diabase which have obviously been derived from the surrounding rocks; (3) fragments of rocks which cannot be identified with any so far revealed by the mining operations. Amongst the minerals present may be mentioned olivine, altered in many cases to serpentine, ruby-red garnet ("Cape ruby"), diopside, ilmenite, enstatite, mica, tourmaline, &c.

The diamonds are confined to the *blue ground* and are never found in the surrounding rocks—known as *reef*—which abut sharply on the pipes. They vary in size from large stones of 100 carats and over down to the smallest ones which are almost invisible to the naked eye.

"Blue-white" stones occur, but many of the South African crystals exhibit a more or less pronounced yellow tinge, whilst others are distinctly brown. The concentration of the diamonds in the matrix is exceedingly small, varying from ·23 carats to ·38 carats per load of 16 cubic feet, and the richness of the deposits arises from the inexhaustible supply of *blue ground* which is available.

The generally accepted view regarding the pipes is that they represent sites of ancient volcanic activity and that the *blue ground* was formed by the pulverising of a deep-seated igneous magna rich in olivine. The pipes or necks were produced by a series of explosions which pulverized the magna and forced it into the vents where it became mixed with the fragments and boulders of the surrounding rocks. The diamonds probably existed in the original olivine rock and experienced the volcanic forces which shattered it; support is lent to this view by the fact that many of the crystals are broken and show distinct signs of having been subjected to rough usage. Another, but less plausible, theory is that the diamonds existed in a deep-seated igneous rock consisting of chome-diopside and garnet and known as *eclogite* through which the brecciated magna forced its way, thus acquiring its load of diamonds.

Since its formation the breccia of the pipes has been weathered and altered; the olivine has been converted largely into serpentine, and a considerable amount of carbonate of lime has been formed as well as various zeolites.

The mining of the *blue ground* is carried on by shafts sank in the surrounding rock. Tunnels are driven from these to the pipes and the diamond-bearing material is excavated layer by layer. (*See* diagram on Wall Case No. 42.)

Formerly the mining was done by open workings and the photographs at the back of the case show the appearance of the pipes when this method was employed.

The *blue ground* after being excavated is hoisted to the surface, where it is spread out in fields and left to the action of the weather for a few months during which period it is turned over by harrows to facilitate decomposition. At the end of this treatment it is soft and friable and resembles the *yellow ground.* From the fields it is conveyed to the washing machines which separate the lighter material and leave a residue consisting of garnet, ilmenite, pyrite, &c., with the diamonds. A sample of this is shown.

Formerly the diamonds were picked out by hand, but a highly interesting mechanical process is now employed. It depends on the fact that diamond has a greater affinity for grease than for water, whilst, for most minerals, the opposite holds good. The residue, then, is passed over inclined plates covered with grease and to these the diamonds cling whilst the other minerals pass on, a complete separation thus being effected.

The De Beers Company owns five mines in the neighbourhood of Kimberley and the working during 1910 resulted in a production of nearly two and a half million carats.

The Premier Mine in the Transvaal has, during the short time in which it has been worked, proved exceedingly productive, and the following table gives the results of the operations for the year 1910:—

Loads of Blue ground treated.	Yield of Diamonds in carats.	Average yield per load.
9,331,882	2,145,832	·23 carats

Many theories have been propounded in order to explain the origin of the diamond, especially in the South African deposits, but all are more or less speculative and open to objection. It has already been stated that the diamonds were most probably brought up with the material of the pipes, but it was suggested by the late Professor Carvill Lewis that the diamonds were formed in the pipes themselves. He supposed that the *blue ground* was originally a fluid, igneous magna, rich in olivine, which was injected into the pipes where it solidified and, by subsequent alteration, assumed the characters of the material as it is now mined. During the passage of the magna through the surrounding rocks various fragments were caught up and the origin of the diamond was attributed to such fragments of carbonaceous shale, part of whose carbon was absorbed and converted at the high temperature and pressure into diamond. The fatal objection to this theory is the fact that *blue ground* is now being mined far below the level of the shales and it is still rich in diamonds, whilst pipes have been found which do not penetrate shales.

Others have attributed the origin of the diamond to crystallisation of carbon in molten iron in the interior of the earth. In this respect the experiments of Moissan (p. 34) are extremely suggestive, whilst diamonds have been found in meteoric iron which has fallen to the earth (Case 21). Such meteoric diamonds have probably originated in a manner analagous to those produced by Moissan, but it is doubtful if such was the origin of those now found in the pipes. Mr. Gardner F. Williams, who was manager for many years of the mines at Kimberley, mentions as an objection to this view that the diamonds are never found intimately associated with such contents of the *blue ground* as magnetite, an oxide of iron, which might represent the oxidation product of the metallic matrix. As already mentioned, Friedländer has succeeded in making diamonds by exposing graphite to the action of fused olivine, and his results are very suggestive when it is borne in mind that a large proportion of the *blue ground* consisted originally of that mineral.

Other theories have been brought forward to explain the occurrences in India and Brazil. The deposits at these places are quite different from those in South Africa and olivine is not present in association with the diamond. Some have invoked the aid of the compounds of chlorine with carbon which, under certain conditions, might give rise to diamond, but such speculations have not yet been endorsed by experiment. It has also been suggested that the diamonds existed in pegmatite veins and a French investigator, M. Chaper, has reported the occurrence of diamonds in such veins in India. Doubt has, however, been thrown on this occurrence and, even if it were correct, the problem would be no nearer to solution, for very little is known as to the mode of formation of such rocks. In short, the method, or methods, of formation of the diamond in nature remains quite uncertain.

Australia is unimportant as a source of diamonds but a few specimens are exhibited here. In New South Wales the diamonds are widely distributed but the yield is meagre and the crystals are small. They are found in alluvial gravels which carry gold and tin and have been discovered in most cases by miners in search of these metals. A specimen is exhibited from Soldier's Hill, Cope's Creek, which shows the diamond set in a conglomerate consisting of water-worn fragments of sandstone, quartz, granite and tourmaline. Specimens are also exhibited from Ovens Diggings, near Melbourne, and from Ophir, west of Bathurst. The mode of occurrence in all cases however is similar. It is interesting to record, however, that two diamonds have been found in basalt at Oakey Creek, near Copeton.

German South-west Africa has lately sprung into prominence as a source of diamonds and two samples of the diamond-bearing material from Luderitzbucht are shown here. It is a somewhat coarse sand consisting, for the most part, of rounded pieces of quartz with jasper, chalcedony, agate and garnet.

The yield for 1910 was 813,323 carats.

Rhodesia is represented by a few specimens. Here diamond has been found in a clayey sand accompanied by quartz, magnetite, garnet, beryl, zircon, staurolite, kyanite, chrysoberyl and corundum.

The exhibit includes a series of models of some of the largest and most famous diamonds which have been found from time to time at the various localities. The history of several of these stones is obscure and the weights given are frequently only approximate.

Of special interest is the "Koh-i-Noor," which came into the possession of the East India Company in 1849. It was presented to Queen Victoria in 1850 and was recut in 1852 when its weight was reduced from $186\frac{1}{16}$ carats to $106\frac{1}{16}$ carats.

The largest diamond found hitherto is, of course, the well-known "Cullinan," models of which—presented by Messrs. Levy and Nephews—are exhibited here.

It was found on the 26th January, 1905, in the *yellow ground* of the Premier Mine, near Pretoria, and was named after Mr. Cullinan, the Director of the Company. The rough specimen was apparently only a part of a crystal and weighed $3,025\frac{3}{4}$ carats* (carat = 205·304 milligrams), which is equivalent to 621·2 grams, or nearly 1 lb. 6 oz. avoirdupois. It was presented in January of 1907 to His late Majesty King Edward, and was cut by the firm of Asscher and Company, Amsterdam.

Two large and magnificent brilliants, seven smaller stones and ninety-six still smaller brilliants were the result of this operation, the total weight of cut material being $1,036\frac{5}{12}$ carats, which is equivalent to a yield of $34\frac{1}{4}$ per cent. of the rough material.

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* This is the figure given by Mr. Spencer in the paper already referred to.

The following table gives the weights of the stones:—

No.		English carats.	Grams
1.	Pendeloque Brilliant	$516\frac{1}{2}$	106·04
2.	Oblong „	$309\frac{3}{16}$	63·48
3.	Pendeloque „	92	18·89
4.	Square „	62	12·73
5.	Heart-shaped „	$18\frac{3}{8}$	3·77
6.	Marquise „	$11\frac{1}{4}$	2·31
7.	„ „	$8\frac{9}{16}$	1·76
8.	Oblong „	$6\frac{5}{8}$	1·36
9.	Pendeloque „	$4\frac{9}{32}$	0·88
10.	Ninety-six small brilliants	$7\frac{3}{8}$	1·51

Fluor-spar (Case L).

Hardness, 4.
Specific Gravity, 3·19-3·02.
Singly refracting.
Refractive Index, 1·43.

This mineral is used to a very limited extent for ornamental purposes. It consists of a fluoride of calcium, and crystallises in the cubic system with fine bold cubes as the typical form. Crystals of phenomenal size are sometimes found and cubes, measuring eighteen inches along the edge, are exhibited in Pedestal Case XV.

Probably no other mineral exhibits such a large suite of beautiful colours and the specimens exhibited here are supplemented by a series shown in Case VIII. at the opposite end of the gallery. The commonest colour is some shade of purple, but green, brown, yellow, pink, and colourless crystals are found. The pigment may be some organic material and heat readily alters the tint of a specimen; examples of this are shown.

Fluor-spar has a very perfect cleavage parallel to the octahedral planes, which renders the crystals exceedingly brittle. This property, coupled with the low degree of hardness of this mineral, explains why it is so little used as a gemstone. When so employed, it is usually called after the stone which it resembles, the name being prefixed by the word "false"; thus yellow fluor-spar is "false topaz," purple fluor-spar is "false amethyst," green fluor-spar is "false emerald," and so on. Such stones can be detected at once by their inferior hardness.

The dark-purple, massive variety, known as "Blue John" is found only at Tray Cliff, near Castleton, Derbyshire, and has been worked for ornamental purposes for a long time. The beautiful vase, No. XXII., standing behind this case is considered to be one of the best examples of this work in existence.

Ordinary crystallised fluor-spar is an exceedingly widespread mineral and beautiful specimens have been obtained from the Cornish and Devon mines and from the Weardale district of Durham.

Quartz and other forms of Silica (Cases M_1-M_4).

Silica, or dioxide of silicon, is the most widespread mineral in nature and, occurring as it does in such a variety of forms, necessarily claims a large amount of space for its illustration. Many of the varieties of silica have been used for ornamental purposes from very early times, but, owing to their abundance, their value is small, and they are employed at the present time in the cheaper forms of jewellery. Case M_1 and M_2 are devoted to crystallised silica, or *quartz,* whilst Cases M_3 and M_4 illustrate, for the most part, those varieties whose crystalline structure is visible only under the microscope and which, in consequence, are designated as *microcrystalline* or *cryptocrystalline.*

QUARTZ.

Hardness, 7.	Specific Gravity, 2·65.
Doubly refracting.	Refractive Index, 1·56-1·55.

The crystals of quartz belong to the rhombohedral system, the common form being an hexagonal prism terminated by rhombohedral faces which occur usually in two sets of three, thus giving the appearance of a six-sided pyramid (Fig. 28). They possess no cleavage and the prism faces are frequently striated in a transverse direction. Quartz has a vitreous lustre, its refractive index is low, and its dispersive power is weak, so that it possesses none of the optical properties usually associated with a gemstone. The following varieties of transparent quartz are recognised:—*rock-crystal, smoky quartz, citrine,* and *amethyst.*

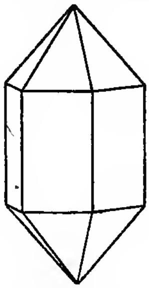

Fig. 28.—*Quartz.*

Rock-crystal (Case M_1) is clear, colourless quartz, which occurs in crystals varying in size from the merest speck up to those measuring a yard or more in length. A fine group is exhibited from Dauphiné, France, and a still larger one will be found in Pedestal Case XV.

Inclusions of other minerals are very common in rock-crystal, which often, too, contains cavities filled with gases and liquids. A fine series of specimens illustrating these points is shown here. Especially attractive is the "Venus-hair-stone," in which the enclosed mineral is rutile in golden-yellow needles. Inclusions of tourmaline, chlorite, actinolite, oxide of iron are frequently met with, and are illustrated here both by rough and polished specimens.

Rock-crystal is not much used nowadays as a gemstone, although specimens are occasionally cut as brilliants and sold as "occidental diamond," It may be mentioned, in passing, that, with the exception of diamond, no colourless stone possesses much value at the present time. Formerly rock-crystal was extensively employed as a medium for all manner of beautiful carvings, but this art decayed when the manufacture of glass became successful. Nowadays, rock-crystal is largely used for spectacle-lenses and for other optical purposes.

Specimens showing the inclusions mentioned above are sometimes cut *en cabochon* or carved into objects of various kinds; four snuff-bottles cut from such material are shown. Mention has already been made of the staining of specimens of this mineral and examples of these "firestones," as they are called, are shown here (p. 29).

Rock-crystal is very widely distributed, but the best examples are found in the cavities of granite and gneiss. Good specimens are shown from various localities in the Alps, where formerly the material was much sought after. Most of the rock-crystal used at the present time comes from Brazil and Madagascar, which are represented here by a good series of examples, and attention may be called to the large crystals from the former country which are mounted on pedestals and placed on either side of the Nevill Cases. In this country good crystals come from Snowdon, N. Wales, the Slate Quarries of Delabole, Tintagel, Cornwall, and many other places. Rock-crystal is often known locally as "diamond" and hence arise such names as "Cornish diamonds," "Bristol diamonds," "Buxton diamonds," &c.

Rock-crystal may be distinguished from any other stone by its low specific gravity, its low refractive index, and its lack of fire.

Smoky quartz is simply rock-crystal coloured brown, and all gradations in colour occur from very faint-brown to almost black. The name *morion* is applied to the deeply tinted specimens, whilst *cairngorm* is the reddish-brown variety found in the mountain of that name in Banffshire, Scotland.

The colour of smoky quartz is due to a volatile organic compound which is discharged by heat. The very dark specimens, when moderately heated, lose a portion of the colouring matter and take on a fine reddish-brown to yellow tint. It is then put on the market under such names as "false topaz," "Spanish topaz," or "citrine."

The natural *citrine* is a yellow quartz which shows the peculiar amethyst structure (*vide infra*) and which is of somewhat rare occurrence.

Smoky quartz shows dichroism, which is strongest in the deeply coloured specimens. Some of the dark-brown stones in the case give, in the dichroscope, a pale yellowish-brown and a deep-brown image. The paler varieties are apt to be confused with topaz, but the quartz is softer and lighter.

Smoky quartz resembles rock-crystal in its mode of occurrence and large specimens are shown from the Alps, the Urals, and from Aberdeenshire. A specially fine cairngorm is set with other stones from Scotland in the lid of a snuff-box.

Amethyst (Case M_2) is simply purple quartz. The colour varies from very pale-violet to deep-purple and is often more or less irregularly distributed in the same specimen. Several of the stones here show this, whilst, in others, distinct patches of yellow can be seen. The cause of the amethystine colour is doubtful, but it has been ascribed to traces of manganese oxide which are sometimes detected by chemical analysis. When heated strongly amethyst is decolourised, but, if only a moderate heat is applied, the stone becomes yellow, and is then often sold as citrine. Dichroism is more or less pronounced according to the depth of colour and some of the darker specimens when examined with the dichroscope show images coloured pale-pink and reddish-violet, respectively.

The crystals of amethyst are similar externally to those of ordinary quartz, but, in many cases, they have a complex internal structure consisting of layers or lamellae in twin position to one another. This fact is often revealed by striæ on the crystal faces and can be seen well in microscopic examination.

Amethyst is usually cut in steps, but many of the stones shown here are mixed cut, with the crown of a brilliant and the culasse step cut. Only the clear transparent material is facetted, but the coarser and less transparent amethyst, often called "root of amethyst," is sometimes carved into snuff-bottles, umbrella-handles, or other objects. Fluor-spar is often substituted for such amethyst, but the fact that the fluor-spar yields to the knife whilst the amethyst does not affords a sure and ready test.

The clear, transparent cut stone may be confused with purple corundum, or *oriental amethyst,* but the low specific gravity and hardness of the quartz are diagnostic. Much of the amethyst used in jewellery comes from Brazil, where it occurs associated with agate in the amygdaloidal cavities of a decomposed lava. It is also found in the same way as the other varieties of quartz, *i.e.*, in the cavities of gneiss and granite. Formerly the rocks around Oberstein, Germany, yielded good specimens which were cut there. This source is now exhausted, but the industry survives on material imported from South America.

Cat's-eye.—In this variety the presence of parallel fibres of asbestos gives rise to a luminuous band which is best seen when the specimen is cut *en cabochon.* The asbestos may be weathered out and hollow canals left which give the same effect. The quartz cat's-eye is often confused with a variety of chrysoberyl (p. 60), which has a somewhat similar appearance and is distinguished as *oriental cat's-eye* or *cymophane.* The latter stone is much harder and heavier than quartz. Specimens of cat's-eye are exhibited from Ceylon, which is the chief source of this stone, and where it is rather highly esteemed. *Tiger-eye* is fibrous quartz of a golden-yellow colour, which gives a beautiful chatoyant effect when cut and polished. A slab of the rough material shows the fibres running in a wavy manner, and approximately perpendicular to the sides. The colour is due to the presence of hydrated oxide of iron and varies from golden-yellow to deep-brown. In a specimen polished so that the fibres run parallel to the surface, the colour changes with every change in the inclination of the incident light.

In several plates of tiger-eye shown here there are bands having a deep-blue to greenish-blue colour, and various stones, cut *en cabochon,* consist entirely of such blue material. The name *hawk's-eye* is sometimes applied to this variety, and microscopic examination shows it to consist of quartz, enclosing innumerable parallel fibres of *crocidolite,* which is a silicate of iron and sodium (Case S). Crocidolite, under the influence of meteoric water, is altered into a mixture of silica and hydrate of iron which possesses the fibrous structure of the original mineral. Now, if a mass of partially altered crocidolite be infiltrated with silica, it is clear that both *tiger-eye* and *hawk's-eye* result. In the former the alteration of the asbestos has been complete, in the latter it has not been altered at all, whilst the variegated specimens represent intermediate stages. It is possible, too, that alteration of the crocidolite may go on even after the infiltration by silica and hawk's-eye be so converted into the yellow tiger-eye.

These varieties are always cut either as plates with the polished surface parallel to the fibres or *en cabochon* with the fibres running parallel to the base of the stone. By treatment with hydrochloric acid the iron hydrate can be dissolved out of tiger-eye, which is then colourless and porous, and, by soaking such material in suitable dyes, bright artificial tints are produced. Examples of this will be found in the case.

Tiger-eye was formerly rare and commanded a good price, but as the supply increased it fell in value, and, from being a somewhat expensive gem, it has become a fairly common ornamental stone out of which are fashioned umbrella-tops, paper-weights, cameos, &c.

It comes exclusively from Griqualand West, where it is found as veins in a quartz-schist.

Siderite or *sapphire quartz* also owes its colour to enclosed crocidolite, but the fibres are arranged irregularly and are not parallel as in hawk's-eye.

Rose quartz, as its name implies, has a delicate pink colour, which may be due either to organic matter or to small amounts of titanium. Exposure to heat or even to strong sunlight discharges the colour. This variety is sometimes cut *en cabochon* and an intaglio in it is shown. Its use as a gemstone, however, is rather restricted.

Avanturine quartz.—In this variety enclosed plates of mica act as little mirrors and give a peculiar, gold-spangled appearance to a polished surface in reflected light.

The colour, as seen from the specimens here shown, may be reddish-brown, yellow or green, and the stone, cut with a flat or slightly rounded surface, is frequently mounted in rings or brooches. The larger pieces are worked into bowls or vases, and attention may be drawn to the large vase which stands at the head of the staircase. It was presented by the Tsar Nicholas I. to Sir R. I. Murchison in recognition of his services to Russian geology. The material consists of micaceous quartz-rock which passes into true avanturine; it was mined at Bieloretsk in the Altai Mountains, and was polished at Tomsk.

Green avanturine comes from India and China in which latter place it is much prized and wrought into carvings, examples of which are shown.

A variety of felspar, known as *sunstone*, or *avanturine felspar*, strongly resembles avanturine quartz and is used in much the same way. The superior hardness of the quartz distinguishes it however.

Examples of *avanturine glass* are shown here. It consists of a readily fusible glass enclosing octahedral flakes of copper and has a much finer appearance than the natural stone. A glance usually serves to distinguish between the two; the glass, moreover, is much softer and has a higher specific gravity than the true avanturine.

Jasper (Case M_3) consists of massive, compact quartz impregnated with much impurity. This consists mainly of clay and oxide of iron and gives rise to the many colours seen in the specimens exhibited. Red, brown, yellow and green jasper are common, and were in olden times extensively used as ornamental stones. Nowadays the use of jasper is quite restricted, and it can hardly be dignified with the title of gemstone. Polished specimens from various localities are shown, and the brown Egyptian jasper is illustrated by rounded nodules and by a box fashioned from it.

A fine series of the chalcedonic varieties of silica is shown in Case M_4 and their applications in the arts is also well illustrated. These varieties have no external crystal form and appear at first sight to be quite amorphous. They have, however, a fibrous structure, which is usually apparent only under the microscope. The fibres, moreover, are doubly refracting and crystalline and hence chalcedony and its varieties are often referred to as *microcrystalline* or *cryptocrystalline* silica. The specific gravity is less than that of quartz, being about 2·60, whilst the hardness, 6½, is also lower. A most important property of these fibrous forms is their porosity, which enables them to be stained in a homogeneous manner by immersion in suitable liquids. Many of the bright, vivid colours in the specimens here are the result of such artificial treatment, and the methods employed will be referred to under agate.

Chalcedony consists of a mixture of the doubly refracting fibres above referred to with more or less opaline or amorphous silica which is isotropic. The colour is usually undecided with greyish or bluish tinges predominating. When white, it is often called *white carnelian*, and several cut and polished of such material are shown here. Chalcedony is never quite transparent, and varies from semi-transparent in the clear varieties to feebly translucent in white carnelian. The usual mode of occurrence is as stalactitic or botryoidal masses in rocks of various kinds, and large specimens illustrating these structures are shown from Trevascus, Cornwall, and from Iceland. It is frequently found as a thin coating on the joints and fissures of rock-masses, but such material is not sufficiently thick for the purposes of cutting. Chalcedony in the form of *agate* is of widespread occurrence in the amygdaloidal cavities of decomposed basaltic rocks, and most of the material cut at the present time comes from the agate localities of Brazil and Uruguay. Cameos, signet-rings and various objects such as vases and bowls are cut from it; when mounted for jewellery it is usually cut *en cabochon*.

Plasma is chalcedony coloured by the inclusion of a green chloritic mineral called *green earth* or *delessite*. It is this mineral which almost invariably occurs as the outermost skin of the agate and which causes the peculiar appearance of *moss agate* (p. 52). In plasma it is regularly distributed throughout the chalcedony, which thus is coloured uniformly green. It is not much used for ornamental purposes nowadays, although it seems to have had rather an extensive application in ancient times. Two fine cameos, the larger one of which represents one of the Cæsars, are shown along with a specimen of the rough material from Openhau in the Black Forest.

Heliotrope is plasma spotted with red and is also known as *blood stone*. It is found in the valley of the Nerbudda, India, and is used for cameos and carvings of various kinds. The background is not always uniformly green, but often shows patches of brown and yellow which rather mar the beauty of the specimen.

Chrysoprase owes its fine green colour to a small amount of a hydrated compound of nickel. When a specimen is heated it loses its colour but regains it if the stone is immersed in water. The well known locality of Kosemutz, in Silesia, is illustrated by several specimens. Here the chrysoprase occurs as veins in serpentine associated with common chalcedony and asbestos.

The stone is usually cut *en cabochon* with a low rounded surface and has been used for seals and cameos, an example of this latter application being shown here. The colour can be improved by soaking the material in a solution of a nickel salt, and common chalcedony, when so treated, resembles the natural chrysoprase so strongly that detection is almost impossible. Specimens coloured in this way are shown amongst the series of stained chalcedony.

Carnelian is chalcedony coloured red by oxide of iron, or hæmatite. The colours may show all variations from deep-red through brown and yellow shades to pure white, and specimens are shown consisting of white and red layers to which the name *carnelian-onyx* is applied. A fine Chinese carving in red and white carnelian is exhibited in the case. The brown shades are due to the presence of brown hydrate of iron, and such material, when heated to a moderate temperature, takes on a fine red colour owing to the hydrate losing water and being converted into the oxide. If the temperature be too high the colour is discharged and the stone becomes quite brittle and easily reduced to powder. Light carnelians can also be improved in colour by immersion in a solution of an iron salt and subsequent heating to produce the oxide of iron.

Carnelian is found in the valley of the Nerbudda and at most of the agate localities of South America.

Sard is the fine deep-brown chalcedony which owes its colour to the hydrate of iron mentioned above. Thus carnelian grades into sard and the terms are often used indiscriminately.

When a specimen shows layers of brown and white the name *sardonyx* is applied; cameos cut from such material are shown. Sard of good colour is rather rare, but chalcedony is often artificially stained to simulate it. This is done by immersing the stone in a solution of brown sugar and then heating it. The mode of occurrence of sard is similar to that of carnelian, and it is used for the same purposes.

Agate.—A fine series, illustrating the mode of occurrence and the applications of this stone, is shown here. It is supplemented by an excellent suite of specimens, presented by the late Colonel Waldo-Sibthorp, and exhibited in Table Case XVIII., whilst in the adjoining Table Case XIX. will be found specimens illustrating the many structures shown by this variety.

Agate consists for the most part of chalcedonic silica arranged in bands, often of extreme tenuity, which are distinctly marked off from one another. The differences in the bands arise from varying degrees of transparency and colour. Clear chalcedony may alternate with milky opaline layers and the prevailing tint of the specimen be a gray or faint-blue, or strongly marked bands of jasper, carnelian or sard may be present, giving rise to the varieties *chalcedony-agate*, *jasper-agate*, and *carnelian-agate*.

According to the structure and arrangement of the layers, different kinds of agate are recognised. Thus, when they are all parallel or concentric, the specimen is called *band-agate;* when they preserve a curved outline and then suddenly bend into a re-entrant angle and so give a fanciful resemblance to the outline of a bastion, the name *fortification-agate* is applied; and in *eye-agate,* the zones are arranged around a series of points. Specimens of all these varieties are exhibited.

Sometimes the bands preserve a curved outline for some distance and then sharply bend and form a series of horizontal layers (*see* specimens 84 and 84a, Case XIX.) to which the name *onyx* is applied; but the term is somewhat loosely used. The typical *onyx** of jewellery consists of a series of parallel bands which are alternately black and white. This variety, as will be shown later, is almost invariably produced by artificial staining.

The home of the agate is in the amygdaloidal cavities of ancient lavas. These cavities were formed by the gases occluded in the molten rock and were probably pear-shaped at first, being drawn out by the movement of the viscous mass. On subsequent decomposition of the rock by circulating water, the mineral components were broken down and the siliceous solutions so formed deposited their charge in the steam vesicles in the form of agate. The cavity is sometimes completely filled with chalcedonic material, but frequently there is a hollow space in the centre and a layer of crystallised quartz—often of an amethyst colour—with the crystals all pointing inwards, forms the last zone of the agate. The outer skin of the agate usually consists of a thin coating of *green earth*, or *delessite*, which is derived from the original ferromagnesian minerals in the lava. This material sometimes projects into the main mass of the agate and gives rise to the peculiar appearance of *moss agate.* The solutions seem to have penetrated

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* *Note*—The name *onyx* is also applied to a stalagmitic carbonate of lime from Mexico.

the walls of the original cavities in a uniform manner, and the funnel-shaped tubes which run from the interior to the skin of the agate represent the path along which they escaped.

The seat of the agate industry is the town of Oberstein, situated on the Nahe, a tributary of the Rhine, and about 40 miles from Bingen. The decomposed lava of this district was for a long time the chief source of the rough material and many of the specimens in Case XIX. came from the hill known as Galgenberg, about two miles from Oberstein. For many years, however, this locality has been exhausted, and the agate is now imported from Southern Brazil, and the neighbouring states of Uruguay and Paraguay. The mode of occurrence in these places is typical and the agates are often found washed out of the red clay which is the residuum of the decomposed basalt.

India yields a fair amount of agate from the weathered basalts of the Deccan, and cut and polished specimens from that country are shown here. The chief localities are in the lower valley of the Nerbudda, where good specimens of *moss agate, mocha stone* (*see* later), with *carnelian*, and *heliotrope* are also found.

The cutting of the rough material is carried out by natives at Cambay.

The amygdaloidal rocks of Scotland yield agate at various places, a well known locality being Montrose, Forfarshire, where good specimens can still be obtained. A series of polished Scottish agates is exhibited on the wall, adjoining Case XIX.

Few agates are put on the market nowadays without having been artificially coloured in some way or another. The clear chalcedony layers are more or less porous and absorb the colouring matter whilst the white opaline bands are quite impervious to it. Thus staining not only renders the tint more vivid, but also brings out the zonal structure of the specimen.

The process most widely employed is for the production of the *onyx* of jewellery, *i.e.*, a stone showing alternate bands of black and white. This is a variety which is extensively used for such diverse objects as bowls, vases, beads, buttons, hat-pins, handles for sticks, and for cameo-work. The stone is first immersed in a solution of sugar or honey which is kept at a temperature just below the boiling point for several days or even weeks, depending on the porosity of the material. It is then taken out, washed and soaked in warm sulphuric acid. By this means the sugar or honey absorbed from the first bath is converted into carbon which gives the black colour.

The fine blue colour seen in the bowl presented by the late Mrs. E. Warne is got by soaking first in a solution of ferric salt, and then in a solution of potassium ferrocyanide (yellow prussiate of potash), when a deposit of prussian blue is formed in the pores.

The green tints seen in some of the specimens are got by soaking either in a solution of a nickel salt or in a solution of chromic acid and then heating.

Reds of various tints are often produced in agates by heat and the methods of producing the colours of carnelian and sard have been already referred to. The fine yellow seen in one or two of the specimens shown here is got by treatment with hydrochloric acid.

Aniline dyes have been utilized but the colours are fugitive, and in most cases unnatural.

Fine milk-white layers can be got either by heating the chalcedony bands, or by treatment with caustic potash.

The porosity of agate is most important from the commercial point of view and the highest value is always obtained for the rough material which stains most easily. When stained, the stones are cut into the required shapes on large sandstone wheels, polished on wooden cylinders and sent from Oberstein all over Europe. Most of the "native pebble" sold at various resorts in Great Britain is simply South American agate cut at Oberstein.

Various other varieties conclude the series. *Brecciated agate* is interesting as being found, not in amygdaloidal cavities, but in a cleft, or fissure in the rock; it has been crushed and recemented, and presents the peculiar appearance shown by the polished specimen here.

Moss agate, as has already been mentioned, owes its appearance to enclosures of green earth, whilst *mocha stone* is chalcedony with minute cracks which have been infiltrated by oxide of manganese. The patterns taken by those infiltrations are often arborescent and strongly resemble various kinds of plants. These varieties come mostly from India. *Mocha stone* takes its name from Mocha, near the entrance to the Red Sea, from which place specimens formerly came.

OPAL (Case X).

Hardness, 6.	Specific Gravity, 2·3-1·9.
Singly refracting.	Refractive Index, 1·45.

Opal is amorphous silica in a more or less hydrated condition. The percentage of water varies from as high as 16 per cent. in some specimens to as low as 2 per cent. in others. Opal frequently carries more or less impurity, consisting of the oxides of iron, calcium, and magnesium, and hence its specific gravity is not constant, but varies between 1·9 and 2·3.

Opal occurs in many different forms, from the clear colourless *hyalite* to the white and opaque *milk opal,* and it is found chiefly as an alteration product in the cavities of rocks like andesite and trachyte.

Only two kinds, known as *precious opal* and *fire opal,* are important as precious stones, and of these the former is one of the most popular gems at the present time; *fire opal,* on the other hand, is not nearly so frequently met with. *Precious opal* owes its beauty to the remarkable play of colours shown when light falls on the surface of the stone. Vivid greens, reds, and blues, in fact, all the colours of the spectrum flash out a pale, translucent matrix. These colours are not due to any foreign pigment, for, if the stone be viewed by transmitted light, they are quite absent and only the pale, translucent, milky appearance of common opal is seen. A thin section of precious opal, when examined under the microscope, is seen to be full of cracks and fissures, and some have attributed the play of prismatic colours to the interference effects which these fractures produce on the incident light, an analagous example being iridescent quartz. A more recent view is that the iridescence is caused by minute lamellae of opal lining the fissures and possessing a refractive index different from that of the main mass.

Several varieties of precious opal are recognised. In *harlequin opal* the iridescent areas are arranged in a regular manner as in a mosaic, whilst in *flash opal,* there is simply a large patch of colour which changes according to the direction of the incident light.

Black opal, as its name implies, is almost opaque and has a deep-blue to almost black background, with patches showing a magnificent play of colour. The opacity and dark colour are due to inclusions. This variety comes exclusively from Australia.

Girasol is the name applied to pale-blue, translucent opal showing a milky band of light as the stone is moved.

When precious opal is heated the play of colours vanishes and the stone becomes lifeless and turbid owing to the expulsion of the water. Some specimens show no play of colours until immersed in water, when they become full of fire and remain so for some time after they have been taken out and dried. The effect, however, is merely temporary and the stone becomes quite lifeless as the water evaporates. Such opals are often soaked in oil when they retain their beauty only until the oil decomposes and renders the whole stone brown and unsightly.

Most of the specimens in the case are cut *en cabochon,* a style which is almost invariably used with this stone in order to show off its beautiful properties. The use of opal as a medium for carving and engraving is illustrated and the inlaid slab shows how specimens with only a thin film of the precious material may be employed. The matrix of one of the cameos has been artificially darkened probably by immersion in oil and subsequent gentle heat.

The chief localities for precious opal are Queensland, New South Wales, Hungary, Honduras, and Mexico.

In Queensland and New South Wales the mode of occurrence is essentially the same. Here the opal is found in sandstones which may be more or less impregnated with iron as in Queensland or quite white and free from iron as in New South Wales. These sandstones are of Cretaceous age and have had their bedding-planes, joints, and fissures infiltrated with opal at a date long subsequent to their formation. An interesting proof of this is the replacement of crystals of gypsum and various fossils by precious opal; a fine example of the former is shown in the case, whilst examples of the latter are shown in Table Case XIII.

In Queensland the ferruginous material of the sandstone has frequently segregated into nodules which are penetrated by fissures of contraction, and the opal is found filling these cracks and often forming a considerable mass in the centre.

Hungary was, until the discovery of the Australian localities, the chief source of precious opal and has yielded much material of the finest quality. Here the stone is found filling the fissures and cavities of a decomposed andesitic lava, and is associated with many of the varieties of common opal. These, of course, are in much greater abundance than the precious opal which is often seen merely as small specks flashing out of a matrix of white, turbid opal. The chief locality is near Czerwenitza where the opal is confined to a breccia formed of fragments of the andesite. Iron pyrites is a common associate at this locality. The precious material is usually in very small masses and pieces larger than a hazel-nut are rare.

In Honduras the opal occurs in a decomposed trachyte, but the play of colours in many of the stones from this locality is apt to deteriorate on exposure to the air. Examples are also shown from the State of Queretaro, Mexico, where, also, decomposed trachyte is the parent rock.

Fire opal is the transparent or translucent variety which has a reddish-brown colour due to the presence of traces of iron. The colour varies from the deeper shades to pale-yellow and sometimes is irregularly distributed with dark and light patches appearing on the same specimen. In addition to the main tint, fire opal sometimes shows a play of colours analogous to the precious opal and this property is shown by some of the specimens exhibited here.

Often a stone deteriorates more or less rapidly on exposure to sunlight and, like the precious opal, it is exceedingly liable to be cracked and fissured if it experiences a sudden shock or a change of temperature. Well coloured specimens are cut as brilliants or *en cabochon* when they have a particularly effective appearance.

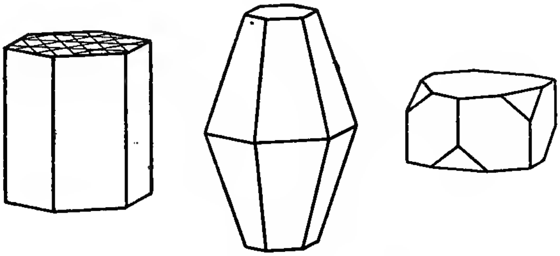
The chief locality is at Zimapan, in the State of Hidalgo, Mexico, where the material occurs in a decomposed trachytic rock with other varieties of opal as associates.

The other forms of opal which conclude the series are unimportant in the present instance and call for little attention. *Hyalite* or *Muller's glass* is the clear transparent variety; *hydrophane* is interesting as it readily absorbs water and becomes transparent; *resin-opal* derives its name from its yellow colour and translucent appearance; *menilite* occurs as brown concretions in shale at Menilmontant, near Paris; in *wood-opal* portions of the trunks of trees have been completely replaced with preservation of the organic structure. Specimens are also shown illustrating structures already mentioned in connection with the chalcedonic forms of silica.

CORUNDUM (Case N).

Hardness, 9.	Specific Gravity, 4·0.
Doubly refracting.	Refractive Index, 1·77-1·76.

Corundum is the mineralogical name for the crystallised native aluminium oxide, aluminina, and comprises some of the most beautiful and costly stones on the market to-day. An inspection of the series exhibited gives some idea of the many forms affected by this mineral. *Emery* is the compact granular variety intermixed with more or less magnetite or haematite. Common corundum lacks transparency and, on that account, is not used as a gemstone. It occurs well crystallised in forms belonging to the rhombohedral system. The crystals may be either prismatic (Fig. 29) or pyramidal (Fig. 30), and rhombohedral faces also occur (Fig. 31). Many of the specimens show on the pyramidal and prismatic faces striations parallel to the basal plane whilst on the plane itself there is sometimes a fine network of lines intersecting at 60°. Polished sections are exhibited to show this. These striations are due to twin lamellae, in the first case parallel to the base and, in the second, parallel to rhombohedral planes. The cohesion between the lamellae is somewhat weak and crystals having this complex structure exhibit a parting parallel to the twin-planes; simple crystals have no cleavage. On account of their hardness, emery and corundum are much employed as abrasives.



Crystals of Corundum.

Fig. 29. Fig. 30. Fig. 31.

The most important varieties, however, are those whose clearness, transparency and fine colour render them fit for gemstones. The best known and most valuable kinds are the *ruby*, or transparent red corundum, and the *sapphire*, or transparent blue corundum. Specimens showing colours other than red or blue are named after stones to which they have a superficial resemblance but with which they possess no relationship whatever, and the prefix "oriental" is placed before the name in order to show that a variety of corundum is meant. Thus yellow corundum is *oriental topaz*; green corundum, depending on its particular nuance, is *oriental emerald* or *oriental chrysolite*; purple corundum is *oriental amethyst* and so on; the pure colourless variety goes under the name of *leuco-sapphire*. Under ordinary circumstances, the term *sapphire* is reserved for the blue variety but is often applied to the stones just referred to, being qualified by an adjective descriptive of the particular tint. Thus oriental topaz is *yellow sapphire*, oriental amethyst is *purple sapphire*, oriental emerald is *green sapphire*, &c. Dealers often refer to stones showing peculiar tints as "fancy" sapphires.

Cut specimens of most of these stones are exhibited here and it must be remembered that, despite their apparent dissimilarity, they are essentially the same in chemical composition, crystalline form, hardness, specific gravity and refractive index. The colour has been ascribed in some cases to traces of metallic oxides, in others, to small quantities of organic material, but the causes have not yet been definitely settled.

Ruby is the most important variety, and, for good specimens, commands a higher price than any other stone at the present time with the possible exception of emerald. The high refractive index, strong vitreous lustre, and fine red colour render the appearance of a cut specimen highly effective, whilst the great degree of hardness enables it both to take and to retain a high polish. The colour varies in intensity from a deep-red to pale-pink, but the particular tint known as *pigeon's blood* is the most highly esteemed, and occurs with greatest frequency amongst the Burmese stones.

On account of its double refraction, ruby is dichroic, a property which is best seen in the more deeply coloured specimens although it is quite distinct in the paler varieties. When viewed along the optic axis, *i.e.*, in a direction perpendicular to the basal plane of a natural crystal, a well coloured stone appears of a deep-red, almost purple tint; in a direction at right angles to this the colour is much paler and inclines to yellowish-red. These colours are seen side by side in the dichroscope and are represented on the plates taken from Sir A. H. Church's book on precious stones, and exhibited at the end of Case P. On account of the dichroism care must always be observed to cut a rough specimen so that the table is as nearly as may be parallel to the base of the crystal; in this way a much deeper colour is obtained than if it were parallel to a prism face.

When a ruby is heated strongly it loses its colour, but, on cooling, it changes from white to green and finally regains its original red at ordinary temperatures. From this behaviour it is inferred that the pigment is not organic, but most probably chromium oxide. Analyses of natural specimens have revealed traces of this compound whilst, as already mentioned, it is the colouring material of the artificial stone. Still, it is a fact that some rubies show no trace of chromium on chemical examination, and the cause of the colour in such cases is unknown.

Rubies are often cut as brilliants, a style which is rendered quite effective by the high refractive index of the stone. The step cut is also employed though much more rarely than the brilliant, whilst a mixture of the two, with the crown in the brilliant style and the culasse cut in steps, is sometimes met with.

The dispersive power of ruby is weak and hence no *fire* is seen, but the beautiful body colour combined with the dichroic effects amply compensate for this. The hardness, dichroism and high specific gravity of this stone are sufficient to distinguish it from any other red stone. Thus spinel and garnet are singly refracting and not dichroic; red tourmaline is lighter as is also pink topaz. Ruby yields in point of hardness to diamond alone, and will scratch any of the above stones. Imitations in red glass are all softer and singly refracting.

The chief localities for ruby are Burma, Siam and Ceylon, where the usual mode of occurrence is as crystals and rolled pebbles in sands and gravels. In Burmah the home of the ruby is a crystalline limestone of Upper Cretaceous age which occurs in the hills surrounding Mogok—a place east of the Irrawaddy and north of Mandalay. The rubies appear to have been developed in this rock by the metamorphic action of intrusive granite, but another view is that the limestone originated from the felspar of the gneisses with which it is associated. The formation of the limestones from the calcium-aluminium-felspar, anorthite, would be accompanied by the production of hydrated silicate of aluminium which might give rise to ruby.

The limestone itself is not rich enough to justify mining operations, but it weathers into a yellow, clay-like deposit in which the rubies are concentrated. This clay is found on the slopes of the hills, in the valleys, and in large hollows weathered out of the parent rock. As associates of the ruby are found other varieties of corundum (including sapphire), spinel, tourmaline, felspar, pyrites, &c. The annual production is valued at about £100,000.

The Siamese rubies are all derived from alluvial sands and have not yet been found in the parent rock. At Chantabun the sands seem to have an origin analogous to those at Burma, but in the district of Klung the ruby-bearing material seems to have been derived from the igneous rock of the surrounding country. Sapphire is also found at the latter place as well as ilmenite, quartz and zircon. The stones from Siam are of poorer quality and less valuable than the Burmese ones.

Ceylon is more famous for its sapphires than for its rubies and reference will be made to it when the localities for that variety are described.

Sapphire.—There are one or two slight points of difference between this blue variety and the ruby to which attention may be drawn. Thus it will be noticed that the rough crystals of sapphire very often affect a pyramidal habit as opposed to the prismatic-rhombohedral forms of the ruby. Again, sapphire is slightly harder than the other varieties and will always scratch a ruby. Further, sapphire loses its colour at high temperatures and does not regain it on cooling. It has been suggested that the pigment may be an organic substance but recent work by Verneuil has proved that the colouring matter of some sapphires is iron and titanium.

The behaviour of coloured corundums towards radium emanations has already been referred to (p. 17).

Sapphires show all shades of blue and the colour is so deep and intense in some that they appear almost black. All possible transitions occur from such stones through the paler shades into the colourless leuco-sapphire. Irregularity in the distribution of the colour and a strong tendency to variegation are characteristic of the sapphire; in many of the specimens in the case there are patches of varying depth of tint, whilst in some of the rough crystals from Ceylon blue and yellow zones alternate; green and blue are distinctly seen in the cut stone from Anakie.

Sapphire is, like the ruby, dichroic and gives deep-blue and greenish-blue images in the dichroscope. The deep-blue corresponds to the light travelling along the optic axis and hence in cutting the same rule must be observed here as in the case of the ruby.

The asterism of sapphire has been already referred to. Specimens, when cut *en cabochon* and in such a way that the greatest thickness coincides with the principal axis of the crystal, show a six-rayed star or at least an opalescent effect in reflected light. The name *star-sapphire* is applied to such stones and several examples are exhibited. The effect is most probably caused either by minute hollow canals running more or less parallel to the prismatic faces of the crystal or by small inclusions arranged in a similar manner.

Sapphire is distinguished from blue stones in much the same way as ruby from red ones. Spinel (blue) is softer, lighter, singly refracting and not dichroic; blue tourmaline is softer and lighter, whilst the same remarks apply to iolite.

The chief localities are Siam, Ceylon, India, Montana, and Queensland, all of which are represented in the collection.

The Siamese sapphires are found associated with other varieties of corundum, including ruby, in a sandy clay at Battambong. They are of fine quality and are put on the market in large numbers. The original source of the stones in this region has not yet been traced.

Many different precious stones are found in the gem gravels of Ceylon, and of these, sapphire plays an important part. The gravels are found near the foot of Adam's Peak, in the district around Rakwana and Ratanpura. They are 1-2 feet thick, and, in addition to sapphire, carry such stones as ruby, zircon, tourmaline, spinel, chrysoberyl, amethyst, garnet, besides other minerals. The rocks from which the gravels are derived have not yet been traced, but the mineral facies indicates that they are probably granites or gneisses with limestone.

The locality at Kashmir, India, is interesting because here the sapphires have been found in granitic veins piercing mica-schist and limestone. The detrital material derived from these rocks also yields sapphire in association with tourmaline, quartz, and other minerals.

In Montana the parent rock appears to have been a basalt, but the sapphires are found in glacial sands resting on schists.

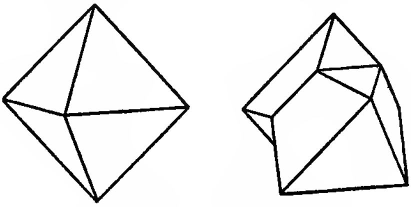
At Anakie, in Queensland, sapphire occurs in an alluvial deposit which consists largely of boulders of an altered sandstone, locally known as "billy." The original source of the corundum appears to be the basaltic rock which occurs in the neighbourhood.

SPINEL (Case N).

Hardness, 8.	Specific Gravity, 3·65-3·60.
Singly refracting.	Refractive Index, 1·72.

Spinel is the name for a group of minerals which show similar chemical constitution and crystallise in the cubic system. Only one of this group is used as a gemstone and, for this reason, it is distinguished as *precious spinel*; the characters given above apply to this variety alone. It consists of a double oxide of magnesium and aluminium, and frequently carries traces of chromium and iron to which the colours affected by this mineral have been ascribed.

As already mentioned the crystals belong to the cubic system, and are all of octahedral habit. They may be simple (Fig. 32) but compound or twin-forms (Fig. 33) are common. So frequent is this type in spinel that similar crystals of other minerals are said to be twinned on the *spinel law.*



Crystals of Spinel.

Fig. 32. Fig. 33.

The colour, as seen from the specimens here, shows a wide range with various shades of red common; blue is also fairly frequent, but colourless spinel is rare, at least in specimens large enough for cutting. When the colour approaches the red tint of the ruby the stone is called *ruby spinel,* whilst the name *balas ruby* is applied to those of paler shades. Very often a distinct purple tinge is seen in red spinel, and when this is very pronounced, the name *almandine spinel*—in allusion to its resemblance to the garnet of that name—is given.

Rubicelle is orange spinel having a pronounced yellow or, at least, yellowish-red tinge.

The brilliant cut and step cut are used with spinel, but the mixed cut is exceedingly common, and most of the examples in the case have been treated in that way. The stone possesses a strong vitreous lustre, and this, combined with the fairly high refractive index, renders the appearance of a cut specimen quite effective.

Spinel is distinguished from nearly every stone which it resembles by its single refraction and consequent lack of dichroism. The dichroscope alone is sufficient to determine spinel from ruby, sapphire and tourmaline. To discriminate between spinel and garnet is not so easy, as they are both singly refracting, but garnet has a higher specific gravity (Sp. G. 4). If the stones are in the rough a conclusive test is their behaviour before the blowpipe; garnet fuses easily to a slag, whilst spinel is infusible.

As regards mode of occurrence, spinel is found in much the same way as precious corundum, and the two are frequently associated. Examples are shown from the gem gravels of Ceylon and Burma.

CHRYSOBERYL (Case N).

Hardness, 8½.	Specific Gravity, 3·8-3·64.
Doubly refracting.	Refractive Index, 1·76-1·75.

Chemically this mineral belongs to the group of spinels as it consists of a double oxide of beryllium and aluminium. It differs from the members of that series, however, in crystallising in forms belonging to the rhombic system. The crystals may be simple but twinning is common and gives rise to complicated forms having an hexagonal appearance as shown by some of the specimens in the case.

Typical chrysoberyl has a yellow colour which may vary from a fine golden tint to yellowish-green or pale-green. The yellowish-green colour is perhaps the commonest and stones so coloured are sometimes referred to as *oriental chrysolite,* a name which is also applied to a variety of corundum (q. v.). The colour in chrysoberyl is never very intense, and the stones show little dichroism, still the high refractive index and strong lustre render the appearance of a cut specimen very pleasing, whilst the great degree of hardness enables it to preserve its beauty for a long time.

In the *cymophane*, *oriental cat's-eye* or *cat's-eye chrysoberyl,* as it is variously called, a large number of minute canals, arranged in a regular manner give rise to a band of light, or, at least, to an opalescent sheen where the stone is cut *en cabochon*.

Alexandrite is the dark-green chrysoberyl which differs from the varieties already described in being strongly dichroic; in the dichroscope one of the images is green whilst the other is pinkish-red. This variety has the curious property of appearing green by daylight and red by lamplight, a fact which has been put down to the absorption bands seen when light which has passed through alexandrite is examined spectroscopically. These absorption bands exist in the blue and in the yellow parts of the spectrum so that the light which emerges from the stone consists to a large extent of green and red rays. Now, if the stone is being examined in light rich in green rays, it will appear green, whilst, if the light is rich in red rays, the stone will appear red.

Chrysoberyl, when transparent, is cut in any of the styles referred to in connection with other coloured stones, and step cut, mixed cut and brilliant cut specimens are exhibited.

The yellowish-green varieties have often been confounded with *chrysolite*, but, as the latter stone has a hardness of only 6½ and a specific gravity of 3·3, the two are easily distinguished.

Yellowish-green *spodumene* (p. 82) has also been confused with chrysoberyl, but it is lighter (specific gravity 3·17) and softer (hardness 6½-7).

Cymophane is always cut *en cabochon* and its resemblance to the *cat's-eye quartz* has already been referred to (p. 46).

Transparent chrysoberyl comes from the Minas Novas district of Brazil, where it is associated with the spodumene referred to above. Good specimens of transparent chrysoberyl as well as cymophane are found in the gem gravels of Ceylon.

The original locality for alexandrite was the right bank of the Takovaya River in the Urals, where the mineral occurs associated with emerald in a mica-schist. Specimens from this locality are shown, and it will be seen that they have the complex hexagonal form mentioned above. They are usually much fissured and a very small proportion of the material is suitable for cutting. The locality was discovered in 1830 on the day when the Czar Alexander II. came of age, and the stone was named after him.

Alexandrite of gem-quality is also found in Ceylon, and some of it shows a chatoyancy similar to that of the cymophane.

EUCLASE (Case N).

Hardness, 7½.	Specific Gravity, 3·1-3·05.
Doubly refracting.	Refractive Index, 1·67-1·65.

This mineral is of sparing occurrence and is very rarely cut for jewellery. It consists of a silicate of beryllium and aluminium with water and is found in crystals belonging to the monoclinic system. They are prismatic in habit with the faces striated vertically, and they exhibit a very perfect cleavage parallel to a prism face.

Euclase may be quite colourless, but it usually shows a very delicate green, bluish-green or blue tint strongly reminiscent of the aquamarine (p. 64). Such coloured material is distinctly dichroic.

Examples are shown from Boa Vista, Brazil, and a cut specimen illustrates the high lustre which is brought out by polishing.

PHENACITE (Case N).

Hardness, 7¾.	Specific Gravity, 2·96.
Doubly refracting.	Refractive Index, 1·68-1·66.

Phenacite consists of a silicate of beryllium and crystallises in the rhombohedral system. It is usually colourless, but yellow or pink phenacite is sometimes found. The natural crystals shown here have rather a dull appearance, but the fine brilliant cut specimen, weighing 18½ carats, shows the high lustre which is brought out by polishing. Phenacite is interesting as being, of all gemstones, the most transparent to the Röntgen rays. It occurs at various localities, but it has little importance as a gem. Specimens are shown from Takovaya, Ekaterinburg, in the Urals, where crystals of considerable size are found in a mica-schist.

BERYLLONITE (Case N).

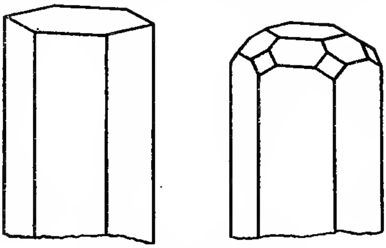
Hardness, 6.	Specific Gravity, 2·84.
Doubly refracting.	Refractive Index, 1·56-1·55.

This mineral is very rarely used as a gemstone, partly on account of its low hardness and its weak refractive and dispersive powers, and partly because the rough material is so rare. It consists of a phosphate of sodium and beryllium, and crystallises in the orthorhombic system. The crystals are colourless, have a perfect basal cleavage, and a brilliant, vitreous lustre which is well seen in the cut specimen shown here. Beryllonite occurs associated with phenacite in a granitic vein at Stoneham, Maine, U.S.A.

BERYL (Case O).

Hardness, 7¾. Specific Gravity, 2·71-2·68;
Doubly refracting. Refractive Index, 1·58-1·57.

Under this head is included not only the dull, turbid, common beryl, but also a number of transparent precious varieties identical in composition and properties but differentiated according to colour. They all consist of a silicate of beryllium and aluminium and carry traces of impurity to which the tints are doubtless due. The crystals belong to the hexagonal system and are usually prismatic with the prism faces strongly striated in a vertical direction. Many of the specimens here show no terminal planes, but on some the basal plane occurs alone (Fig. 34), whilst on others the intersection of that plane with the prism faces is modified by the faces of hexagonal pyramids (Fig. 35). The cleavage is basal and indistinct.



CRYSTALS OF BERYL.

Fig. 34. Fig. 35.

Common beryl is of frequent occurrence in granite, and the crystals sometimes attain a large size. It is usually of a greenish tint, and, owing to its lack of transparency, is never cut as a gemstone. The precious varieties of beryl are prized solely on account of the colours which they display. Colourless, transparent beryl is found, but the low refractive index and the weak dispersion render it featureless, and it is rarely cut as a gemstone. The colour most highly esteemed is, of course, the fine green shown by a good specimen of *emerald*, the rarest variety of beryl, and one of the costliest stones at the present time.

In *aquamarine* the colour is pale-blue to greenish-blue, whilst material possessing a yellow colour is called *golden beryl*. A good series illustrating these varieties—both cut and in the rough—is exhibited.

The *emerald*, like most precious stones, shows variations in colour from darker to paler tints, but the shade most esteemed is a "dark-velvety-green," an expression which also describes the lustre of a good specimen. None of the cut stones in the case shows this well, and the nearest approach to it is seen in the two fine crystals in the matrix, the one presented by the late Mrs. E. Warne, and the other by the late Henry Ludlam, Esq. The colour has been ascribed to traces of organic matter, but as it withstands a high temperature, it is more likely to be due to small amounts of chromium. Emerald is dichroic, and, with the dichroscope, gives a yellowish-green and a dark, bluish-green image. The dichroism is observable by the unaided eye in a well cut specimen, and distinct bluish-green flashes can be got from the back facets when the stone is moved about. Flawless emeralds are exceedingly rare, specimens being usually marred by cracks and inclusions which greatly impair the transparency. It is a curious fact that many of the crystals from Colombia are clear and transparent when brought from the mine and develop the fissures on exposure; further, some of them show a tendency to burst into fragments. It is the exceeding rarity of really good specimens which makes this stone so dear, and practically any price can be demanded for a flawless emerald of a few carats in weight.

The emerald is usually step cut, but it is sometimes cut as a brilliant, as a rosette, or *en cabochon.*

The distinguishing features of emerald are its low specific gravity, its comparative softness, and its dichroism. These characteristics are quite sufficient to discriminate between it and any other stone to which it has a superficial resemblance. Thus the green corundum, or *oriental emerald* (p. 55), is harder and heavier; the green garnet, or *demantoid* (p. 75), bears a strong resemblance to emerald, but it lacks dichroism and is heavier; green tourmaline, diopside, chrysolite, and hiddenite, amongst other stones, may be confused with emerald, but they all differ in having a higher specific gravity. A green paste is made which is difficult to tell from the genuine stone by mere inspection, but it has no dichroism and is softer.

In its mode of occurrence emerald is unique, inasmuch as it is practically never found in gravels or sands, but always in the parent rock. This is typically a mica-schist, but a striking exception is afforded by the mines of Muzo, Colombia, where the emeralds are found in veins of calcite in a bituminous limestone. As associates of the emerald there may be mentioned pyrites, quartz, and other minerals, of which *parisite*, the rare carbonate of cerium, is the most interesting. This locality is by far the most important, and is the main source of emeralds at the present time. The crystals never attain a great size and a fair idea of their dimensions can be got from the specimens shown here. As regards colour, they usually incline to the darker shades of green, but some of the specimens are rather pale.

The other localities represented here include Egypt, the Habachthal in Tyrol, and the Ural Mountains, in all of which the parent rock is a mica-schist. At Emmanville, New South Wales, emeralds occur in an offsboot from a granite-mass which penetrates clay-stones.

Aquamarine possesses the same chemical composition and crystal-form as emerald, but is characterized by its pale, bluish-green, blue, or yellowish-green colour. The tints have been ascribed to the presence of small amounts of iron. In contrast to the emerald, it is not infrequently found in large, transparent masses, free from flaws, and consequently its value is very much lower. Faults are, however, common enough and usually take the form of cavities and striæ, as seen in the large cut specimen in the centre of the tray.

Dichroism is observable in all except the very pale stones, the dichroscope yielding a pale-blue and a pale-yellow, or practically colourless, image.

Aquamarines are cut in steps or as brilliants and have also been employed in cameo-work. Examples of these methods of treatment are shown here.

Specimens of yellow beryl and pink beryl—a variety which has lately been found in Madagascar—are also exhibited.

The low specific gravity is usually sufficient to distinguish these pale varieties of beryl from any stone, *e.g.*, blue topaz or euclase, which resembles them in appearance.

The home of the aquamarine is in the cavities of granite rocks where it occurs in quite large crystals. Many of the specimens in the case came from Adun Tschilon in north-eastern Siberia, where the beryl occurs in the cavities of a quartz-topaz rock penetrating granite. Examples are also shown from the neighbourhood of Ekaterinburg in the Urals, and from the granite of the Mourne Mountains, County Down, Ireland. On one of the specimens from the former locality the crystals are invested with a layer of ochreous material which frequently fills up the cavities of the granite.

TOURMALINE (Case O).

Hardness, 7¼.	Specific Gravity, 3·15-3·0.
Doubly refracting.	Refractive Index, 1·64-1·62.

This stone has a most complicated chemical composition, which varies widely in different specimens. Corresponding to the variations in composition there are distinct differences in specific gravity and in colour, so that this stone differs from those already considered in that its tint is not due to traces of impurity, but is, to some extent, an expression of its chemical composition. Tourmaline is a complex silicate of boron and aluminium with magnesium, iron and the alkali metals, *i.e.*, sodium, potassium and lithium, present in variable quantities. Iron-tourmaline is usually black, alkali-tourmaline may be red, green, or colourless, and magnesium-tourmaline, yellow, brown, or even black. There is, however, no hard and fast line between these rough divisions which grade into one another.

Despite their wide differences in composition, all varieties unite in having the same crystalline form. The crystals belong to the rhombohedral system, and usually take the form of prisms terminated by one or more sets of rhombohedral faces (Fig. 36). The prisms are roughly trigonal, *i.e.*, three-sided in section, and bear deep vertical striations which are well seen in the specimens shown in the case. The crystals are usually attached to the matrix by one extremity of the prism and doubly terminated ones are rare. When they do occur, however, the development and arrangement of faces at the one end is different from that at the other, and tourmaline in consequence is said to be *hemimorphic.*

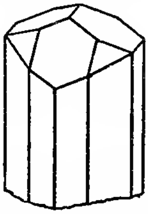


Fig. 36.—*Crystal of tourmaline.*

The commonest variety of tourmaline is the black *schorl* which is quite opaque, and never used as a gemstone. It is represented here by a good suite of specimens from Bovey Tracey, Devonshire.

The clear, transparent, precious tourmaline shows great diversity of colour and is somewhat extensively cut for jewellery. The following colour-varieties are recognised:—*achroite* or colourless tourmaline; *rubellite* or red tourmaline; *indicolite* or blue tourmaline; green tourmaline is " Brazilian emerald," " Brazilian chrysolite," " Ceylon chrysolite," depending on the particular shade and on the place where it is found. Crystals sometimes occur, cf. the specimens exhibited from Madagascar, in which an outer shell of rubellite encloses a kernel of brown tourmaline or *vice versa;* specimens are also shown in which the crystals are pink at one end and green at the other. In such cases there are differences in composition between the differently coloured portions of the crystal.

Tourmaline is remarkable for its dichroism which, in the deeply coloured kinds, is stronger than in any other gemstone. When, for example, a piece of green tourmaline is viewed in a direction parallel to the prism edge, *i.e.*, along the optic axis, it appears almost black, whilst if it be viewed across the prism edge it has a fine green colour. In every case, no matter what the colour may be, tourmaline shows the deepest shade when viewed along the optic axis, and this fact must be remembered when rough material is being cut. Strongly coloured stones must be cut with the table parallel to the prism edge, whilst, in pale stones, the table must be perpendicular to that direction.

Tourmaline readily acquires an electric charge. This may be accomplished by simply rubbing a stone with flannel, or by heating it gently, and letting it cool, when it readily attracts small pieces of paper (pyroelectricity).

Tourmaline is usually cut in steps with the above mentioned precautions as to the direction of the table, and, with a deeply coloured stone cut in the manner described, the dichroism is quite apparent to the unaided eye. The other optical properties of this mineral call for no special mention; its refractive index is low, its dispersion is weak, and its lustre is of the usual vitreous type.

Tourmaline, presenting as it does so many different colours, has been confused with other stones, from which however it can be distinguished by its lower specific gravity and its pronounced dichroism. These tests are sufficient to discriminate rubellite from ruby, red spinel, and pink topaz, and indicolite from sapphire, and blue spinel. Green tourmaline has been almost invariably confused with chrysolite, but the latter stone is heavier and shows very weak dichroism. Sometimes, too, it is mistaken for emerald, which is however much lighter.

Tourmaline is a mineral of wide distribution, and is found most frequently in granites and gneiss. Fine green crystals in dolomite are shown from St. Gothard, Switzerland, but this occurrence is quite exceptional. Brazil, Siberia, California, Elba, Madagascar all yield tourmaline, examples of which are in the case, whilst it also occurs in the gem gravels of Ceylon.

KYANITE (Case O).

Hardness, 7·5.	Specific Gravity, 3·68-3·60.
Doubly refracting.	Refractive Index, 1·73-1·72.

Kyanite has only a limited use as a gemstone, a fact which is accounted for by the lack of rough material having the proper colour and sufficient transparency. It consists of a silicate of aluminium, and often carries small amounts of ferric oxide to which is ascribed the blue colour typical of this mineral. The crystals belong to the triclinic system and are usually elongated prisms flattened prominently parallel to one of the prism faces. There is a very perfect cleavage parallel to this face and also a parting parallel to one which truncates the prism obliquely. The interesting point about the crystals, however, is the great difference in hardness shown in different directions. If a knife be drawn vertically along the large prism face it scratches it easily, whilst if it be drawn transversely across the face no scratch is made; in the former direction the hardness is 5, in the latter it is 7. The other prism faces have a hardness of about 7, and consequently cannot be scratched by the knife.

Kyanite has usually a pale-blue colour, but white, grey, and yellow varieties are shown; these, however, are never cut. The blue crystals are seldom transparent, and the colour is usually distributed in an uneven manner. The dichroism is quite distinct in the more deeply coloured specimens, the images seen in the dichroscope being light-blue and dark-blue respectively. The stone shown here is cut *en cabochon* but good specimens are sometimes facetted.

Kyanite is occasionally substituted for sapphire, but it can be distinguished by its poor lustre, its lower specific gravity, and its hardness. It is somewhat widely distributed in gneiss and mica-schist, but transparent crystals are confined to one or two localities. Those shown here came from Monte Campione, Faido, St. Gotthard, where the kyanite is associated with staurolite.

ANDALUSITE (Case O).

Hardness, 7½. Specific Gravity, 3·18.
Doubly refracting. Refractive Index, 1·64-1·63.

In composition this mineral is identical with kyanite, but it crystallises in the orthorhombic system. The crystals are prismatic and square in section. The colour may be white, grey, reddish-brown, or green, but, as commonly found, andalusite is not transparent enough for cutting. It occurs as rolled pebbles in the sands of Minas Novas, Brazil, the locality which yields most of the material of gem-quality. The outstanding feature of andalusite is its strong dichroism. When looked at in one direction, a specimen appears green, whilst in another direction, at right angles to the former, it appears of a rich brownish-red colour. In this respect andalusite strongly resembles alexandrite (p. 60), but it can be distinguished by its lower hardness and specific gravity. Three step cut stones are exhibited to illustrate the differences in colour found in this mineral.

SPHENE (Case O).

Hardness, 5½. Specific Gravity, 3·45-3·35.
Doubly refracting. Refractive Index, 2·06-1·91.

When properly cut, sphene is one of the most beautiful of gemstones, as it possesses a high refractive index, very strong dispersion, and pronounced dichroism, a combination of properties which is present in no other member of the series. Unfortunately its hardness is low.

Sphene consists of a silicate and titanate of calcium, and occurs usually in wedge-shaped crystals belonging to the monoclinic system. Much of the material is opaque and unfit for cutting, but beautiful transparent crystals, yellow or green in colour, are found associated with felspar and chlorite in the Grisons, Switzerland.

The small but beautiful stone shown here is mixed cut, and exhibits in a high degree the strong dichroism and dispersion, as well as the adamantine lustre of this mineral.

BENITOITE (Case O).

Hardness, 6½. Specific Gravity, 3·65-3·64.
Doubly refracting. Refractive Index, 1·80-1·76.

This mineral was discovered in 1907 and has since been used as a gemstone, though only to a limited extent. It consists of a silico-titanate of barium, and, in this respect, is nearly related to sphene. It crystallises in the rhombohedral system and the crystals invariably have a pyramidal aspect with the faces occurring in sets of three. The colour is typically pale- to deep-blue with a slight violet tint, but colourless crystals are not unknown, whilst, as in the sapphire, blue and white patches may be present on the same crystal. Benitoite is very strongly dichroic; when a crystal is viewed along the principal axis it appears colourless, whilst in a direction at right angles to the axis, it appears of a fairly deep-blue colour. Thus in cutting rough material, the table must be ground as nearly as possible perpendicular to the basal plane and not, as in the sapphire, parallel to it. Benitoite has been confused with sapphire, but it is much softer and lighter.

The only locality for this mineral is on the west side of the Diablo Range, San Benito County, California, where it occurs in serpentine and associated with natrolite, neptunite, amphibole, and various copper minerals.

IDOCRASE (Case O).

Hardness, 6½.	Specific Gravity, 3·4-3·3.
Doubly refracting.	Refractive Index, 1·720-1·718.

Idocrase consists essentially of a silicate of calcium and aluminium with water. In addition to these constituents, small amounts of ferric oxide, manganese oxide, magnesia, potash and soda are present from which it will be seen that the chemical composition is rather complex. Idocrase crystallises in the tetagonal system with the crystals more or less prismatic in form. They are usually lacking in transparency and are commonly of a green or brown colour, though yellow or even blue crystals are not unknown.

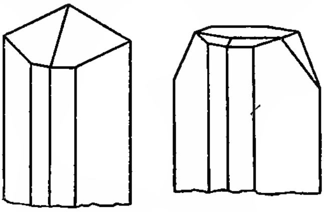
Material of sufficient transparency for cutting comes from one or two places only, and the stone has quite a restricted use in jewellery. Idocrase is weakly dichroic, the two images seen in the dichroscope being green and yellowish-green respectively. Crystals are shown from Ala, Piedmont, where they occur in chloritic schist with serpentine; two cut specimens are also exhibited.

TOPAZ (Case O).

Hardness, 8;	Specific Gravity, 3·56-3·50.
Doubly refracting.	Refractive Index, 1·63-1·62.

A fine series of specimens of this mineral, both cut and in the rough, is shown here. Topaz is one of the very few precious stones which contain fluorine, this element being here combined with alumina and silica to form a fluo-silicate of aluminium. Variable amounts of water are also present and are regarded as replacing a corresponding quantity of flourine. Although the percentage of water is small —1·8-2·5 per cent.—it has been found that the variations in the specific gravity and optical properties noticeable in different specimens of this mineral are due to the differences in the amount of water which enters into their composition.

Topaz is frequently found in fine, bold crystals which belong to the rhombic system. The prism faces are always well developed and are usually striated in a vertical direction. The yellow crystals from Brazil are terminated at one end by a four-sided pyramid (Fig. 37), whilst the greenish-blue crystals from Siberia show a more complex termination consisting of the basal plane, sloping domes, and pyramidal faces (Fig. 38). The crystals are almost always attached to the parent rock by one end of the prism and doubly terminated ones are rather rare. The transverse cracks on some of the specimens are the traces of the very perfect basal cleavage which characterises this mineral. A crystal of topaz can be split with the greatest of ease into plates parallel to the basal plane, and this property renders cut specimens somewhat fragile and liable to fracture when subjected to a sudden shock.



Crystals of Topaz.

Fig. 37. Fig. 38.

The range of colour in topaz is, perhaps, not so wide as in some of the stones already described, but a sufficiently interesting suite is presented by the specimens shown here. The majority of the rolled pebbles are colourless, and stones cut from such material may be easily confused with diamond, rock-crystal, or with white corundum.

Diamond has the same specific gravity but is much harder and shows greater *fire*; rock-crystal is softer and lighter; and white corundum is harder and heavier (specific gravity = 4·0).

Yellow is the typical colour of topaz, so much so, that, as already mentioned (p. 55), the name has been applied to yellow corundum, and to yellow quartz, with somewhat confusing results. The tint varies in intensity from the merest tinge to the deep, yellowish-brown seen in one or two of the cut specimens on the tray, whilst a distinct reddish-brown is observable on some of the crystals from Brazil.

The fine, greenish-blue colour presented by the Siberian crystals is almost identical with that of the aquamarine, and it is impossible to distinguish cut specimens of the two stones by mere inspection; aquamarine is, however, much lighter (specific gravity 2·7) than topaz and is a little softer.

Natural crystals of a pink colour are rare, but a good example from Brazil is shown here. The fine pink stones sold as *rose topaz* are all produced by the heating of yellow ones (p. 29).

The colour in some cases is apt to be fugitive, and has been ascribed to an organic compound; in other cases it withstands a fairly high temperature, and is probably due to some metallic oxide.

Dichroism is shown by most coloured topazes, but even in the more deeply-tinted specimens, it is never apparent to the unaided eye, although it is distinct enough in the dichroscope. With yellow stones, the images are dark and pale, and sometimes one of them is distinctly pink; the pale-blue stones give a faint-pink and a blue image; whilst with rose topaz, the images are fairly deep-pink and practically colourless.

The refractive index is low, the dispersion is weak, and the lustre is of the usual vitreous type. Colourless topaz, therefore, presents no particularly striking features, and it is the coloured varieties which are chiefly employed in jewellery. These are cut in steps with a small table, but examples cut as brilliants are also shown.

Topaz occurs at many localities, but the crystals are frequently much fissured and unfit for use as gems. It is usually found in granitic and gneissic rocks and sometimes it occurs as rolled pebbles in the beds of rivers. Many of the fine brown crystals come from the neighbourhood of Ouro Preto, in the south-west of Minas Geraes, Brazil, where they occur, associated with quartz, in a decomposed clay-slate. At Mursinska in the Ural Mountains, topaz of a fine blue colour is found associated with beryl, quartz and felspar in the druses of the granite. Beautiful transparent crystals are shown from this locality and also a large colourless one from Miask, another locality in the Urals.

Attention may also be directed to the fine group from Adun Tschilon in Transbaikalia, where, as already mentioned in the description of beryl, quartz and topaz form a topaz-rock.

Specimens are also shown from the Schneckenstein, Saxony, from San Louis Potosi, Mexico, from Tasmania, Japan, and from one or two other places. All these localities are, however, unimportant as compared with Brazil and Siberia which are the chief sources of topaz of gem-quality.

CHRYSOLITE (Case P).

Hardness, 6½;	Specific Gravity, 3·44-3·35.
Doubly refracting.	Refractive Index, 1·70-1·66.

This mineral is also known as *olivine*, and it invariably shows a yellowish-green to leek-green colour with none of the wide variations so prominent in many gemstones. Unfortunately, the name, *chrysolite*, has been applied to several other stones showing similar colour, and it is often difficult to know what stone is meant when the term is used by jewellers. The name, *peridot*, is applied to the dark-green variety illustrated here by one or two cut specimens.

Chrysolite consists of a silicate of magnesium and iron, and, as the ratio of the amounts of these two metals varies considerably, differences in specific gravity and intensity of colour are found. In general, specimens rich in iron have a higher specific gravity and a deeper colour than those poor in that metal.

The crystals belong to the rhombic system and are sometimes, like those in the collection, flat and platy with the large prominent face vertically striated.

Chrysolite is dichroic, a property which is, of course, more pronounced in the dark, leek-green *peridot* than in the paler, yellowish-green varieties. The images in the dichroscope are coloured yellow and green respectively. The lustre of this stone is vitreous, but cut specimens, especially if the colour be deep, have a somewhat oily appearance which is characteristic, and can be seen in the examples in the case. The refractive index is not high, and the dispersion is weak, but the beautiful body-colour renders the appearance of a cut chrysolite very pleasing. The specimens here are step cut—the mode of treatment usually adopted—and one or two show the slightly convex form sometimes given to the table.

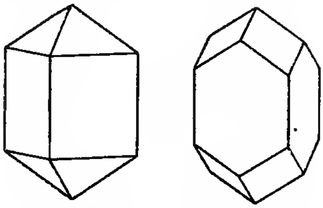
Reference has already been made to several of the stones which have been confused with chrysolite. They include green corundum or oriental chrysolite, chrysoberyl, green tourmaline and emerald, from all of which it can be distinguished by its specific gravity. The same property discriminates it from green garnet, and moldavite, both of which have yet to be described.

Chrysolite is widely distributed in various igneous rocks, but always in grains or small crystals which are useless for the purposes of jewellery. Specimens of sufficient size and transparency for cutting have been found in the parent rock at only one locality, namely, the Island of St. John, in the Red Sea, where crystals occur in the cavities of an olivine-rock, or *dunite*, which is much decomposed and serpentinized. They have a distinctly yellowish-green tinge, and are in no way comparable in appearance with the leek-green peridot. This stone was extensively used in olden times for decorative purposes, but the source of the rough material has not yet been found. The peridot now put upon the market is generally believed to be derived from old ornaments and jewellery.

ZIRCON (Case P).

Hardness, 7½;	Specific Gravity, 4·8-3·9.
Doubly refracting.	Refractive Index, 1·97-1·92.

This stone consists of a silicate of zirconium and occurs widely disseminated in granites, gneisses, and rocks of that nature, usually, however, in the form of dull, opaque crystals which are useless for decorative purposes. The crystals belong to the tetagonal system and are usually in the form of prisms terminated by a four-sided pyramid (Figs. 39 and 40). The clear, transparent precious zircon almost always occurs as rounded crystals and pebbles in sands and gravels, and samples of such material from various localities are shown here. The colour, as shown by the



CRYSTALS OF ZIRCON.

Fig. 39. Fig. 40.

series here, exhibits a wide range, and one or two names have been applied to different varieties. Thus *hyacinth* or *jacinth* is the fine red to brown zircon, whilst pale-yellow to colourless stones are known as *jargoons*; in addition to these, zircons of various other tints, *e.g.*, fine green, golden-yellow, puce-coloured, &c., are represented. Mention has already been made of the decolourising effects of heat on some zircons and the improvement in lustre which is also effected thereby (p. 29).

Coloured zircons are not sensibly dichroic and the images in the dichroscope rarely show an appreciable difference. The refractive index is high, and the lustre almost adamantine, but specimens are often marred by a peculiar cloudiness which detracts from their beauty. An interesting point is the absorption bands which are observed when the light which has passed through zircon is examined with an ordinary pocket spectroscope. These bands were first noted by Sir A. H. Church and are illustrated on the plate taken from his book and hung on the outer end of this case. The presence of uranium has been suggested as the cause of the absorption, but the matter has not been completely explained as yet.

The specific gravity of zircon affords an interesting series of variations and shows a wider range than in any other mineral. The leaf-green zircons usually have a specific gravity of about 4, whilst that of the red jacinth and the colourless variety is about 4·7. Another peculiar phenomenon is the increase in specific gravity which often takes place when a stone is heated. It has been advanced that there are really three modifications of this mineral:—(*a*) zircon with a specific gravity of 4·0 which cannot be increased by heating; (*b*) zircon with a specific gravity of 4·0 which can be increased by heating; and (*c*) zircon with a specific gravity of 4·7.

The jacinth is often mistaken for essonite, a variety of garnet (p. 73), but no confusion should arise when it is borne in mind that the latter stone is singly refracting and much lighter (sp. gr. 3·64) than zircon. Differences in specific gravity and hardness also distinguish the jacinth from corundum of similar colour.

The green zircon is also confused with tourmaline and green garnet, but here again the specific gravity is very useful; the absorption spectrum of the zircon affords confirmation of its identity.

The resemblance of white zircon to diamond has already been dealt with (p. 29).

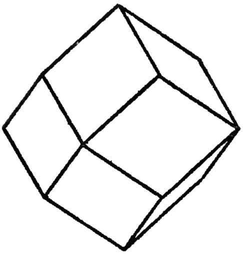
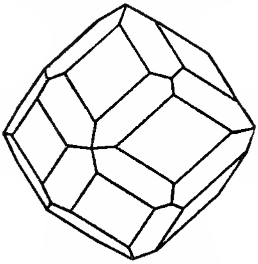
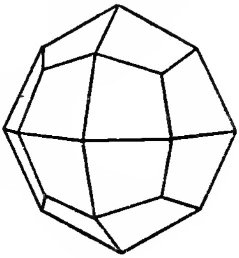
The chief locality for zircon of gem-quality is Ceylon, where it occurs in the gravels previously referred to.

Examples are also shown from Tasmania, New South Wales, and Expailly, France.

GARNET (Case P).

This is a name applied to a group of minerals, several of which have been rather extensively used in jewellery. As regards composition, they all consist of a double silicate in which one of the metals may be calcium, iron (ferrous), magnesium, or manganese, whilst the other may be aluminium, iron (ferric), or chromium. Hence there is calcium-aluminium-garnet, calcium-iron garnet, magnesium-aluminium-garnet, and so on. These varieties are not sharply separated, but grade into one another, with the result that garnet of one type usually contains varying amounts of metals which form garnets of another type.

Despite their differences in composition the members of this group all crystallise in the cubic system with the rhombic dodecahedron as the typical form (Fig. 41). Sometimes the twenty-four edges of the dodecahedron are truncated by the planes of the icositetrahedron (Fig. 42), and when this is carried far enough the simple icositetrahedron, *i.e.*, a twenty-four sided figure, is produced (Fig. 43). Examples of natural crystals showing these forms are exhibited, and attention may be specially directed to the large, perfect, dodecahedral ones as giving some idea of the size which they attain. Garnet possesses no cleavage, and is singly refracting, but, owing to the differences in composition existing amongst the various members of this group, there is considerable divergence in physical properties. The specific gravity may vary from 3·6 to 4·3, the refractive index from 1·7 to 1·88, and the hardness from 6½-7½, whilst the colour, depending as it does on the chemical constituents of the mineral, displays considerable variety of depth and shade.

Crystals of Garnet.

Fig. 41. Fig. 42. Fig. 43.

Garnet is widely distributed in the earth's crust, and is usually found in schists, gneisses, and in limestones which have been acted upon by intrusive igneous rocks; sometimes, too, it is found in serpentine. The greater part of the material is too dull and not sufficiently transparent for cutting, but at several localities beautiful clear stones are found which have been largely utilized for gems. The gem-varieties of garnet comprise *essonite* or *cinnamon stone*, *almandine* or *precious garnet*, *pyrope* or *Bohemian garnet*, and *demantoid*, all of which are differentiated by colour, specific gravity, hardness, and refractive index.

Essonite (hardness, 7¼; specific gravity, 3·65-3·63; refractive index 1·76), is a yellowish-red to honey-yellow variety of calcium-aluminium-garnet, the colour being due to small quantities of iron and manganese which replace a corresponding amount of calcium. This stone possesses the somewhat peculiar property of appearing to greatest advantage under artificial light when it takes on a fine, fiery-red appearance. It has often been confused with the red variety of zircon but its lustre is far below that of the hyacinth, whilst it is much lighter and it is singly refracting. Nearly all the material of gem-quality comes from Ceylon where it occurs as rolled pebbles often of considerable size. Specimens are shown from this locality, and also from the Mussa Alp, Ala, Piedmont, where very fine crystals occur in cavities in serpentine.

Pyrope (hardness 7¼; specific gravity, 3·8-3·7; refractive index, 1·8), is magnesium-aluminium-garnet and usually possesses the fine, blood-red colour seen in the specimens in the case. Besides the above mentioned metals, pyrope frequently carries variable quantities of calcium, iron, manganese, and chromium, to the last three of which the colour is doubtless due. This variety is seldom found in distinct crystals and nearly always occurs as grains in association with rocks rich in olivine, or in serpentine which has resulted from the alteration of that mineral.

In Bohemia the garnets are picked out of gravels formed by the disintegration of serpentine, and extensively used in jewellery. This is the chief locality (hence the name *Bohemian garnet*), but pyrope of good quality has been found at other places, notably at the diamond mines in South Africa, where it is known as "Cape ruby." Pyrope forms a very effective stone when cut, as it combines a fine colour with absolute freedom from flaws. The stones are usually small and rarely exceed one carat in weight. They can be distinguished from ruby by their single refraction, absence of dichroism, lower specific gravity, and by the fact that the colour is usually tinged with black.

Almandine (hardness, 7¼; specific gravity, 4·3-4·0; Refractive index, 1·77), is iron-aluminium-garnet which frequently carries certain amounts of magnesium, calcium, and manganese. It has —like pyrope—a deep-red colour, but very often shows distinct tinges of purple which distinguish it at once from that variety. The high specific gravity is noteworthy, as is also the presence of well marked absorption bands seen when light transmitted through the stone is examined spectroscopically. These absorption bands are illustrated in the plate which hangs at the outer end of this case.

Almandine is widely distributed and the crystals frequently are of large size. The parent rock is commonly a mica-schist and attention may be specially directed to the well formed crystals from Fort Wrangel, Alaska. In Ceylon it is found as pebbles in the gravels, and in India it occurs in the disintegration products of mica-schist and gneiss. Many other localities yield this variety which has often been confused with ruby. Examples are shown from Adelaide, S. Australia, which are sometimes known as "Adelaide rubies" but the low degree of hardness of almandine combined with its absence of dichroism are quite sufficient to determine it.

Almandine is treated in many ways as shown by the series of cut specimens exhibited here, and when cut *encabochon* it goes by the name of *carbuncle*. A fine example of such a stone will be found amongst the series.

Demantoid (hardness, 6½; specific gravity, 3·86-3·83; refractive index, 1·90). This name is applied to a transparent, green variety of calcium-iron-garnet. The colour varies from the deep-green of the emerald to the yellowish-green of the chrysolite, and the stone has in consequence been known as "Uralian emerald" and "olivine," and is still sold under that name. It has a strong lustre, a high dispersion and refractive index, and these qualities give a very effective appearance to a cut specimen. The hardness is, however, low, and this renders demantoid unsuitable for jewellery which is subjected to hard wear. This garnet can of course be distinguished from the chrysolite and from emerald by its specific gravity and its absence of dichroism.

A number of specimens both cut and in the rough are exhibited from the Bobrovka River, Syssersk, the Urals, where the garnet is found as rolled pebbles, and also in the parent rock which consists of serpentine associated with dolomite.

THE FELSPARS (Case Q).

This group of minerals is one of the most important and widespread in the rocks of the earth's crust, but few of its members are suitable for use as precious stones. The felspars are silicates containing at least two metals, one of which is always aluminium, whilst the other may be potassium, sodium or calcium. The group is thus divided into potassium-felspar, or *orthoclase*, and sodium-felspar and calcium-felspar which are known as *plagioclase*. As in the case of the garnet group, however, the felspars are usually intermixed, with the result that orthoclase often carries appreciable amounts of sodium and calcium, whilst the plagioclase felspars constitute a series in which sodium-felspar, or *albite*, stands at one end, calcium-felspar, or *anorthite* at the other, and between the two are a whole series of intermediate members, consisting of mixtures of albite and anorthite in varying proportions.

Orthoclase crystallises in the monoclinic system, plagioclase, in the triclinic, but there is a close resemblance between the two sets of crystals. Both possess two principal directions of cleavage which are at right angles in orthoclase, whilst, in plagioclase, they are slightly oblique. The specific gravity of the felspars varies from 2·5 to 2·75, the hardness is about 6, and the refractive index is low.

Large, well developed crystals are often found lining the cavities of granite and gneiss, and a fine suite of specimens is shown here. Such material is however, dull, turbid, and quite unfit for gem-purposes. Felspar is employed in this respect only when it shows some special optical effect, or when it possesses a colour sufficiently beautiful to compensate for its deficiency in most of the properties which go to make a good gemstone.

The varieties which have been used for decorative purposes are:—*Moonstone, amazonstone, sunstone* or *avanturine felspar*, and *labradorite*.

Moonstone (specific gravity 2·5). When orthoclase occurs in clear colourless crystals, it is known as *adularia*, examples of which will be found in the case. Adularia sometimes shows a pronounced sheen which is confined to certain crystallographic planes, and to this variety the name *moonstone* is applied. The sheen takes the form of a shimmering play of white light which, in some cases, has a distinct bluish tinge; specimens in which the latter colour is pronounced are the most valuable. Some of the stones in the case are cut with a flat surface which then appears uniformly translucent and milky; others, however, cut *en cabochon,* show a translucent band grading off into a matrix of transparent adularia.

The cause of the peculiar appearance is the presence of small platy inclusions arranged parallel to the particular plane from which it is observed.

Moonstone is cut either with a flat surface or *en cabochon* and is quite ineffective if facetted, a point which is brought out by the specimen cut as a brilliant and placed alongside of those fashioned in the usual way. Its use as a medium for cameos and intaglios is also illustrated.

The chief locality is Ceylon where it is found either as pebbles in the gem gravels, or as rough fragments in a clay which has probably resulted from the decomposition of an igneous rock.

Moonstone may be distinguished from a good glass imitation by its double refraction.

Attention may be here directed to the polished specimen of *augite syenite* from Norway, which is somewhat extensively used as an ornamental stone in modern buildings. This stone owes its beauty to the beautiful *schiller* seen on the crystals of orthoclase which form a constituent of the rock-mass.

Amazonstone is a potassium-felspar which differs from orthoclase in being triclinic and in possessing a fine green to bluish-green colour; in other respects, *e.g.*, chemical composition, hardness, specific gravity, it is identical. The green colour has been ascribed to traces of copper, and to small amounts of organic matter.

The deeply coloured specimens, alone, have any value as gem-stones, and they are cut with a low rounded surface; owing to its opacity, amazonstone is never facetted. Larger pieces have been fashioned into vases and other ornamental objects.

Amazonstone resembles orthoclase in its mode of occurrence, and a typical locality is Pike's Peak, Colorado, which yielded some of the fine specimens shown in the case. Here the mineral is found in the cavities of a coarse granite and in intimate association with albite.

Sunstone or avanturine felspar. This variety resembles the similar form of quartz (p. 47) and owes its metallic sheen to the inclusion of small plates of haematite, gothite, or some such mineral, arranged in a parallel manner along the principal cleavage plane of the mineral.

The avanturine effect is found in several felspars but is most common in oligoclase (specific gravity 2·65) which is a sodium-calcium-plagioclase. The specimens shown here are brown, but the colour varies and may be white or even greenish.

Sunstone may be distinguished from avanturine quartz by its lower hardness and by the presence of parallel striations on the surface which result from the complicated twin structure of the mass.

The locality represented here is Arendal, Norway.

Labradorite is, perhaps, the most beautiful of all the varieties of felspar. It belongs to the plagioclase series and differs from oligoclase in having the percentage of calcium greater than that of sodium; it is consequently a calcium-sodium-felspar. Under ordinary conditions it appears of a dirty-grey colour and has rather a greasy lustre, but, when a suitably cut specimen is placed in certain positions with regard to the observer, a remarkable change takes place. The lustre becomes metallic and a beautiful coloured sheen spreads over the surface. The colours vary, but blue, green, and yellow predominate, and various shades of red are sometimes present. The polished specimens in the case have been placed so as to show the effect well, but the visitor will find that in only one position is the maximum sheen obtained from any specimen; immediately it is looked at from another direction the colours vanish. The sheen is seldom distributed over the surface in a uniform manner, but is interrupted by dull lifeless patches which mar the beauty of the specimen. It is, moreover, best seen on a cleavage surface and appears to be due in part to the presence of small lamellar inclusions. This explains all the colours except blue which is often found when the inclusions are absent. The blue colours have been ascribed to polarisation effects caused by the lamellar structure of the mineral.

Labradorite is usually cut with a flat surface, and has been employed for various ornamental objects, and it affords quite an effective medium for cameo-work, as can be seen from the fine examples in the case.

The specimens shown here came from Labrador, the original locality, where the mineral occurs in association with hypersthene (Case R) as rolled blocks lying along the coast.

OBSIDIAN (Case Q).

Hardness, 5½. Specific Gravity, 2·6-2·3.
Singly refracting.

This substance is also known as *volcanic glass*, and, strictly speaking, is not a mineral but a rock; it has, however, been used from time to time for ornamental and other purposes, a fact which sometimes justifies its finding a place here. In composition it is exceedingly variable but it always carries a large percentage of silica with some alumina and smaller quantities of potash, soda, and iron oxide.

Obsidian resembles artificial glass in many respects; it has no crystalline structure, the hardness and specific gravity are low, the fracture is conchoidal, and the lustre, quite vitreous. The colour is very deep, and commonly quite black, but reddish-brown, grayish and bluish varieties are known. Microscopic examination reveals the presence of numerous cavities and inclusions which often consist of small crystals; they give rise to the beautiful sheen observed in some of the cut specimens in the case.

Obsidian is too widespread and plentiful to be of much value, but it has been used for mourning jewellery in much the same way as jet; it can always be distinguished from the latter by its colder feel. Other black minerals, *e.g.*, tourmaline, have a higher specific gravity, and show other points of difference which will at once suggest themselves.

Obsidian was much employed by the ancient Mexicans, and a core is shown from which were stripped off flakes to be used as knives and various weapons, such as arrow-heads, points for lances, &c.

Obsidian is found at many localities, *e.g.*, Lipari, various parts of America, and Mexico—the source of some of the specimens shown here.

The brown obsidian, occurring as balls in the Marekana River, Siberia, is interesting, and is illustrated here both by rough specimens and a cut stone.

MOLDAVITE (Case Q).

Hardness, 5½. Specific Gravity, 2·36.
Singly refracting.

This substance has already been referred to in connection with chrysolite, and specimens are exhibited here. It has a dark-green colour and has many of the physical characters of a glass, but there are one or two points against its being an artificial product. Thus it contains much more silica than any glass made at the present time, and it carries no potassium and very little calcium. It is fusible with difficulty to a clear mass and does not exfoliate in the same way as obsidian.

The origin of moldavite has been the subject of much discussion; but after an elaborate study of its peculiar surface-markings and other characters Dr. Franz E. Suess concludes that it is a meteoric substance. The chief locality is in Bohemia where it is found in the soil; the value of cut stones is very small.

LAPIS-LAZULI (Case R).

Hardness, 5½. Specific Gravity, 2·4.

This stone has been used for ornamental purposes from early times and it was known to the ancients as sapphire. It is characterized by its beautiful colour which, in the best specimens, is a uniform dark-blue of extraordinary depth and intensity. Material of this description is, however, rare, and paler tints—sometimes with a tinge of green—are common, whilst white veins and patches often give the specimen a mottled appearance. The bowl in the case illustrates these points well. One or two of the polished slabs show glistening spangles of iron pyrites scattered over the surface; they give a not unpleasing effect, although, by decomposition, they are apt to make the specimens unsightly.

Lapis-lazuli is practically opaque and is consequently never facetted. It has a poor lustre and appears quite dull except on a polished surface. It shows no cleavage and breaks with a splintery fracture displaying a finely granular structure on the broken surface. When examined closely with a lens, or even with the unaided eye, lapis-lazuli appears to be really a mixture of different substances and not a homogenous mineral, a fact which is proved by microscopic and chemical examination. When thin sections are looked at under the microscope they are seen to consist of a matrix of calcite in which are imbedded numerous grains, some of which are colourless whilst others show various shades of blue.

Chemical examination has proved that the grains really comprise three different minerals:—(a) *hauyne,* a silicate of sodium, calcium and aluminium, with sodium sulphate, (b) *lazurite,* a silicate of sodium and aluminium with sodium sulphide, and (c) *sodalite,* a silicate of sodium and aluminium with sodium chloride. In addition to these three minerals there are of course the inclusions of iron pyrites mentioned above, and also grains of hornblende and augite.

The colour, however, depends entirely on the presence of hauyne, lazurite and sodalite, and as the proportions of these vary so does the colour, and the percentage composition of the stone.

Lapis-lazuli is used chiefly for small ornaments such as bowls and vases, though good specimens are sometimes cut with a flat surface and mounted in rings and brooches. Chinese and Egyptian carvings in this stone are exhibited here. It has been applied to the decoration of the interior of buildings, notable examples being the palaces of the Tsars in St. Petersburg. Large, well coloured specimens are now somewhat rare and vases are no longer turned out of the solid rock. The lapis-lazuli in most of the modern ornaments is simply a thin veneer cemented on to metal. Lapis-lazuli was formerly employed in the production of the ultramarine of the artist. For this purpose the rock was powdered, washed, and the blue minerals carefully separated. The pigment so obtained was exceedingly expensive but now an artificial product, having the same composition as the lazurite mentioned above, is prepared by fusing up a mixture of clay, carbonate of soda and sulphur. Examples of the natural and of the artificial ultramarine are placed side by side.

Lapis-lazuli is always found in association with limestone which has been impregnated by the action of some igneous intrusive rock. The chief locality is Badakschan, in Afghanistan, which is the source of most of the specimens shown here. It is also found at the westerly end of Lake Baikal, and in the Andes, Chili.

A blue artificial paste, and agate, stained artificially, may be confused with lapis-lazuli, but they are both heavier, whilst the agate is, of course, much harder.

EPIDOTE (Case R).

Hardness, 6½.	Specific Gravity, 3·5-3·36.
Doubly refracting.	Refractive Index, 1·77-1·73.

This mineral is more noted for the size and perfection of its crystals than for its use as a gemstone, which is exceedingly limited. It consists of a silicate of calcium and aluminium in which a proportion of the aluminium is replaced by iron; a certain amount of water is also present.

The crystals belong to the monoclinic system, and, as can be seen from the specimens shown here, are sometimes quite large. They are commonly prismatic with the faces deeply striated parallel to the greatest length, and with two directions of cleavage parallel to two faces of the prism. The colour varies with the amount of iron, and a characteristic shade is that known as pistachio-green, but dark-green, brownish-green, and black varieties are common, whilst a small cut stone of a clear yellow colour is shown. A notable feature in epidote is the dichroism which is of the most pronounced type; the two images seen in the dichroscope are coloured respectively green and dark-brown. Most of the crystals are too opaque for cutting, but when specimens of sufficient transparency are found they are cut in steps or as flat tables. They can be easily confused with dark-green tourmaline, but the epidote is heavier and softer.

A noteworthy locality is the Knappenwand, in the Unterzulzbachthal, Tyrol, which is the source of many of the large crystals in the collection. Here the epidote occurs as crystals lining the cavities of a rock known as epidotic schist, and associated with calcite, asbestos, adularia, &c.

AXINITE (Case R).

Hardness, 7-6½.	Specific Gravity, 3·29-3·27.
Doubly refracting.	Refractive Index, 1·69-1·68.

This mineral is only very occasionally cut as a gemstone, partly on account of the scarcity of transparent material, and partly owing to the thin platy form of the crystals which precludes the cutting of any but rather small stones from them. It has a complex composition and consists largely of a boro-silicate of aluminium and calcium with varying amounts of iron and manganese to which the clove-brown colour is probably due. The crystals belong to the triclinic system, and, as can be seen on most of the specimens here, have exceedingly acute edges. They are usually clove-brown or plum-coloured, and are quite lustrous. The dichroism is strong and the images in the dichroscope may be violet and green or violet and brown according to the direction in which the stone is viewed. This property is sufficient to distinguish it from any stone with which it might be confused.

Axinite is sometimes cut *en cabochon*, but the specimen shown here is facetted.

Many of the finer crystallized examples exhibited here came from St. Cristophe, Bourg d'Oisans, Dauphiné, where they occur in gneiss associated with albite, quartz and prehnite.

IOLITE (Case R).

Hardness, 7¼.	Specific Gravity, 2·65-2·60.
Doubly refracting.	Refractive Index, 1·55-1·54.

This mineral is also known as *cordierite* or *dichroite*, whilst the stones fashioned from it are sometimes called *water-sapphire*.

In composition, iolite is a silicate of aluminium and magnesium with water, and with part of the magnesium replaced by iron in the ferrous state. It is found in granitic and schistose rocks as large rough crystals belonging to the rhombic system, but they, as shown by the specimens here, are usually too dull and opaque for ornamental purposes. At one or two localities, however, material of sufficient transparency for cutting is found, and a few polished specimens are shown here. The prevailing colour is blue, due probably to the presence of the iron referred to above, but much depends on the direction in which the stone is viewed, as the dichroism of iolite is exceedingly strong, and has given rise to the name *dichroite* already mentioned. In one direction a good transparent example appears of a fine deep-blue tint, in another direction, at right angles to the former, it has a pale-yellow colour, whilst in yet a third direction, perpendicular to the first two, it appears almost white. Hence, as in tourmaline, it is very important to place the table of a cut stone, so that an observer looking through it may get the fine, intense blue colour, *i.e.*, the table must be cut as nearly as possible, perpendicular to the first of the three directions enumerated above.

Apart from its remarkable dichroism, iolite shows no property of note. Its hardness, refractive index and specific gravity are low, and its lustre is vitreous, inclined to greasy.

The low specific gravity distinguishes it at once from blue tourmaline and from sapphire.

Examples are shown from Bodenmais in Bavaria, but most of the iolite used for gem-purposes occurs as rolled pebbles in the gravels of Ceylon.

The minerals of the *Pyroxene group* (Case R) are important as constituents of rocks rather than as gemstones, but several of them possess characters sufficiently interesting and beautiful to justify their employment for decorative purposes. The members of this group are silicates with a general similarity of constitution, whilst they crystallize in forms, which though not identical throughout the whole series, yet show strong resemblance in angles and in directions of cleavage.

The pyroxenes which have been employed as ornamental stones are, *bronzite, hypersthene, rhodonite, spodumene, jadeite,* and *diopside.* Examples of these are shown in this case, and in the one following.

Bronzite (specific gravity 3·2) and *hypersthene* (specific gravity 3·4) crystallise in the rhombic system, and are noteworthy for the metallic sheen which they exhibit when a specimen is cut and polished in a definite crystallographic direction. The sheen, or *schiller,* is caused by the parallel arrangement of platy inclusions along the particular plane. Bronzite is brown in colour, and the specimen exhibited shows a cat's-eye effect on the rounded surface, caused to some extent by the semi-fibrous structure. In hypersthene, the polished surface has a darker colour, and the sheen has quite a coppery appearance. They are both silicates of magnesium with iron, but the percentage of the latter metal is greater in hypersthene than in bronzite, a fact which accounts for its darker colour and higher specific gravity.

Hypersthene comes chiefly from Labrador where it is found associated with labradorite (p. 77), whilst the specimens of bronzite came from Kraubat, Styria, where serpentine is the parent rock.

Rhodonite (specific gravity 3·4-3·68; hardness 5-6) is a silicate of manganese and crystallises in the triclinic system, but it is the fine-grained massive variety which is cut, polished and made into ornaments of various kinds, *e.g.*, boxes, vases, &c.

The mineral has an attractive, rose-red colour, which is, however, sometimes marred by streaks of black due to alteration. Rough and polished specimens are exhibited from Wermland, Sweden.

SPODUMENE (Case R).

Hardness, 7-6½.	Specific Gravity, 3·20-3·15.
Doubly refracting.	Refractive Index, 1·68-1·65.

This member of the pyroxene group consists of a silicate of lithium and aluminium, and crystallises in the monoclinic system. The crystals are prismatic and usually flattened parallel to one of the prism faces, whilst they exhibit two directions of perfect cleavage, approximately at right angles and running parallel to two other faces of the prism. Spodumene is found typically in pegmatite veins and has commonly a dull, almost earthy appearance, and a rather pale, undecided tint; the rough crystal from Chesterfield, Massachussetts, illustrates this well.

Transparent material is confined to a few localities, mostly in the United States, and is divided into the two colour-varieties, *hiddenite* and *kunzite*.

Hiddenite (or *lithia emerald*) is the transparent green to yellow variety which forms an effective gemstone when cut and polished. The green crystals are usually quite small and have been found at only one locality, viz., Stony Point, Alexander County, North Carolina, where they occur with other minerals in the cavities of pegmatite. They have a good lustre and show remarkably strong dichroism, the images in the dichroscope being yellow, and deep-green respectively.

Cut specimens of hiddenite have been confused with emerald and with diopside (q.v.), but the higher specific gravity of hiddenite distinguishes it from the former, whilst the strong dichroism should prevent any confusion with the latter, which is not dichroic.

The yellow variety, illustrated here by a cut stone and rough specimens, comes from Minas Novas, Brazil. It has a strong resemblance to chrysoberyl (p. 60), but is much softer and lighter.

Kunzite is transparent spodumene of lilac-red, violet, or pink colour; the fine cut specimen presented by Messrs. E. Hahn and Company, shows an attractive appearance, although the shade is somewhat pale.

Kunzite is confined to California, where it has been found in large crystals, from some of which very fine gems have been cut. Like hiddenite, it exhibits strong dichroism in the more deeply tinted specimens, and it shows strong luminescence when placed between the poles of an electric machine, or when subjected to the influence of radium emanations.

Kunzite bears a strong resemblance to pink topaz, but it is softer and lighter.

JADEITE (Case R).

Hardness, 7-6½. Specific Gravity, 3·4-3·3.

This mineral has been used from early times for the fashioning of implements and objects of various kinds, and, at the present day, is employed extensively by the Chinese as a medium for all manner of carvings executed with wonderful skill and much appreciated by European collectors.

Jadeite belongs to the pyroxene group and consists essentially of a silicate of sodium and aluminium, and may be regarded as spodumene in which the former metal replaces the lithium. Frequently however, there are traces of other metals, such as calcium, magnesium, iron, chromium and manganese, the last three of which impart the colours seen in some of the specimens in the case. Jadeite is never found in crystals but always as compact, fine-grained and exceedingly tough masses which exhibit a splintery fracture and which sometimes show a tendency to split into plates. The colour is usually white or gray, but various shades of green are not infrequent, and of these the emerald-green, and dark-green are much esteemed by the Chinese. The large boulder in the case shows a mottled appearance with green spots on a white background, and a polished plate, having a very pale, amethystine tint is also shown; a red or pink jadeite has also been recorded. The fine emerald-green colour has been ascribed to chromium, whilst iron is the cause of the other tints, with the exception of the amethystine one which is possibly due to manganese. Jadeite is translucent to opaque and never transparent, whilst the lustre is vitreous and inclined to greasy. Thin sections examined under the microscope are seen to consist of an aggregate of fibrous, interlocking crystals of pyroxene; to this matted structure is due the extraordinary toughness of this mineral, which is greater, even, than that of steel. It is practically impossible to break up a rounded block of jadeite with a hammer, and the method usually adopted is to heat it up to a fairly high temperature and then to pour water over it. Jadeite fuses readily before the blowpipe and colours the flame bright yellow, but these and other properties will be referred to when *jade*, or *nephrite*, another mineral, with which it is almost invariably confounded, comes to be discussed.

Implements of prehistoric age fashioned out of this mineral have been found at various, widely separated localities, but the original sources of the material have not yet been discovered. The only locality where jadeite is found *in situ* is in the Kachin Hills, Upper Burma, where it is extensively quarried and exported to China. Here the mineral occurs, according to the latest view, as an intrusive dyke in serpentine, and associated with albite, chlorite, and amphibolite.

DIOPSIDE (Case S).

Hardness, 6. Specific Gravity, 3·3.
Doubly refracting. Refractive Index, 1·70-1·67.

This mineral is occasionally cut as a gemstone and a few typical specimens are shown here. It belongs to the pyroxene group and consists of a silicate of calcium and magnesium with part of the latter metal replaced by iron in the ferrous state. The colour—which is due to the presence of iron—varies from a very pale-green to a deep bottle-green, and crystals are found with the parts near the point of attachment to the matrix deeply coloured, whilst the free end is quite pale to almost colourless; an example of this is shown. The crystals belong to the monoclinic system, are prismatic, and show the two directions of cleavage characteristic of the pyroxene group. They frequently are of fair size, but the larger specimens are usually flawed, and most of the transparent gem-material is supplied by the smaller ones.

Dichroism is quite unobservable in the lighter varieties, and is very faint in the more deeply coloured ones, so that this property is useful in distinguishing diopside from other stones which are appreciably dichroic; the lustre is of the usual vitreous type.

Diopside is usually step cut, and a specimen cut *en cabochon* is shown here. The particular crystals above referred to occur in a chlorite schist at Schwarzenstein, in the Zillerthal, Tyrol, whilst pale-green diopside, as already mentioned, accompanies the essonite in the cavities of serpentine at Ala, Piedmont. To distinguish between this stone and chrysolite is difficult, as they both have weak dichroism and similar specific gravity; chrysolite is however harder, and if anything, shows slightly more dichroism.

JADE OR NEPHRITE (Case S).

Hardness, 6½-5½ Specific Gravity, 3·0-2·9.

This mineral belongs to the amphibole or hornblende group of minerals and consists of a silicate of calcium and magnesium with a certain amount of iron which is responsible for the colours seen in many of the specimens in the case. Jade bears a strong resemblance to jadeite in general appearance and in being extremely tough, and it appears to have been applied in the same way by early man for the fashioning of weapons and objects. Formerly the name "jade" included them both, but careful chemical and microscopic examination disclosed the fact that under this name two distinct minerals were included; even yet this is not generally appreciated and the name "jadeite" is seldom used by collectors. It may be of interest to summarize briefly the essential differences between the two minerals:—

	Jade.	*Jadeite.*
Hardness	5½–6½	6½–7.
Specific Gravity ...	2·9–3·0	3·3–3·4.
	Fusible with difficulty.	Easily fusible.
	Does not colour the flame yellow.	Colours the flame yellow.
Composition ...	A silicate of calcium and magnesium.	A silicate of sodium and alumium.

When examined in thin sections under the microscope, jade is seen to be built up of interlocking fibres, which, however, do not show the properties of pyroxene, but of amphibole. Thus in cross-section the fibres have cleavage cracks intersecting, not at 90°, or thereabouts, as in jadeite, but at 120°, and there are numerous other differences, for an account of which the student is referred to any book on mineralogy.

From the foregoing account it will be seen that, when dealing with rough specimens, the differences between jade and jadeite can be easily established. Much of the material, however, comes to Europe in the form of carvings on which it is impossible to make any test except that of specific gravity, and even that is debarred if the specimen is a large one; such carvings are invariably sold as jade, and, as the materials are equally prized, no great harm is done.

In external appearance jade bears a strong resemblance to jadeite. It shows all colours from pure white to various shades of green, has a somewhat greasy lustre and is translucent to almost opaque. The white variety has little iron and may be regarded as a compact tremolite, whilst the darker ones have a greater content of iron and may be regarded as compact actinolite (specimens of these minerals will be found in the case). Various minerals have been confused with jade, amongst which may be mentioned green serpentine (Case U); this is, however, much softer, and can be easily scratched with a knife, whilst jade resists steel.

The best known localities for jade are in Eastern Turkestan, and specimens are shown from the old quarries lying in the valley of the Karakash, in the Kuen Lun Mountains. Here the jade was found as a layer 20 to 40 feet in thickness associated with gneiss, but the quarries seem to be exhausted. Numerous other localities exist in the neighbourhood of these mountains, and jade pebbles are found in many of the adjoining river-beds, and in detrital deposits which are exploited. The material goes to China where it is worked into most intricate and beautiful carvings, examples of which are shown here. Specially noteworthy is the fine flower vase carved in green jade and mounted on an ivory stand.

New Zealand is also a well known locality which is represented here by a good suite of specimens. The Maoris seem to have appreciated this mineral at an early date and have utilized it for making weapons and ornaments of various kinds. New Zealand jade has, typically, a rich green colour, and is found both as rolled pebbles in the rivers and as deposits *in situ* in schist, and in serpentine at one or two places in South Island. Examples of the rough material are shown, whilst the way in which the Maoris work it is illustrated by a very fine *tiki*, or idol, a large *adze*, and several ear-pendants.

Siberia is also represented here by a small polished slab, whilst in the lower part of Case XVI. a fine green boulder is shown. The latter came from the Sajan Mountains, west of Lake Baikal, where the jade occurs as blocks, often of considerable size, in alluvial deposits. Pebbles are shown from India, but the occurrence here is unimportant, whilst a specimen is also shown from Jordansmuhl, in Silesia, where the jade occurs as a thin layer between serpentine and granulite.

SERPENTINE (Case U).

Hardness, 4 (about). Specific Gravity, 2·65-2·5.

This material is, properly speaking, a rock, but, as it is used for ornamental objects, *e.g.*, vases and columns, and as it is sometimes substituted for jade and jadeite, a short description of its properties may be useful. Serpentine consists of a hydrated silicate of magnesium and usually carries more or less iron. It shows very fine colours which may be green, red, brown, &c., and masses often are mottled in a very beautiful manner (*c.f.*, the specimens in the case and the columns and ornaments in the Hall). Green serpentine is very often passed off as "jade," but the two can be easily distinguished by the test for hardness; serpentine yields readily to the knife whilst jade does not.

Serpentine has usually resulted from the alteration of rock-masses rich in *chrysolite* or *olivine*. This mineral, as already pointed out, consists of a silicate of magnesium and iron, and it is easily decomposed into serpentine and magnetite, *i.e.*, magnetic oxide of iron, a mineral which is usually present as opaque black granules in the altered mass. Such is the origin of the serpentine which occurs in large masses at the Lizard, Cornwall, where it is worked into ornaments, examples of which are shown here.

TURQUOIS (Case X).

Hardness, 6. Specific Gravity, 2·8-2·6.

This mineral consists of a hydrous phosphate of alumina coloured by copper which is present in varying quantities; small amounts of iron, also, are frequently revealed by analysis. It is quite opaque and consequently does not show any of the properties, *e.g.*, refraction, dispersion, double refraction, dichroism, which are usually associated with a highly esteemed gemstone. Turquois is valued for its colour alone, which, in the best and rarest specimens, is an intense sky-blue, but is usually much paler, whilst many stones are quite green; in fact this mineral exhibits a whole series of tints ranging from the highly-prized deep-blue, through paler shades to greenish-blue, from that to apple-green, and finally to pale, greyish-green. It not infrequently happens that a deeply coloured specimen tends to become much paler when exposed to sunlight, and stones that possessed a fine colour in the moist surroundings of the mine often become bleached and valueless when brought to the surface and dried. The original colour can be temporarily restored by placing such turquois in damp earth, and this trick is sometimes resorted to in order to deceive intending purchasers. Immersion in a solution of ammonia will sometimes restore the blue colour to a stone which has become green, but, as in the former case, the improvement is not permanent. Pale turquois is sometimes stained blue in the same way as agate (p. 51), but, if a drop of ammonia be placed on the back of such a stone, the spot becomes green or colourless, and the device is thus easily detected.

Turquois is never found in crystals but always as amorphous masses filling veins or cavities in the mother-rock, which may be igneous or sedimentary. When, however, thin sections are examined under the microscope, they are seen to consist of innumerable grains or fibres which are doubly refracting and consequently crystalline; like chalcedony, turquois is micro- or cryptocrystalline. The hardness is low for a gemstone, but turquois will always scratch glass, although it yields to a file.

When heated in a closed tube turquois decrepitates violently, loses its colour and falls to powder, whilst the artificial material already described (p. 33) fuses quietly.

Most of the specimens shown here are cut *en cabochon*, but flat stones are exhibited engraved with gilt characters, a method of treatment which is especially common in eastern countries where the turquois is highly prized.

Most of the well known localities for this mineral are illustrated here and a good series is exhibited from the Sinai Peninsula. The specimens came from the Wadi Meghara and were presented by Major C. K. Macdonald who rediscovered the ancient workings at that place. Here the turquois occurs filling seams and cavities in a ferruginous sandstone.

Persia has long been noted for its turquois, the best known mines being situated in the province of Khorassan, and in the district of Nishapur. The village of Maaden is the centre of the mining, and the home of turquois is here a porphyritic trachyte which pierces limestones, sandstones and slates. In places this trachyte forms a breccia cemented by limonite, and the precious material occurs in intimate association with the iron ore.

The detrital deposits derived from the weathering of the igneous rock are also exploited and here the turquois is found with a colourless or greyish weathered crust enclosing a kernel of material of good colour.

New Mexico has also furnished good stones and specimens are shown from Mount Chalchihuitl, Los Cerillos, Santa Fé Co., where the turquois is found in porphyritic andesites which have been bleached and mineralized by the influence of volcanic vapours. Other places in this state have also yielded turquois, notable amongst them being Burro Mountains, in Grant Co., where it occurs in a decomposed granite, and also in the Jarilla Mountains in Otero Co., where trachyte is the parent rock.

One or two stones are placed here which resemble turquois in composition and are sometimes confused with it.

Variscite (hardness, 4; specific gravity, 2·4) is a hydrated phosphate of aluminium having an apple-green or emerald-green colour. It has a vitreous lustre, takes on a good polish, and has sometimes been cut *en cabochon* for jewellery. It can be distinguished from turquois by its lower hardness and specific gravity. Specimens are shown from Utah, U.S.A., where the variscite occurs as nodules in a crystalline limestone.

Odontolite is simply fossil-bone stained blue or green by phosphate of iron. It can be distinguished from turquois by the fact that it is heavier and softer and shows traces of organic structure.

APPENDIX.

In order that the determination of the more important precious stones may be facilitated, a few tables have been inserted here. The stones have been classified according to colour and have then been arranged in order of specific gravity; other physical constants have been tabulated as it is necessary that some of these should be determined before any conclusion is arrived at as to the identity of a specimen. Only the transparent stones have been tabulated as it is with these that difficulty usually arises. The translucent and opaque stones, with one or two exceptions, can be readily determined sometimes by mere inspection.

Table I.

Colourless Stones.

Stone.	Specific Gravity.	Hardness.	Refraction.	Refractive Indices.
Zircon	4·7	7½	double	1·97–1·92
Corundum	4·0	9	double	1·77–1·76
Topaz	3·56–3·50	8	double	1·63–1·62
Diamond	3·53–3·52	10	single	2·43
Tourmaline	3·04	7¼	double	1·64–1·62
Phenacite	2·96	7¾	double	1·68–1·66
Beryllonite	2·84	6	double	1·56–1·55
Beryl	2·71–2·68	7¾	double	1·58–1·57
Rock-crystal	2·65	7	double	1·56–1·55

Table II.

Red and Pink Stones.

Stone.	Specific Gravity.	Hardness.	Refraction.	Refractive Indices.	Dichroism.
Zircon	4·7	7½	double	1·97–1·92	not observable.
Almandine ...	4·3–4·0	7¼	single	1·77	absent.
Ruby	4·0	9	double	1·77–1·76	distinct.
Pyrope	3·8–3·7	7¼	single	1·80	absent.
Spinel	3·65–3·60	8	single	1·72	absent.
Topaz	3·56–3·50	8	double	1·63–1·62	distinct.
Kunzite	3·18	7–6½	double	1·68–1·65	strong.
Tourmaline ...	3·05	7¼	double	1·64–1·62	strong.
Beryl	2·71–2·68	7¾	double	1·58–1·57	weak.
Fire Opal ...	2·2	6	single	1·45	absent.

Table III.

Yellow and Brown Stones.

Stone.	Specific Gravity.	Hardness.	Refraction.	Refractive Indices.	Dichroism.
Zircon	4·7–4·4	7½	double	1·97–1·92	not observable.
Oriental Topaz ...	4·0	9	double	1·77–1·76	weak.
Chrysoberyl ...	3·8–3·64	8½	double	1·76–1·75	weak.
Essonite ...	3·65–3·63	7¼	single	1·76	absent.
Topaz	3·56–3·50	8	double	1·63–1·62	distinct.
Epidote	3·5–3·36	6½	double	1·77–1·73	strong.
Sphene	3·45–3·35	5½	double	2·06–1·91	distinct.
Idocrase	3·4–3·3	6½	double	1·720–1·718	weak.
Axinite	3·29	7–6½	double	1·69–1·68	strong.
Spodumene ...	3·20–3·15	7–6½	double	1·68–1·65	weak.
Andalusite ...	3·18	7½	double	1·64–1·63	strong.
Tourmaline ...	3·10	7¼	double	1·64–1·62	strong.
Beryl	2·71–2·68	7¾	double	1·58–1·57	weak.
Smoky Quartz ...	2·65	7	double	1·57–1·56	distinct.

Table IV.

Green Stones.

Stone.	Specific Gravity.	Hardness.	Refraction.	Refractive Indices.	Dichroism.
Zircon	4·40–4·00	7½	double	Variable; go as low as 1·86.	not observable.
Oriental Emerald	4·00	9	double	1·77–1·76	distinct.
Demantoid ...	3·86–3·83	6½–6	single	1·90	absent.
Alexandrite ...	3·80–3·64	8½	double	1·76–1·75	strong.
Epidote	3·50–3·36	6½	double	1·77–1·78	strong.
Idocrase	3·40–3·30	6½	double	1·720–1·718	weak.
Chrysolite ...	3·40–3·30	7–6½	double	1·70–1·66	weak.
Diopside	3·30	6	double	1·70–1·67	very weak.
Hiddenite ...	3·20–3·15	7–6½	double	1·68–1·65	distinct.
Andalusite ...	3·18	7½	double	1·64–1·63	strong.
Tourmaline ...	3·10	7½–7	double	1·64–1·62	strong.
Euclase	3·10–3·05	7½	double	1·67–1·65	distinct.
Emerald	2·71–2·68	8–7½	double	1·58–1·57	distinct.
Aquamarine ...	2·71–2·68	8–7½	double	1·58–1·57	distinct.

Table V.

Blue Stones.

Stone.	Specific Gravity.	Hardness.	Refraction.	Refractive Indices.	Dichroism.
Sapphire... ...	4·0	9	double	1·77–1·76	strong.
Kyanite... ...	3·68–3·60	7–5	double	1·73–1·72	distinct.
Benitoite ...	3·65–3·64	6½	double	1·80–1·76	strong.
Spinel	3·65–3·60	8	single	1·72	absent.
Topaz	3·56–3·50	8	double	1·63–1·62	weak.
Tourmaline ...	3·1	7½–7	double	1·64–1·62	strong.
Beryl	2·71–2·68	7¾	double	1·58–1·57	weak.
Iolite	2·65–2·60	7½–7	double	1·55–1·54	strong.

Table VI.

Purple and Violet Stones.

Stone.	Specific Gravity.	Hardness.	Refraction.	Refractive Indices.	Dichroism.
Almandine ...	4·3–4·0	7¼	single	1·77	absent.
Oriental Amethyst	4·0	9	double	1·77–1·76	distinct.
Spinel	3·65–3·60	8	single	1·72	absent.
Kunzite	3·18	7–6½	double	1·68–1·65	strong.
Amethyst ...	2·65	7	double	1·56–1·55	distinct.

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[March, 1912.]