## INCLUSIONS IN DIAMONDS

by E. Gubelin, Ph.D., C.G., F.G.A.

INCLUSIONS in diamond have not attained their rightful recognition. That gemmologists have not brought them into the limelight may be due to the fact that the diamond has been regarded as being free from inclusions of particular interest, except for what is known in the diamond trade as " carbon spots," " feathers," and " cracks," and the absence of any form of synthesis was also responsible for the lack of interest in investigating the characteristic inclusions in diamond. The term " carbon spots " may have a double meaning ; according to Mr. B. W. Anderson, any inclusion consisting of carbon or a carbonaceous compound may be logically called a " carbon spot," be it a diamond or graphite. In the French and German translation it refers to and means " coal." I am convinced that coal never occurs in diamond whereas carbon inclusions in either of the dimorphous forms of graphite or diamond may be found quite frequently.

Indeed, black specks, " carbon spots " as they are termed in the diamond trade, are so plentiful that I decided to delve into the study of these inclusions, and consequently found most of them to be either amorphous aggregates or broken particles of the original magma or any of the minerals subsequently referred to. It may be mentioned that in bad light almost any inclusion in diamond appears
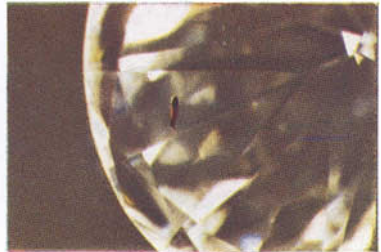
INCLUSIONS IN DIAMONDS
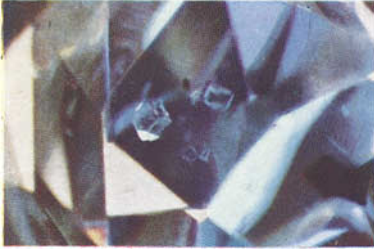
DIAMOND 1
Diamonds included in diamond

DIAMOND 2
Enclosed garnet crystal

DIAMOND 3
Enclosed enstatite crystal

DIAMOND 4
Enclosed garnet crystal

DIAMOND 5
Enclosed enstatite crystals

DIAMOND 6
Enclosed zircon crystal

DIAMOND 7
Three Generations
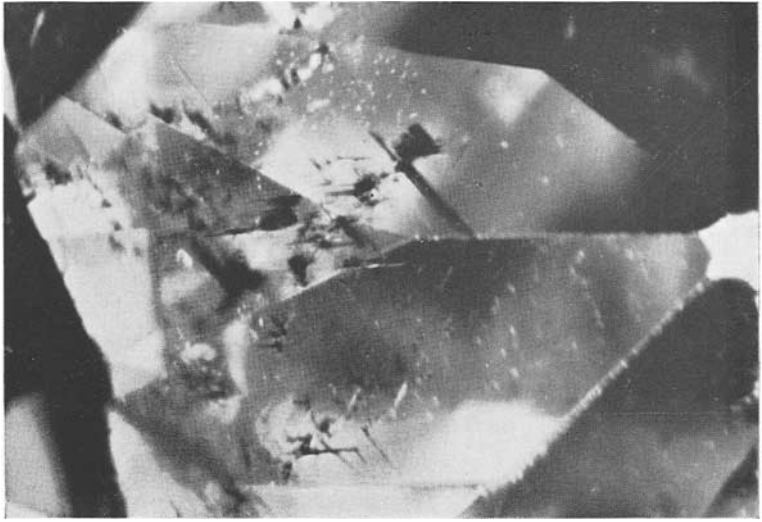
DIAMOND 8
Three Generations

Photo micrographs: E. Gubelin.

black ; diamonds should always be examined in the best available light, preferably in dark-ground illumination which really causes the inclusions to reveal their true nature. The most common inclusion in diamond is a black mineral, which may be graphite or some ore, such as hematite, magnetite or ilmenite, but besides these there are many other colourless, transparent or coloured inclusions which are much more intriguing.

Diamond inclusions may be classified in the same groups as the inclusions in other gemstones. Thus we have solid, fluid and gaseous inclusions, and with reference to the time of formation of the host diamond we may discern inclusions which were formed either before the diamond was born (known as pre-temporary), or at the same time as the diamond (con-temporary), or after the diamond was completed (post-temporary inclusions).

Since the purport of this paper is to discuss critically the so-called " carbon spots," particular concentration will be focused on the solid inclusions. Solid inclusions may be either particles of the original magma, as already stated, or crystallized bodies. The amorphous particles of the magma appear as shapeless, irregular grains, crumbs, clusters or lumps of black colour. Sometimes they are surrounded by cracks due to strain, which may also appear black when the diamond is so inclined as to cause the transmitted light to be totally reflected on the crack. As to the type of mineral inclusions in diamond, one can expect to encounter any of the accessory minerals present in the original magma. There is strong evidence that some diamonds had crystallized out of the magma before eruption and occasionally even before the consolidation of the peridotite and pyroxenite rocks, because diamonds are sometimes found in these rocks. Furthermore, it has been ascertained that the majority of carbon, in some form or other and under conditions in which it could crystallize into diamond, remained in the magma long after the solidification of the peridotite and pyroxenite rocks. Therefore we may find mineral inclusions which are con-temporary in the first born diamond and pre-temporary in the younger diamonds. This may account for the fact that we encounter both well-developed, euhedral and on the other hand xenomorphous, worn or broken specimens of the same mineral species, e.g. zircon and garnet, within diamond.

Investigations have proved that many of the solid inclusions in

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Masses of stalked crystals of graphite in a diamond from
South Africa. 100 ×
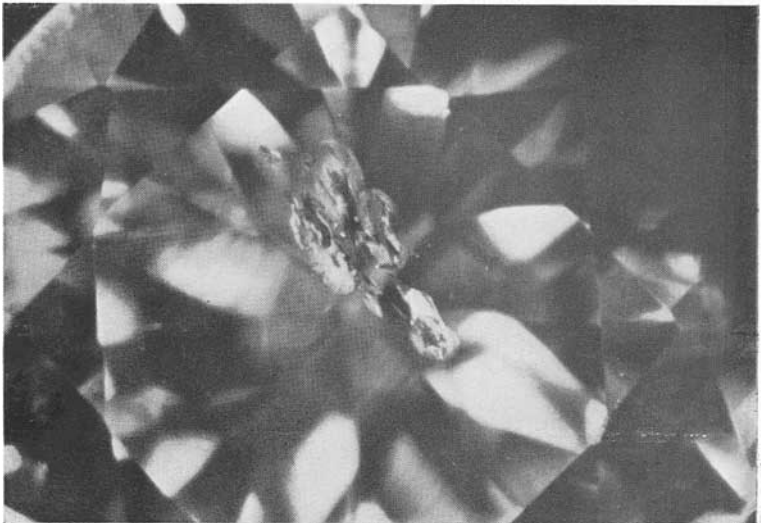
Crushed particles of the magma. They form irregular
black crumbs which may be mistaken for "coal"
inclusions. 75 ×

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the diamond are those occurring as primary crystals in the magma from which the diamond crystallized ; these solid inclusions were probably present in the magma before its eruption and its eventual consolidation into the rock now called Kimberlite. It is therefore only reasonable to assume that among the pre-temporary solid inclusions occurring in diamond we may expect to find those minerals which crystallized out of the magma before eruption, and in addition to graphite there are garnet, magnetite, chlorite, enstatite, chrome-diopside and biotite inclusions ; olivine, phlogopite, and zircon also belong to this group. These pre-temporary inclusions may be recognized on account of their strongly xenomorphous, resorbed, worn or broken bodies. Sometimes they are covered with some black foreign substance which may be graphite, chlorite or crusts of the original magma.

That many inclusions crystallized out of the magma at the same time as the formation of the diamond took place is unequivocal, because it is not uncommon to find diamonds with inclusions of both garnet and chrome-diopside, while, on the other hand, garnet and chrome-diopside occasionally occur as host minerals of diamond. These as well as other con-temporary mineral inclusions such as magnetite, ilmenite, hematite, zircon, graphite and perhaps enstatite, usually display well-developed, euhedral crystal habits.

Apart from the minerals referred to above, the diamond itself forms a very important inclusion. There are numerous instances of a diamond crystallizing around another diamond, the inner diamond usually differing in crystal form, orientation and colour from the outer crystal. By far the most common habit is the rounded octahedron ; sharp-edged diamonds as inclusions are less frequent, but '' macles '' have been observed.

The enclosed embryonal diamonds portray all the same crystallographic characteristics, such as growth marks, rounded edges, a frosted surface and even inclusions, exactly as their fully-fledged '' adults '' and mothers. They may vary in colour, but are usually darker than the host diamond. The inner diamonds are sometimes coated or surrounded by some alien black material which may be magma or graphite. The growth of the embryo was not necessarily one continuous process ; in frequent cases the crystallization was interrupted and before it restarted the tiny diamond may have been chemically or mechanically attacked, thus frosting or slightly resorb-
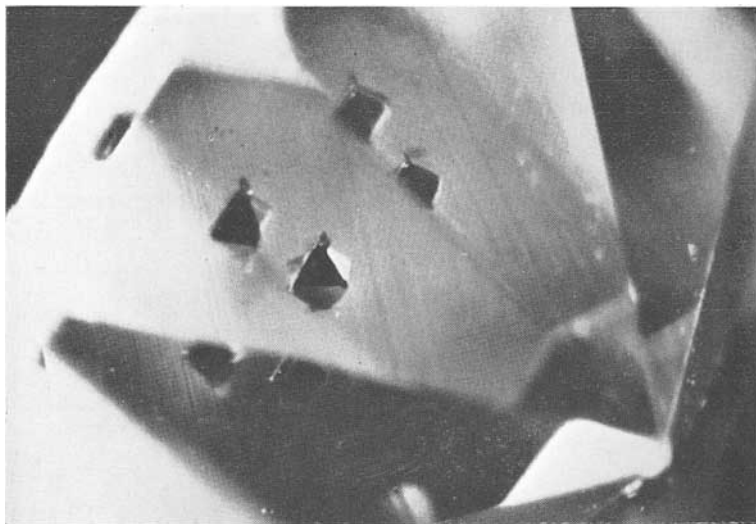
Beautiful, euhedral octahedron of magnetite (mirrored
several times by the facets of the brilliant-cut host
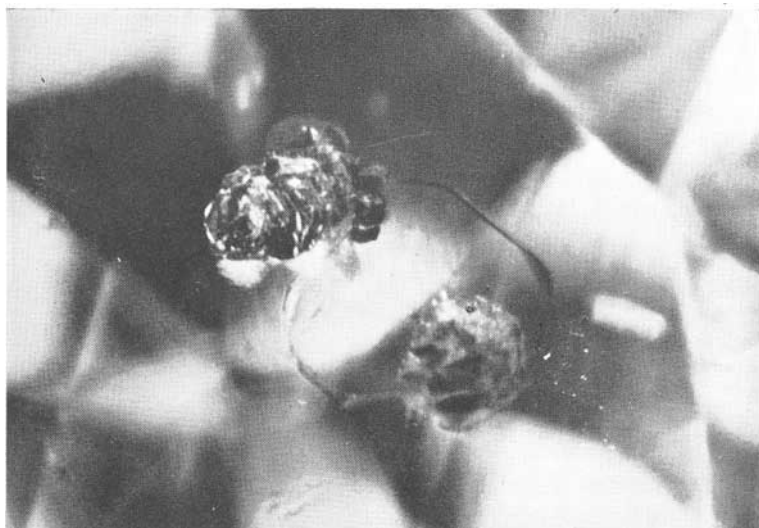diamond) in a diamond.   75 ×
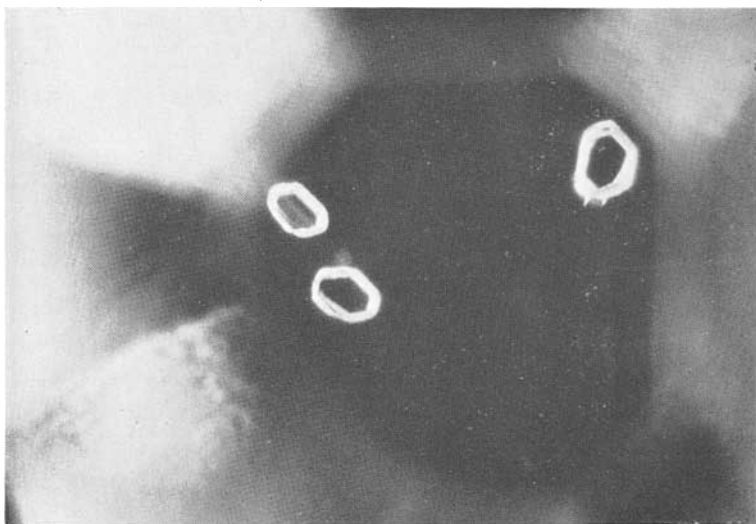
Group of euhedral quartz crystals in a diamond from
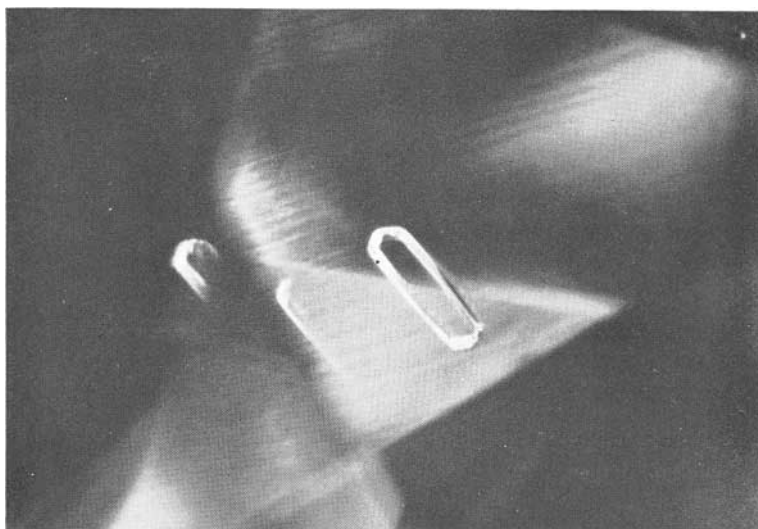Brazil.   75 ×

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ing its body, or it may have been coated with some foreign matter. The formation of the second embracing diamond did not absolutely assume the same crystal habit nor orientate after the crystallographic directions of the primary diamond. The latter, therefore, rarely acted as a seed crystal with regard to the second diamond, but usually was just embedded like any other foreign mineral inclusion. The fact that the included diamond is generally of darker colour may imply that colour, particularly yellow to brown, denotes a greater age. It is a rare but thrilling occasion to meet with a diamond displaying " three generations," so aptly termed by Mr. B. W. Anderson and depicted in the colour plate. The first diamond to crystallize was a yellow specimen, which was shattered before it was enclosed by the second, hemi-octahedral crystal, a so-called " flat " of colourless transparency, both of which were later on re-embedded in a third diamond which grew unmolested to a size sufficiently big to be cut into a brilliant.

Zircon, an inclusion of some significance and of local diagnostic value, which is present in many gemstones, commands special attention as an inclusion in diamond. It may exist as a fresh euhedral crystal or a resorbed broken pebble ; these crystals or pebbles may be associated in groups or occur singly. Of course, the size of the enclosed specimens varies in accordance. Quite often these zircon crystals are found to lie in direct contact with a tension crack or to be embedded in the centre of several such cracks radiating from the zircon into the body of the embracing diamond. It is obvious that the zircon crystal is responsible for such internal strain and ensuing cracks ; usually these fissures are minute and confined to small areas, but in larger diamonds and with bigger inclusions they may be noticed with the naked eye.

Now, diamonds containing solid inclusions of foreign matter are liable to break easily, especially when the inclusion is a zircon, because the zircon has a remarkably higher coefficient of thermal expansion. When the diamond becomes hot on the cutting lap, the enclosed zircon reacts to the transmitted heat by expanding, thus creating strong internal strain which may result in the formation of fissures. Many a diamond cutter remembers the unlucky incident when a diamond exploded while being cut because it could no longer bear its internal tension. Investigations have proved that zircon

Two " iron-roses," one of which is particularly well-developed by forming a long cluster of minute hematite tablets. 75 ×

Well-developed, slender crystal of quartz included in a diamond from Brazil. 40 ×

inclusions mainly occur in African diamonds, yet are absent in Brazilian diamonds.

The garnet found in the kimberlite and in the cognate inclusions—the peridotite and pyroxenite rocks—never shows any crystal faces. In all of these rocks the garnets are enclosed by kelyphitic shells.[1] These rounded garnets are often very badly cracked and in the process of recovery they are broken into sharp-edged irregular pieces. If, as is contended, the diamond crystallized out of the magma in exactly the same way as the garnet, then one would expect to find garnet inclusions in diamonds showing crystal faces and sharp edges. Indeed, careful microscopic research has proved that minute garnet and possibly zircon crystals do occur in diamonds as inclusions and that some of these crystals show smooth faces and sharp edges. Garnet inclusions afford a very characteristic feature of South African diamonds.

The black spots, which are of such frequent occurrence in diamond, must be ascribed to graphite or magnetite or hematite or some other ore.

G. Friedel[2] concluded that they consisted of carbonaceous material, since, when exposed on a cleavage surface, they instantly disappear when touched with a blowpipe flame. This was supported by later experiments of G. Friedel[3], who affirms that the material is graphite. The existence of graphite as an inclusion in diamond proves that conditions prevailed in the same magma which permitted the carbon to crystallize either as diamond or graphite. Whether the conditions were the same and whether the diamond and the graphite crystallized simultaneously is difficult to say. Graphite probably belongs to an earlier phase, for, although graphite exists in diamond, diamond is not known to form an inclusion in pure graphite. Moreover, graphite never displays idiomorphous crystals in the diamond. But then, we know of many a case where an enclosed older diamond was covered by a graphite coating.

J. R. Sutton[4], referring to a special case, mentions that it was the first time he discovered an inclusion that was highly magnetic ; thus the proof was given that magnetite is really a mineral which belongs to the internal paragenesis of the diamond. Magnetite very often gives evidence of Dr. Sutton's findings in that it usually has beautifully preserved its octahedral crystal form even as an inclu-

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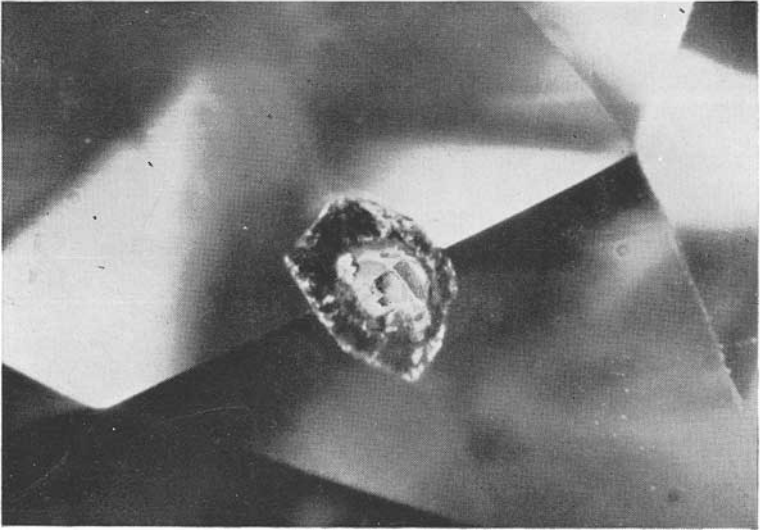
Included crystal of zircon surrounded by a large tension crack. Zircon having a higher coefficient of expansion may often cause the host diamond to crack when it is heated during the process of cutting. 80×

DIAMOND. This interesting picture shows a broken morsel of kimberlite with a diamond octahedron still embedded in its matrix trapped by the secondary diamond. 80×

sion in diamond. In all these cases magnetite may be regarded as a con-temporary inclusion.

Both hematite and ilmenite have also been proved to exist as inclusions in diamond. Of course, besides these minerals just mentioned, black inclusions in diamond may also be formed by the presence of chromite, picotite, ironcarbide or even metallic iron. Dr. Sutton remarks that the black inclusions in diamond are difficult to extract, and the material usually comes out in fragments.

Quartz has never been found as an inclusion in any of the African diamonds, but it has been found in diamonds from Brazil. It may be queried why quartz inclusions should be found in Brazilian diamonds in the face of the fact that the diamonds were formed in ultra-basic magma while the formation of quartz was confined to acid rocks. T. Draper[5] asserts that an ultra-basic magma is not essential to the formation and growth of diamonds and this would appear to substantiate the occurrence of quartz inclusions in diamonds from Brazil and explains why quartz inclusions are found in such stones.

Draper further asserts that in Brazil the formation of diamonds was not necessarily limited to ultra-basic rocks, and this reveals why quartz inclusions do not occur in diamonds from South Africa, where diamonds are only found in ultra-basic rocks.

Besides solid inclusions, it is possible for diamonds to contain gaseous and liquid types. The gaseous inclusions, which are more common than liquid, are usually microscopic bubbles. They usually occur as dense patches and frequently take shapes consistent with growth stages of the crystal. Information about the crystal form of the host crystal which has been lost in cutting can often be obtained by structures formed by dense clouds of gas bubbles settling on a temporary surface during the growth of the diamond.

It is interesting to note that Bauer and Spencer[6] state that: " The enclosures of diamond do not invariably consist of solid matter ; not infrequently there exist cavities in the substance of the diamond which may be vacuous or may contain liquid ; these fluid enclosures are, however, usually of microscopic size. The liquid they often contain does not, as a rule, completely fill the cavity, part of the space being occupied by a bubble of gas, which is sometimes fixed in position and at other times movable, thus clearly indicating the fluid nature of the contents of the cavity. In some
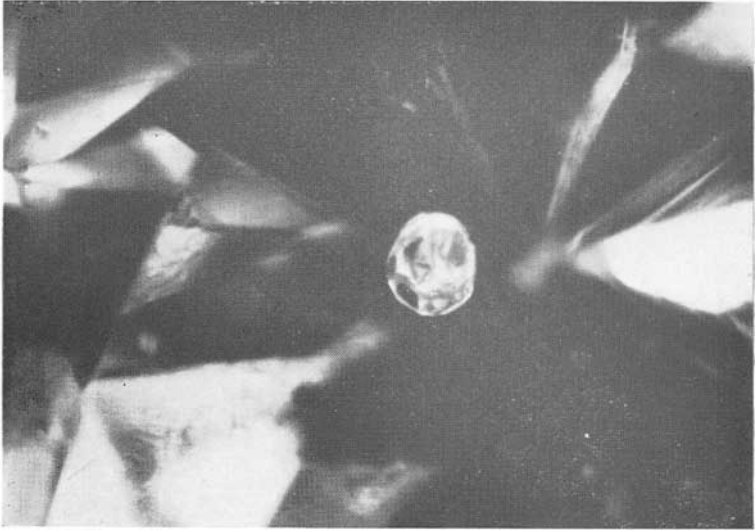
Garnet crystal, which although slightly rounded still
displays euhedral crystal faces.　　It is enclosed in a
diamond from South Africa and belongs to the contem-
porary phase of formation of inclusions.　　75 ×
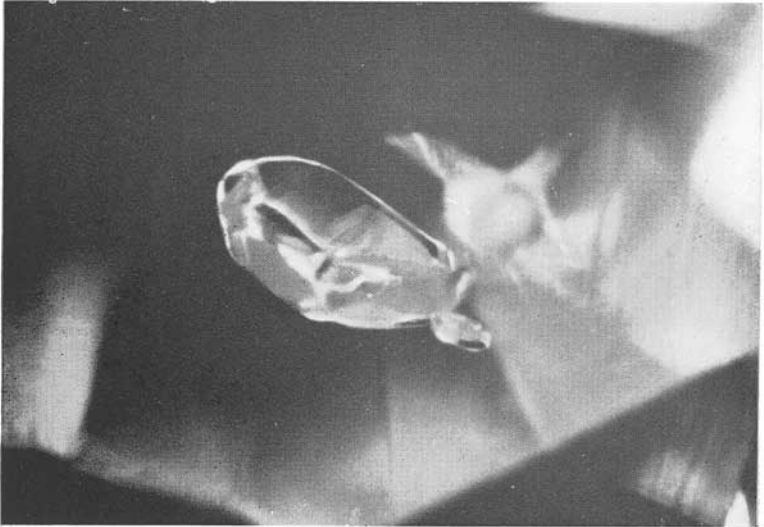
Well-developed idiomorphous zircon crystal embedded in
a diamond from South Africa.　100 ×

cases it can be safely inferred from the behaviour of the liquid when the diamond is heated that it is liquid carbon dioxide. In other cases the properties of the liquid point to its being water or a saline solution.''

Other cavities are quite empty, or only filled with gas ; like the fluid enclosures, these are by no means rare, and, when present at all, occur in large numbers. When observed under the microscope they appear quite black, especially at the visible margins ; this is owing to the fact that the rays of the light travelling through the stone are almost totally reflected at the surface of separation of the substance of the diamond and the bubble of gas ; they therefore fail to reach the eye and the cavity appears dark. This is a fruitful source of error, for such appearances are liable to be mistaken for solid enclosures of a black colour. Such mistakes may be avoided, however, by careful observation, for the outline of cavities is usually rounded, while that of a solid enclosure is irregular and angular ; moreover, most cavities allow the passage of some light, at least, in the centre ; they will therefore appear to have a bright centre sur-rounded by a dark border, which would not be the case with solid enclosures. The presence of these cavities is of practical signifi-cance, since to them is due the cloudiness of the diamond and those faults which are also known under the name of '' Silk.''

In most cases they cannot be detected through a pocket lens in ordinary light and they are particularly treacherous to the one who handles rough diamond as it is most difficult to observe them through the rough crystal faces. In concentrated light, however, they brighten up remarkably, causing some sort of '' Tyndall effect.''

In addition to solid, gaseous or liquid inclusions, diamonds are also found to enclose straight-running clefts, incipient cleavage cracks, and often irregular tension cracks. In the jewellery trade these inclusions are known as feathers, fractures, cracks or cleavage, depending upon their appearance.

All the inclusions described above, which are all very charac-teristic of diamond and therefore of great diagnostic value, might appear as black spots or patches if they were not examined with adequate light conditions. Much harm has been done to the diamond by ignorance and by wrong description and designation of the diamond inclusions and by exaggerating the fact that they affect

Octahedral crystal of a diamond enclosed in a
secondary diamond.   75 ×

the beauty and value of diamonds. The purpose of this paper has
been to show that " coal " does not occur as an inclusion, that even
black spots in a diamond may be formed by rare or interesting
minerals, and that many of the mineral inclusions in diamonds dis-
play some intriguing beauty of their own. It may be hoped that a
more intense study and a better knowledge as well as more adequate
description of diamond inclusions will contribute to the glory of this
gem of gems.

LITERATURE CONSULTED

1.   A. F. Williams. " The Genesis of the Diamond," London, 1932.
2.   G. Friedel. " Bull. Soc. Chim.," Paris, 1884.
3.   G. Friedel. " Sur les inclusions noires contenues dans les diamants du
      Cap," Compt. Rend. Acad. Sci., Paris, 1923.
4.   J. R. Sutton. " Inclusions in Diamond from South Africa," " Mining
      Magazine," 1921.
5.   T. Draper. " Origin and Distribution of Diamond in Brazil," " Gems
      and Gemology," Summer, 1950.
6.   Bauer and Spencer. " Precious Stones," 1904.
      Further :
      K. Schlossmacher. " Edelsteinkunde," Leipzig, 1932.
      E. Cohen. " Uber Einschlüsse in südafrikanischen Diamanten,"
      " Neues Jahrbuch Min.," 1876.

NEW and IMPROVED
INSTRUMENT STANDS

by D. S. M. Field, A.G.A.

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LTHOUGH individual ideas of personal comfort vary far too much for anyone to give definite rules regarding ideal working conditions, no experienced research worker will deny that the position, height, and inclination of an optical instrument are all factors which must be considered if its use is to be a continual enjoyment.

The photographs on the opposite page illustrate how two of the gem testing instruments in common use by the gemmologist have been improved both in appearance and usefulness by the addition of specially constructed laboratory stands.

The spectroscope stand shown in Fig. 1 is a modification of the small but very useful inclined stand designed by R. Keith Mitchell, F.G.A., and distributed in limited quantities by the Gemmological Association. The newer version differs from the Mitchell pattern only in that height (for comfort) and weight (for stability) have been added. Constructed from a solid hardwood block, the stand illustrated is heavily lacquered and hand-rubbed to an instrument finish. The turntable is of chromium-plated brass with a $\frac{1}{4}$ in. x 4 in. wobble-free metal shaft. It is topped with black suede leather.

The refractometer stand (Fig. 2) is of original design, the main purpose of which is to bring the eye-piece of the Rayner instrument up to eye level when the worker is in a normal sitting position ; also to provide greater stability in laboratory use. This stand, too, is constructed of solid hardwood with a hard black lacquer finish. The sides and fitted accessories box are covered with black English morocco leather, which enhances the general appearance of the unit.

Both instruments may be removed or attached to the stands at will as they are required to be used on field trips or in the laboratory.
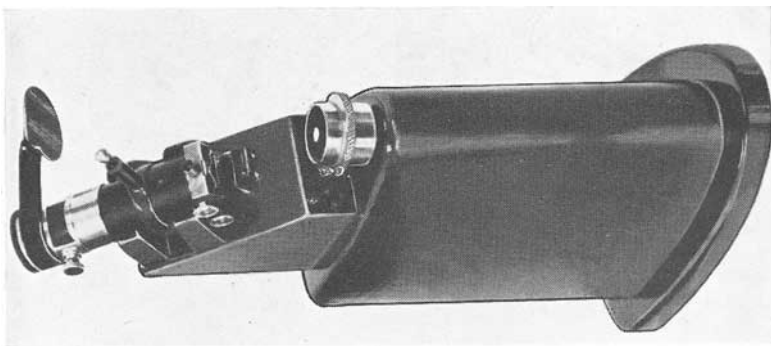
Fig. 1 (*on left*).

Stand for
Beck Prism Spectroscope.

Designed and executed by
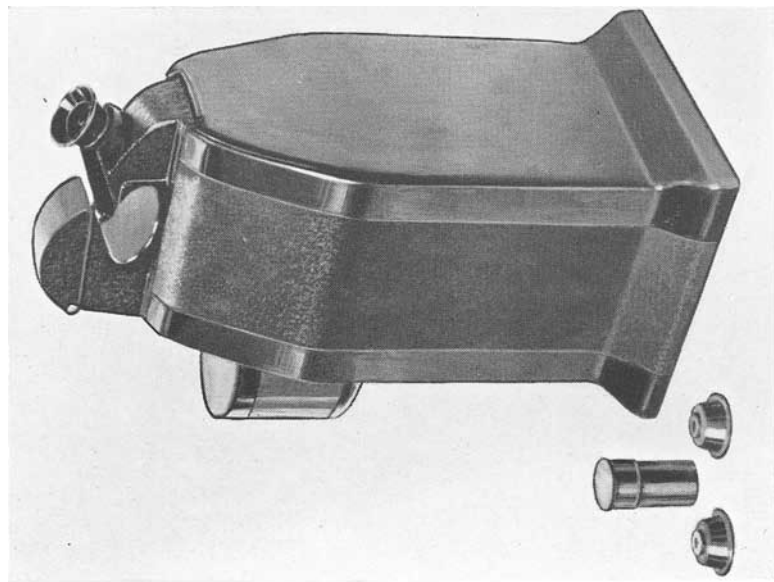D. S. M. Field, 1951.

(Based on the Mitchell
Spectroscope Stand.)

Fig. 2 (*on right*).

Stand for
Rayner Refractometer in
Laboratory use.

Designed and executed by
D. S. M. Field, 1951.

Natural or synthetic ?

by B. W. Anderson, B.Sc., F.G.A.

T HE curious form which included-bubbles can take presents a
fascinating study—and moreover a study of great practical
importance to the gemmologist. With experience, it should
be possible to recognize the characteristic shape and grouping of gas
bubbles in synthetic corundum, synthetic spinel, natural and artifi-
cial glasses, as well as the flattened bubbles in the junction plane of
a doublet.

Distortion into rod- or hose-like forms of bubbles in synthetic
corundum is not very uncommon, but the specimen illustrated by
the photomicrograph reproduced in Fig. 1 showed a patterning
which was altogether exceptional—reminiscent of " feathers " in
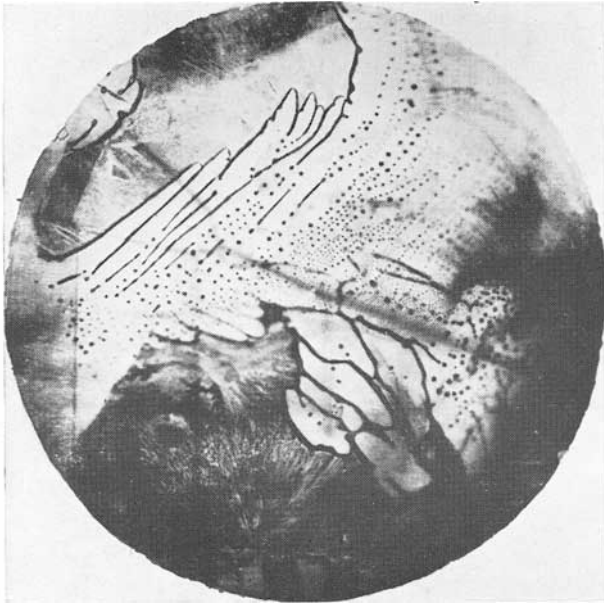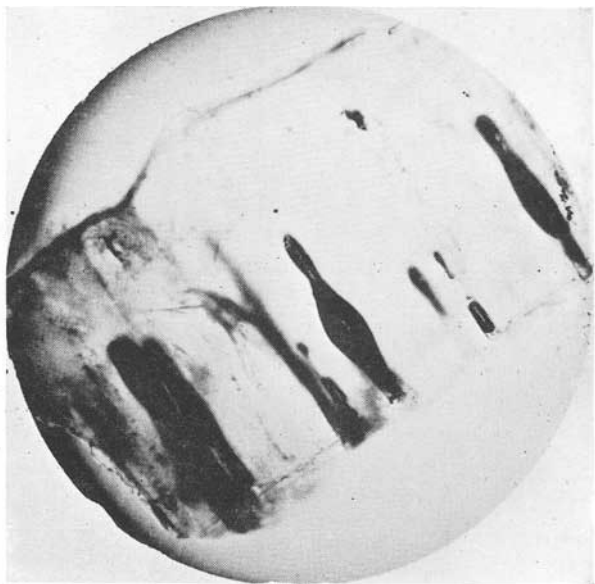Siam ruby or in natural red spinel, and might well pass as a natural
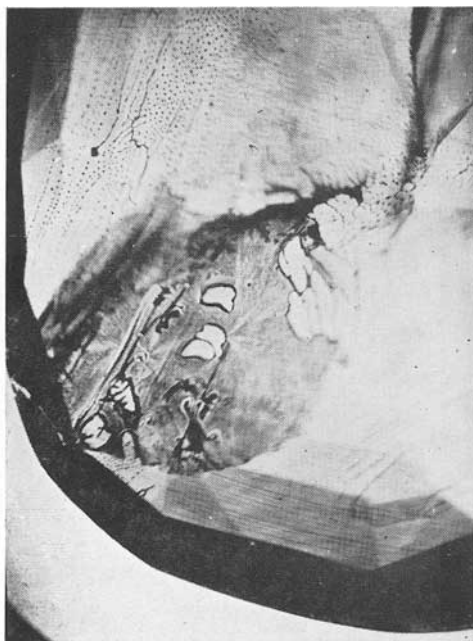

FIG. 1

FIG. 2

FIG. 3

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stone if examined by a beginner. In other directions, the typical curved lines of a Verneuil ruby could be clearly seen: traces of these lines can be seen in the photomicrograph reproduced in Fig. 3.

On the other hand, bubble-like forms are sometimes met with in natural gemstones: notably in blue apatite from Burma and peridot from Hawaii. The elongated bubble-like cavities shown in Fig. 2 are an instance of this kind of deceptively artificial-looking structure in an undoubtedly natural and crystalline mineral. These particular cavities were observed in a yellowish, transparent plagioclase feldspar having the physical properties of labradorite, but with practically no schiller. The density of this small irregular piece was near 2.67, with refractive index 1.563, as determined by immersion. The cleavage angle was approximately 86°, as measured with an eyepiece goniometer.

It is hoped that these photographs will interest experienced gemmologists and serve as a warning to beginners not to interpret inclusions too quickly at their immediate face value.

A NEW GEMSTONE

In a paper read to the Mineralogical Society on Thursday, 24th January, 1952, by Dr. G. F. Claringbull and Dr. W. Hey, it was disclosed that many of the brown and yellow gemstones supposed for many years to be Olivine (peridot) have proved to be a new mineral. The mineral, called Sinhalite, has a composition $Mg.Al.Bo_4$ and refractive index readings for various stones have showed a range 1.667-1.712 (peridot 1.654-1.690) and densities observed have ranged from 3.475-3.496. For the gemmologist it would seem that the first clue to distinguishing peridot and sinhalite in one's collection would be provided by a density test.

The stones so far examined have come from Ceylon.

LARGE SYNTHETIC RUTILE

A magnificently cut synthetic rutile weighing over 29 carats has recently been acquired and placed on display by the British Museum (Natural History). The stone, which is the largest in the United Kingdom at the moment, was cut by Messrs. Charles Mathews (Lapidaries) Limited.

Gemmological
Abstracts

CHAMBERS (R. O.). *Australian gemstones* Gems and Gemology,
Vol. VII, No. 3, pp. 83-88. Fall, 1951.

A discussion of the major gemstones found in Australia, with
special reference to opal. Sapphires from Anakie and Inverell are
from alluvial deposits and probably originated as a rock-forming
mineral in a basalt. The sapphires are found in blues, greens and
yellow colours ; the yellows and greenish-yellows usually have a
distinct golden tinge which is peculiar to Australian stones.
Emeralds are found at Ammaville, New South Wales, and in the
Western Australian goldfields. Some gem beryl has been found at
Harts Range in Central Australia. The topaz found in New South
Wales has a prevailing colour of a pale blue or green. Zircons, in
yellows, browns and reds, are found in Anakie and New South
Wales. Tourmaline is obtained from only one locality—the Kan-
garoo Island off the South Australian Coast. The tourmalines are
found in red, blue and green colours. The opal fields of Queens-
land, New South Wales and South Australia are discussed.
Diamonds were first discovered in New South Wales in 1851. The
stones are small and generally " off-coloured " and are mostly used
industrially. The superior hardness of Australian diamonds is
discussed. Sixteen illustrations.   R. W.

BATCHELOR (H. H.). *Prospecting for opal matrix.* Gemmologist,
Vol. XX, No. 243, p. 205. October, 1951.

First-hand information on the types of opal found along the
upper reaches of the Diamantina river of Queensland. Some opal
matrix is so soft that it crumbles away in the hand ; some is as hard
as jadeite.   R. W.

ANON. *New development increases range of effective heavy liquids.*
Gems and Gemology, Vol. VII, No. 3, p. 103. Fall, 1951.

Suspension of finely divided solids in methylene iodide are said
to produce a density range from 3.32 to 7.5. The liquids are opaque
and the solids settle on standing and require stirring before use.

R. W.

GOEBELER (H.). *Von edlen Steinen.* On precious stones. Pub-
lished by the author, Beckum, Germany, 1951, 51 pp., index,
bibliography.

The author calls his book an introduction to gemmology and
a guide for the amateur. It does not pretend to be a mineralogical
treatise.

About eight pages are devoted to general remarks on the for-
mation of minerals, cutting, the history and simple methods of
determination, mentioning especially specific gravity, hardness, re-
fractive index, double refraction and pleochroism. Twenty-seven
pages deal with the individual gem species, giving chemical com-
position and physical constants, and the concluding pages contain
a few remarks and lists on the stones of the months, misleading
names, doublets and synthetic stones. On the whole, although not
much is said in the booklet, the stated facts are correct ; in a few
instances wrong impressions could be made. Only a small percent-
age of diamonds can be used as counters for gamma-rays ; corundum
belongs to the rhombohedral, not to the rhombic system. The
booklet may make interesting reading for the amateur.

E. S.

SCHLOSSMACHER (K.). *Der neue synthetische Smaragd.* (The new
synthetic emerald.) Gold und Silber, 1951, 4 (9), 10-11.

The new synthetic is the Chatham emerald. Thus the
Igmerald, first marketed in 1935, is already relegated to history.
In 1849 the first reconstructed emeralds were made by fusing
powdered emerald and boric acid and the synthesis proper succeeded
in 1888 (Hautefeuille and Perry). The method is called hydro-
thermal, because crystals are formed from solution at several
hundred degrees C. and under a pressure of about 1,000 atmo-
spheres (14,700 lbs. per sq. inch). To-day crystals of several centi-
metres diameter are made (1 centimetre—0.3937 inch) ; the colour

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is a very attractive emerald green, although the expert may detect a slightly bluish tint. Not more than 1,000 cts. monthly are released from Chatham's factory and the price for the cut stone is 15 to 100 dollars per carat. The stones are cut in the U.S.A. and at Idar-Oberstein, Germany.

The distinction between genuine and synthetic emerald is comparatively simple. The refractive index and double refraction values are as follows:—

Origin	Mean ordinary ray	Mean extraordinary ray	Mean double refraction
Synthetic	1.564	1.561	0.0035
Colombia	1.576	1.571	0.0055
Russia	1.583	1.577	0.0065
South Africa	1.590	1.583	0.0070

Instead of determining the R.I. on the total refractometer, the author observes the Becke effect on his gem microscope, making use of benzoic-acid-benzyl-ester as immersion liquid. Its refractive index of 1.569 lies between those of the synthetic and genuine emeralds.

Specific gravity, too, is a means of differentiation, with the following values:—

Origin	Mean S.G.	Range
Synthetic	2.655	2.645-2.665
Colombian	2.70	
Russian	2.73	
South African	2.76	

The author recommends making use of Thoulet's solution, which is diluted with distilled water until the emerald to be tested is suspended ; the S.G. of the liquid is then determined with a Westphal balance.

Microscopic observation of the characteristic inclusions is another means of disclosing the pedigree. A further indication is luminescence in ultra-violet light, synthetic stones displaying an intense raspberry-red fluorescence. Most genuine stones do not fluoresce at all, but a few exceptions are fluorescent. A similar uncertainty remains after inspection through a suitable colour filter—genuine stones appear deep red to red, whereas synthetics are more orange red. This method requires experience, however, and, in addition, confirmation by one of the above-mentioned means.

E. S.

KENNEDY (N.W.). *The genesis of gemstones.* Part VII. The mechanism of mineral formation. Gemmologist, Vol. XX, No. 241, pp. 181-183. August, 1951.

The continuation of the series under this title. The formation of the glassy rocks and the granitic rocks is discussed. The formation of microlites and crystallites in both natural and artificial glasses. The peculiar conditions existing at the centre of the earth ; the probable happening when the internal fluid magma is ejected to the outer layers, or the surface of the earth, and the types of crystallization which may occur.   R. W.

SWITZER (G. S.). *" Rockhounds " uncover earth's mineral beauty.* The National Geographic Magazine, Vol. C, No. 5, November, 1951.

An entertaining article on amateur rockhunting in the U.S.A. written by a mineralogist who is also well known in the world of gemmology. Diverse subjects mentioned, such as the Paracutin volcano ; how minerals are formed ; equipment required for rockhunting—perhaps better known to us as mineral hunting ; minerals from outer space ; famous collectors and collections ; and some mention of lapidary work. Fluorescence of minerals under ultra-violet light and the preparation of " micromounts," small well crystallized specimens mounted in a small box for examination under a low-power microscope with the aid of top lighting. Illustrated by six pictures in monochrome and 16 pages in colour.   R. W.

Division of Mines, Department of Natural Resources, State of California. Three special reports: 10A, Nephrite jade and associated rocks of the Cape San Martin region, Monterey Co., California. 10B, Nephrite in Marin Co., California. 10C, Jadeite of San Benito Co., California.

These three reports (separately bound) give a very full account of the history and geology of the jade minerals found to date in the State of California. Much of the nephrite is in association with serpentine. The jadeite is found in and around Clear Creek, San Benito Co., California, San Luis Osbispo Co. and Sonoma Co., California.   R. W.

DRAPER (T.). *The diamond mines of Diamantina—past and present.* Gems and Gemology, Vol. VII, No. 2, pp. 49-57. Summer, 1951.

The first part of a series on the diamond mines of the Diamantina area. The history of the diamond mining since the beginning —some two hundred and twenty years ago—is given. Most of the historical survey is taken from Mawe's " Travel in the interior of Brazil." Eleven monotones and one map. R. W.

—— IBID. Part 2. Gems and Gemology, Vol. VII, No. 3, pp. 89-98. Fall, 1951.

Continuation of the historical survey. Discussion of the high-level massa mines and their geology. The story of the companies who have operated in the fields—their successes and failures. Eleven illustrations and one map. R. W.

KRAUS (E. H.). *Nomenclature of gems.* Gems and Gemology, Vol. VII, No. 2, pp. 58-67. Summer, 1951.

A standardized list of acceptable gem names arranged for use by the American Gem Society. The list is divided into four groups, viz., Important gemstones ; Organic gem materials ; Other gem materials ; and Synthetic gem materials, which are then tabled under three headings: Species ; Description ; and Correct Names. The list does not materially differ from the European versions. Under Feldspar Group (labradorite variety) is appended " Transparent or opaque black—Andradite garnet or andradite " ; this is an obvious typesetting error and should be on page 60. Some of the colours given for nephrite are certainly not well known for that mineral. It would have been better to have mentioned that clam pearls are not nacreous. The use of the term " Topaz quartz " for citrine is re-commended. Synthetic almandine spinel and synthetic amethystine sapphire and spinel, which are recommended for the mauve or purple colours of synthetic spinels and corundums, are not in keep-ing with the rest of the nomenclature ; of the synthetic stones, " reddish purple synthetic spinel " for the " synthetic almandine spinel," and likewise " purple " or " mauve " for amethystine, would be better prefixes. R. W.

SCHLOSSMACHER (K.). *Neue Wege in der Edelsteinuntersuchung.*
New methods in gem examination. Gold und Silber, 1951,
4 (10), 28-29.

Before the first world war only the dichroscope and the
measuring of hardness were known to most jewellers. This article
deals with the uses of the total reflectometer and the spectroscope.
Both these instruments are explained in detail.   E. S.

WEINSTEIN (M.). *Scarabs.* Gemmologist, Vol. XX, No. 241, pp.
169-170. August, 1951.

A general article on the history and nature of the carved repre-
sentations of the sacred beetle of Egypt. The materials used for the
ancient scarabs were steatite, faience, glass, wood, ivory, amber and
metal. During the later periods amethyst, rock crystal, obsidian,
lapis lazuli and amazonite were employed. About 1400 B.C. car-
nelian, sard, jasper and hematite were the minerals employed. A
note is given on the Greek scarabs and on the imitations.   R. W.

JAHNS (R. H.) and WRIGHT (L. A.). Gem and lithium bearing peg-
matites of the Pala District, San Diego County, California.
Special Report, 7A Division of Mines, Department of Natural
Resources, State of California. June, 1951. San Francisco,
U.S.A., 72 pages.

A very complete survey of the geology of the gem-bearing peg-
matites of the Pala District. The history of the discovery of tour-
maline, beryl and spodumene which are found in the district and
accounts of the occurrences, localities and varieties of these species
is given. Pale rose and peach-coloured morganite is reported, with
pale blue, green, yellow-green, deep blue and golden yellow beryls.
Some occurrences produce beryls with greenish cores and pinkish
rims. Green, yellow and colourless gem varieties of spodumene are
found besides the lilac-pink kunzite variety. All colours of tour-
malines, except brown, which is rarely found in the pegmatites.
Many variations of parti-coloration are said to occur. The paper-
covered book is well illustrated by monochromes and by eight
coloured plates of cut stones and crystals. Many references are
given and the book is furnished with an index. There are three
maps in pocket attached to back cover.   R. W.

NEW SPINEL DOUBLET

by Robert Webster, F.G.A.

A N opportunity to examine the new synthetic spinel doublets of emerald colour now on the market, first reported in American gemmological literature,[1] allows a fuller description of these " emeralds " to be now given.

The stones examined were of the usual emerald-cut and were of good colour and weighed just over 4 carats each. They were of French origin and are exported from that country under the name *soudé sur spinelle*.

In all cases the crown and the pavilion of the stone gave a refractive index reading of 1.728 indicating the material to be synthetic spinel. The stones show a green residual colour through the Chelsea colour filter and no distinctive absorption spectrum could be seen.

That the stones were composite was evident when they were immersed in liquid, for then the top and bottom halves of the stone were seen to be colourless and the junction to consist of a thin layer of coloured material estimated to be about .4 mm. in thickness. Probably due to the smaller critical angle of spinel compared with that of quartz, the colourless portions of these new stones are not so evident as in the case of the quartz soudé emeralds.

The stones examined were fairly clean and did not show " flaws " or " feathers " like so many of the quartz soudées, although the American report mentions that some stones examined by them showed " flaws " or cracks in the crown which they suggest was caused by heat treatment. Included bubbles were observed, sometimes in one plane, which indicates that they lie in the coloured layer, and between crossed nicols the characteristic " tabby " extinction of synthetic spinel was observed.

Under the long-wave (3650 Å) ultra-violet lamp there did not seem to be any particular effect, but under the short-wave (2635 Å) ultra-violet rays the coloured layer showed up fairly strongly as a
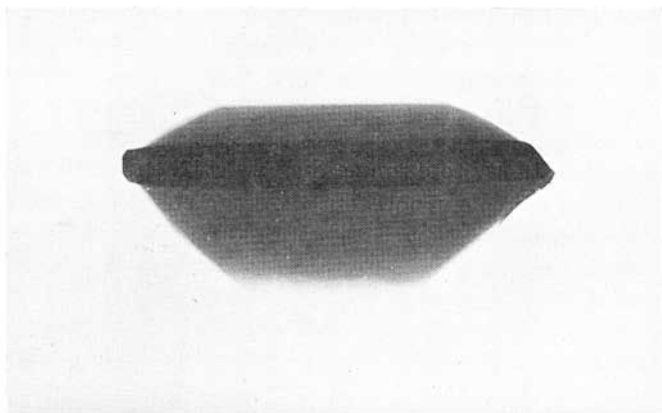
Radiograph of a synthetic spinel soudé emerald showing the lack of penetration by X-rays of the central coloured layer. (Owing to the stone not being set in perfect alignment with the X-ray beam the opaque layer appears to be much thicker than it actually is.) Operating characteristics: Exposure 50 seconds, target to film distance 8 inches, Machlett tube with Mo, target and Be windows tube running at 48 pkV and 18 mA.

dark non-fluorescing line against the pale misty fluorescence of the spinel crown and pavilion. This observation agrees in principle with those of Liddicoat,[2] who remarked that the quartz " triplets " (soudées) showed no fluorescence effect as the quartz does not fluoresce and there would be nothing to throw into relief the non-fluorescent coloured layer. When irradiated with X-rays the typical green fluorescence of the colourless synthetic spinel[3] was seen, but the dark line of the coloured layer was not observed. This may well be due to the difficulty of completely seeing the rim of the stone through the observation window of the X-ray apparatus. In comparison the quartz soudées are quite inert under X-rays.

Anderson[4] reports that the usual quartz soudé emeralds have a remarkably high density, near to 2.8, and that author ascribes this to the use of a heavy lead-glass, coloured green, for the central layer which " colours " the stone emerald green. The knowledge of this high density of the quartz emerald doublets prompted an early determination of the density of these new synthetic spinel

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soudé emeralds. The result showed an enhancement of density above that for synthetic spinel—the values for the four stones determined were found to lie between 3.66 and 3.69, as against 3.63 for synthetic spinel. The increase in density for the quartz soudées is approximately 0.15 and for the spinel soudées 0.045 ; these figures seem to imply that a similar coloured layer is in the new synthetic spinel composite stones as is used for the quartz soudé emeralds, and that it might well be a slice of coloured lead glass. To obtain further information an X-ray direct picture was taken to see whether the central layer was to any extent opaque to the rays. As the radiograph (reproduced) shows, the central layer is very opaque to X-rays and must thus contain heavy atoms. This result tends to confirm the likelihood of the layer being lead glass, but the thinness of the layer must to some extent make this doubtful.

The nature of the actual composition of the layer must remain, at present, unproved. It is interesting to note, however, that some fragments of the substance removed from the edge at the join in a quartz soudé indicated that the substance could scarcely be glass. A spectogram kindly taken by Mr. Anderson clearly showed that copper was present in the material of the layer. Further investigation will be needed in order to elucidate the mystery of the increased density and the nature of the colouring matter, but it is tentatively suggested that an organo-metallic dye in a plastic base may be the answer.

In conclusion, it is pertinent to mention that these composite stones are also being made in small '' calibré '' sizes.

REFERENCES

1. '' New gem substitute resembles emerald.'' '' Gems and Gemology,'' p. 29, Vol. VII, No. 1, Spring, 1951. Los Angeles, U.S.A.

2. '' New fluorescence tests for doublets and triplets.'' Liddicoat (R. T.). '' Gems and Gemology,'' pp. 303 and 307, Vol. V, No. 5, Spring 1946. Los Angeles, U.S.A.

3. Luminescence and photocoloration of synthetic white corundum and spinel. Webster (R.). '' Gemmologist,'' pp. 113-115, Vol. XIX, No. 227, June, 1950. London.

4. '' Gem Testing.'' Anderson (B. W.). 5th Edn., p. 143. London, 1951.

Some speculations on

AN UNUSUAL ZIRCON

by R. K. Mitchell, F.G.A.

B Y the courtesy of a very good friend in Ceylon I recently acquired a rectangular-cut zircon of somewhat unusual appearance. Although not of good gem quality and certainly far from clean, the stone is parti-coloured, one portion being a pale but typical zircon green, while the other part is an equally characteristic orange or golden colour. There is a clear-cut division between the two sections, and although it was thought at first that this might be a twin plane, it proved not to be so.

Parti-coloured gems are not uncommon among tourmalines, corundums and some other mineral species, but if zircon occurs commonly in this form it is not often cut. The full interest of this particular gem was not realized until Mr. C. J. Payne, using a diamond refractometer, checked its refractive indices. It was then found that the differently coloured sections of the stone were each differently refracting, the green portion giving values of 1.853 and 1.863, and the orange part higher readings at 1.866 and 1.876. This at once puts one portion in a lower zircon category than the other, although both can be broadly included in the intermediate group.

A check of the absorption spectra showed that the two parts were again different, the green section having a sharper and better developed spectrum than that for the orange part. Both are rather fuzzy and very far from the well-defined spectra of normal zircons. The stronger definition of the green section of this stone argues that that part may be richer in the radioactive material responsible for the phenomenon.

These facts about two parts of the same stone may not appear significant until we consider the generally accepted theory that the descent from normal or high zircon through the intermediate type to low zircon is due to the inconceivably slow disintegration of the crystal lattice by the radioactive emanations from uranium atoms occurring as impurities in the mineral.

Low zircon has so far been found only in Ceylon and it has been suggested that this is primarily due to the fact that the strata from which the mineral has weathered are immensely older than other

known sources of the gem. Geologically, the rocks are very much pre-cambrian and probably among the world's oldest formations.

Now, what are we to conclude from this? That the Ceylon zircons which have not reached the low condition are much younger than those which have, or that the green zircon, by reason of some impurity which at the same time influences its colour, has proceeded further in disintegration than crystals of different colours? Or is it possible that the disintegration in the low type stones has been occasioned by radioactive emanations from a source outside the crystal? This seems unlikely and is in the nature of a personal speculation.

Examining these three possibilities in the light of the present example, we apparently have these conditions. Either the initial portion, that which is now green, has acted as a '' seed '' crystal around which a later deposit of material, now orange, has formed, or the two parts are of the same age but contain different amounts of radioactive material, causing the green to disintegrate more rapidly than the orange. Or one part of the crystal has been subjected to stronger radioactive emanations than the other.

The evidence of the spectra seems to point to the second of these conditions being, in fact, correct. But against this we may pose the problems of the normal zircon from Burma. These have exceptionally well-developed, sharp spectra of more than 20 lines, arguing a comparatively high percentage of radioactive substance in the crystal lattice, and yet the Burma zircon shows not the slightest sign of disintegration.

Reasoning from this, we come back once more to the fact that the degree of disintegration must be proportional to two things, firstly the age of the crystal and secondly the amount of radioactive substance present. Other and unknown influences may also have some bearing on the matter. One thing is certain. Whatever the influences causing the phenomenon, this specimen establishes that they can produce it to different degrees in one crystal.

Finally, it is interesting to reflect that another branch of radiology has recently come into being in which measurement of the infinitely small residual radioactivity of rocks is used to date them in terms of tens of millions of years. I wonder what the exponents of this new science would make of this present specimen?

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The crystalline
STRUCTURE OF QUARTZ
and its polymers

by Sir James Walton

Q UARTZ is the commonest of all minerals, but in its diversity of form and structure presents more interest and fascination to the physicist and mineralogist than perhaps any other mineral. Many of its crystals are of remarkable beauty and, being very durable, are attractive to the jeweller. Being inexpensive and occurring in almost innumerable varieties, it forms by itself an object of profound interest to the collector ; indeed, there are many collectors who specialize in this subject alone.

The chemical formula is simple, being silicon dioxide (SiO_2) or silica. Although containing no hydrogen and showing none of the characters usually assigned to acids, it is regarded as an acid owing to its power of combining with many metals to form silicates, and all igneous rocks containing an excess of silica, such as granites, quartz porphyries, rhyolites, obsidian and pumice, are known as acid rocks. It occurs to a lesser degree in quartz diorite, tracheite and andesite.

ATOMIC STRUCTURE

The nucleus of silicon contains 14 protons, and since the atomic weight is 28 there are also 14 neutrons. Around the nucleus are the 14 electrons, and, as usual, the inner two shells are complete with 2 and 8 electrons. In the outer shell, therefore, there are only 4 electrons (Fig. 1), which is four short of the stable gas argon. In the oxygen atom there are 8 protons and 8 neutrons in the nucleus and the electronic formula is 2 in the inner shell and 6 in the outer (Fig. 1), which is two short of the stable gas neon. To obtain the stable argon structure the silicon atom combines with four oxygen atoms by homopolar or covalent bonds, each oxygen atom sharing an electron with the silicon atom. The silicon atom thus obtains, in all, the necessary 8 electrons, but each oxygen is left with only 7.

The deficiency is made good by each oxygen combining with a second silicon atom (Fig. 2). Each oxygen atom is thus linked up to two silicon atoms resulting in the formula SiO_2.

Silicon is only known to form either four or six bonds arranged either tetrahedrally or octahedrally (Wells). The latter is rare and in silica and nearly all silicates the arrangement is tetrahedral, the silicon atom being surrounded by the four oxygen atoms by bonds which are equal in strength and the angles between each pair of bonds of equal degree (Fig. 3). The size of the two atoms is, however, very different, that of the oxygen atom being 2.7 Å and that of the silicon only .6 Å. That is, the oxygen atom is $4\frac{1}{2}$ times the size of the silicon. If a model be made of spheres of these proportionate diameters, it will be seen that the silicon atom fits snugly into the space between the four oxygen atoms (Fig. 4).

CRYSTAL PACKING

One of the most interesting facts about silica is that it exists in three disinct crystalline forms, namely quartz, tridymite and cristobalite, which are stable at very different temperatures, thus : —

———> 870° <———————> 1470° <———————> 1710° C. (Melting point)
Quartz   Tridymite   Cristobalite
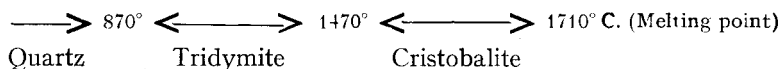
As Wells points out, when once the material is molten recrystallization of the liquid is difficult, the mass usually solidifying as a glass with an extremely small coefficient of expansion and a high softening point, which make it very useful in the formation of crucibles and cooking utensils.

The different forms are not easily converted from one to the other and thus all three are found in nature ; but it is interesting to note that both tridymite and cristobalite usually occur in volcanic rocks, and also that in some of the methods of the artificial production of quartz, quartz crystals separate out below a temperature of 700° C., while at higher temperatures cristobalite is formed. All three varieties also exist as α and β forms which are respectively high and low temperature modifications.

Each variety is made up of the characteristic tetrahedra so linked that each oxygen atom is united to two silicon atoms and thus they all have the formula SiO_2, but the tetrahedra themselves are linked together quite differently in the three forms. The α and β forms

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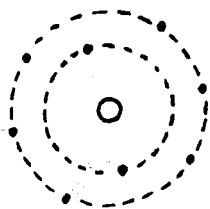
FIG. 1

Scheme of oxygen atom

Scheme of silicon atom.
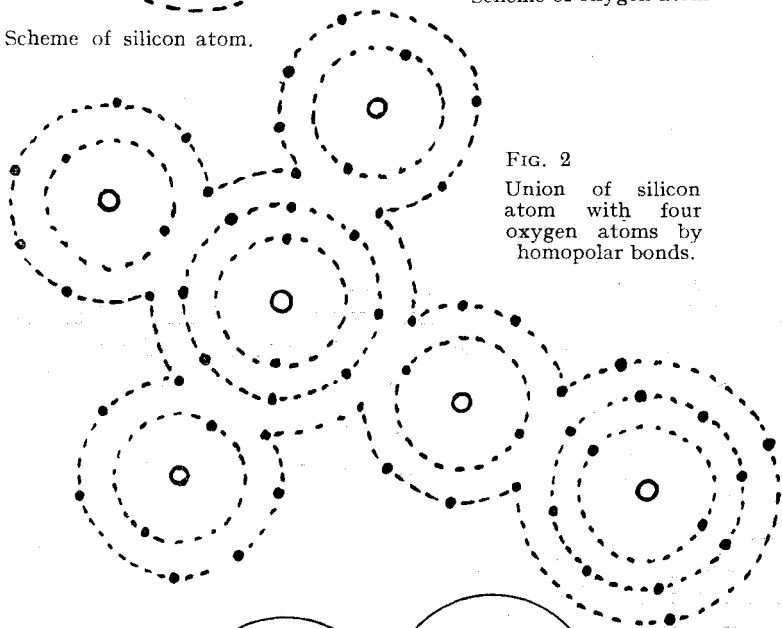
FIG. 2

Union of silicon atom with four oxygen atoms by homopolar bonds.
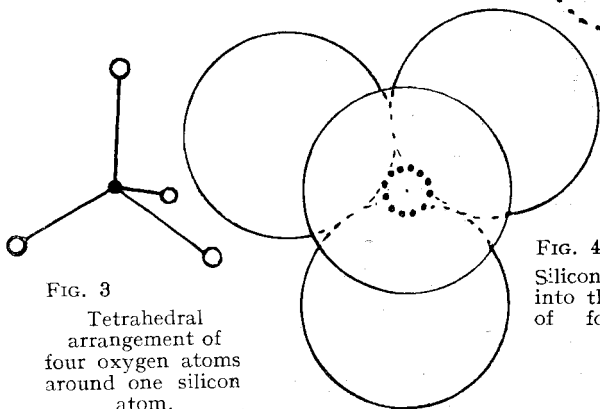
FIG. 3

Tetrahedral arrangement of four oxygen atoms around one silicon atom.

FIG. 4

Silicon atom fitting into the interstices of four oxygen atoms.

differ only in detail with the tetrahedra showing only a slight rotation relative to one another, and hence conversion from one form to another is relatively easy and is reversible. ⋅ The piezo electric characters are altered with such a change but, as will be shown later, the nature of the optical activities of the   and β forms remains constant.

β *Quartz*. This is a much rarer form than α quartz, but it is convenient to consider it first as it has a higher degree of symmetry. It occurs in nature in graphic granite, in granite pegmatites and in porphyries. Crystals belong to the hexagonal division of the hexagonal system and are of the Trapezo-hedral or hexagonal holoaxial type. That is to say, they have one axis of hexagonal symmetry corresponding to the C axis and six axes of digonal symmetry coresponding to the three horizonal crystal axes and lines midway between them ; thus it more closely approaches the beryl class, but it has no centre or planes of symmetry. With this symmetry the oxygen atoms are arranged in hexagonal close packing.

The unit cell is a parallelipiped, three of which are united to give the hexagonal form (Fig. 5). Each horizontal side of the unit cell is 4.88 Å long and the vertical sides 5.37 Å (Sir William Bragg). Each unit cell contains three molecules which lie in three equidistant layers and are arranged in a spiral about a vertical axis so that the crystal has trigonal symmetry (Fig. 6). It is this spiral arrangement which gives the crystals the power of rotating polarized light, for if the grouping of atoms is such that it cannot be superimposed on its mirror image it is said to be enantiomorphous and rotates polarized light.   It is clear that with the spiral arrangement of the silicon atoms this condition will hold. It is also clear that the spiral may be right or left handed when it will rotate the light to the right or left.

The tetrahedral arrangement of the oxygen atoms around the silicon atoms is maintained, the silicon atoms lying in the three equidistant planes and the oxygen midway between these planes. Each oxygen atom has as its neighbours two silicon atoms, but the three do not lie in the same straight line, the lines joining the oxygen atom to the two silicon atoms making with each other an angle of 155° (Fig. 12) (Sir William Bragg).

If the position of the silicon atoms be projected on to the basal plane the resulting figure will show symmetrical hexagons and pairs

of small triangles symmetrically arranged one to the other and the hexagonal symmetry is thereby apparent (Fig. 7).

If α quartz be heated to 573° C. it will be converted into β quartz, the crystal angles altering and the change being associated with a sudden marked lowering of the refractive indices and the birefringence.

α *Quartz*. This is much the more common variety and is the form used in industry and in the fashioning of gems. When the term quartz is used with no distinguishing prefix it refers to this variety. It is extremely widespread in nature, forming about 12% of the constituents of the rocks of the earth's crust. Together with the silicates, silica forms about 28% of the lithosphere.

It has a lower degree of symmetry than β quartz. It belongs to the trigonal division of the hexagonal system and in this division to the trapezohedral or trigonal holo-axial class. Crystals therefore have a vertical axis of only trigonal instead of hexagonal symmetry, corresponding to the C axis, and only three axes of digonal symmetry corresponding to the three horizontal crystal axes. There is no centre and there are no planes of symmetry. The arrangement of the tetrahedra shows only a slight change of rotation from those of β quartz. This is well shown in the figure given by Sir William Bragg (Fig. 8), which depicts the projection of the position of the silicon atoms on the basal plane. It will be seen on comparison with
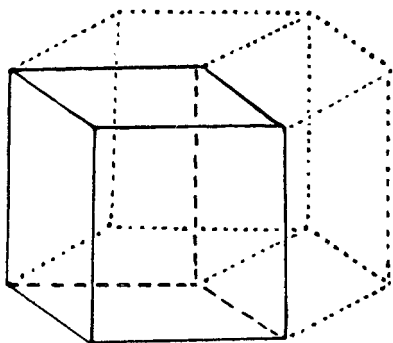
FIG. 5
The unit parallelified cell of quartz united to two others to give the hexagonal form.
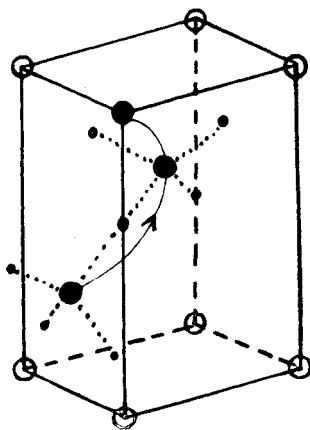
FIG. 6.
The unit cell of quartz. The three silicon atoms forming the spiral are shaded ●
The other silicon atoms unshaded form
the tetrahedra of adjacent cells. The tetrahedral arrangement of the oxygen atoms around two of the spirally arranged silicon atoms is shown ●

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the same figure for β quartz (Fig. 7) that the alternate angles A.A.A. may be regarded as having been pulled out while the intermediate angles have been pushed in. This causes a rotation of the small triangles so that they are not symmetrically placed as regards the atom at their apices. The six-sided spaces are no longer regular hexagons, but show alternate sharp and blunt angles like the base of a scalenohedron of the calcite class. Each set of three of these figures runs across an axis with their three sharp angles directed towards the Angles A.A.A. which have been pulled out. Thus the ends of each axis are different and the crystal would therefore be expected to show piezo electricity. This is exactly what happens, for it is well known that if two opposite prism edges of an α quartz crystal be compressed an electric field is developed along that line, one end of the axis showing positive and the other negative electricity.

When a quartz is heated the small triangles swing round and become symmetrical and the six-sided figures become regular hexagons. There is no lack of symmetry and the piezo-electricity disappears. It may happen that when β quartz is converted back again into α quartz some of the small triangles may swing one way and some the other, for, as Sir William Bragg says, it must be largely a matter of chance which way the triangles turn and it may be that some remains of previous crystallization or some small intrusion may determine which way they turn. If it should so happen that they are turned in different directions this would readily account for the piezo-electric twinning which so commonly occurs.

Since in this change from β to α quartz the spiral arrangement of the silicon atoms is unaffected, the optical characters will not change, the crystal remaining dextro or laevo rotatory as before.

If it be considered that the change is due to pulling out of the alternate angles and the pushing in of the intermediate angles, then a model can be made to show this effect. The silicon atoms are represented by small beads mounted by pivots on small strips of brass accurately drilled at equal distances which represent the bonds. The beads at each angle of the regular hexagon are fixed to jointed levers lying behind the base and connected at their central ends eccentrically with a circular metal disc which can be partly rotated by a lever. When the lever is at its mid point the perfect hexagonal symmetry of Fig. 7 is presented. When pulled down to its full extent the position of the atoms is changed and the resulting figure

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FIG. 7
Projection of the position of the silicon atoms in β quartz on to the basal plane showing the hexagonal symmetry.
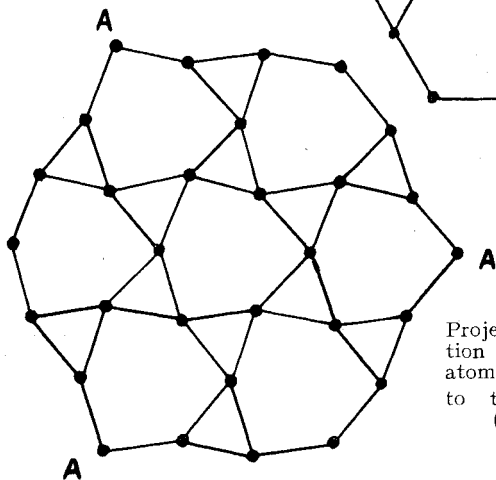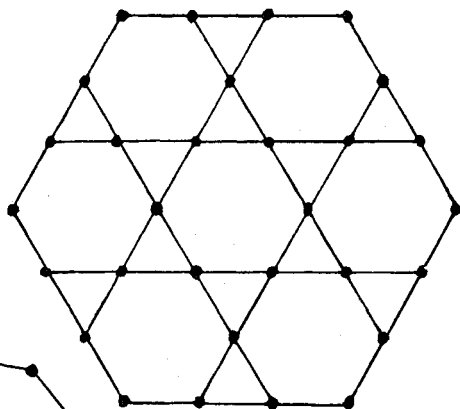
FIG. 8
Projection of the position of the silicon atoms in α quartz on to the basal plane (after Bragg).
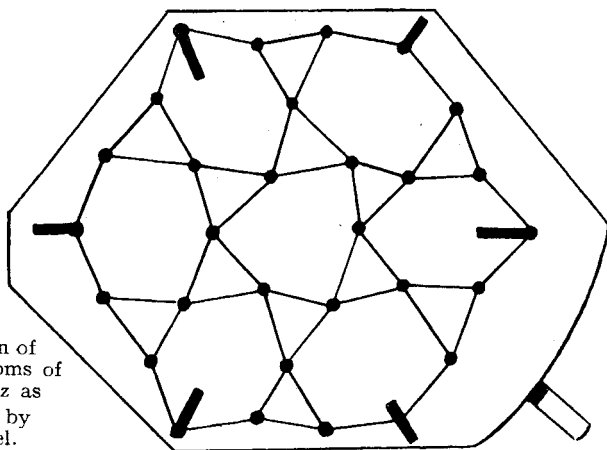
FIG. 9
Position of silicon atoms of α quartz as shown by model.

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has an external form which is an exact replica of Sir William Bragg's figure (Fig. 8), but the arrangement of the internal atoms is somewhat different (Fig. 9). The small triangles are rotated in the opposite direction and the larger spaces, instead of all resembling the base of a scalenohedron, are made up of two different figures, of which there are three of each. One is somewhat diamond-shaped and the other somewhat barrel-shaped. The central space alone resembles the base of a scalenohedron. Of the two forms of figure, one of each is placed at the opposite ends of an axis, the acute angle of a diamond-shaped figure forming the pulled out angle. If the lever is pushed up to its full extent the exact opposite figure is obtained, the extended angles become retracted and vice versa ; at the same time, the diamond-shaped figures become barrel-shaped. In fact, the figure represents a piezo-electric twin. The figure having the two kinds of spaces arranged alternately gives a representation of the ditrigonal symmetry of quartz and the different kind of space at each end of an axis represents the piezo-electric character of the crystal. Yet it does not agree with the results of X-ray crystallography, although the bonds, being made of rigid inelastic brass, must show accurately the mechanical effects of expansion and compression of the alternate angles. Dr. Claringbull has given an ingenious explanation of this discrepancy which would seem to be the most likely. He suggests that the model represents the effect of forces on only a small group of atoms, while in the crystal there are many other atoms around, which may give, as it were, extra thrusts and pulls resulting in a change of pattern.

In addition to the piezo-electric twins described above, there is another variety, the structure of which is made very clear by Sir William Bragg's figures. It occurs in both α and β quartz. If a model (Fig. 10a) of a right-handed quartz crystal be cut in a slanting plane the two parts will show the arrangement of the internal atoms as in Fig. 10b, while in a left-hand crystal they will be as in Fig. 10c. It is evident that b and c cannot be fitted together if the axes are in the same straight line, but they can be if fitted as in Fig. 10d, when the angle between the two parts is 84° 33'. This will give a twin, one part of which is dextro and the other laevo rotatory. The fit is not absolutely perfect and a certain amount of strain occurs at the junction. If it were not so there would be, as Sir William Bragg states, no reason why a crystal should ever grow regularly.
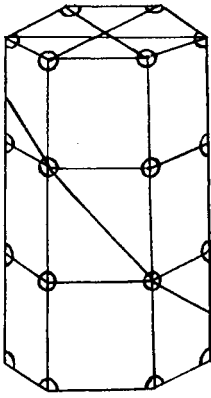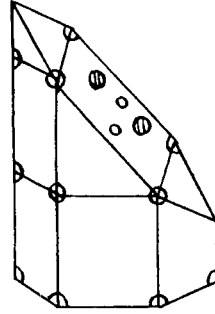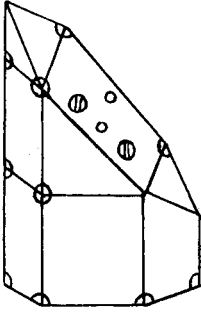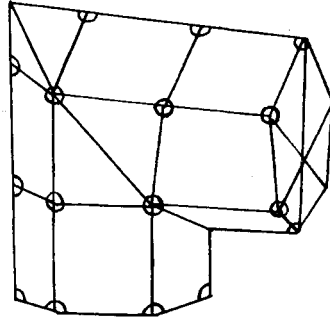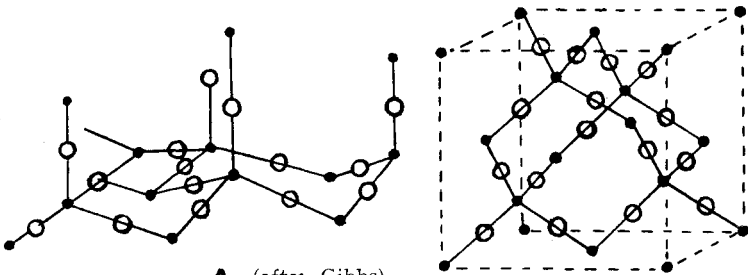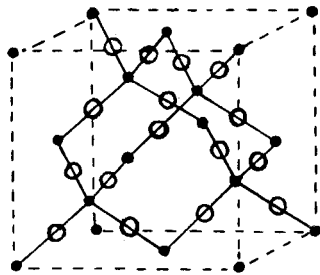
FIG. 10 (after Bragg).

A.

B.

C.

D

FIG. 11

A   (after Gibbs).

The structure of β tridymite (a) and β
cristobalite (b) Si = ● O = o.

B. (after Wyckoff)

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Twinning about a pair of prism faces with interpenetration, which is extremely common, is also associated with a difference in the individuals of their optical activities.

Tridymite. This is a comparatively rare form which, like quartz, exists as α and β varieties, the α variety being ortho-rhombic and the β hexagonal. It occurs chiefly in acidic volcanic rocks such as rhyolite, trachyte, and andesite, and less often in dolerite ; the crystals are usually minute, thin and tubular, being parallel to the basal pinacoid (0001). It often occurs as twins and the crystals may be united to form fan-shaped groups. Its properties differ considerably from quartz, the specific gravity being only 2.28-2.33 and its refractive indices 1.469 and 1.473 (Dana and Ford). Parting may be present parallel to the c axis and prismatic cleavage may occur.

Cristobalite. This is also relatively rare but exists in both α and β varieties, the former being probably tetragonal and the latter cubic. Hence β cristobalite has the same relation to β tridymite that zinc blende has to wurtzite, one showing cubic and the other hexagonal close packing. The crystals occur as white octahedra. It occurs with tridymite in andesite, in lava and also in meteorites. Its specific gravity is 2.27 and its refractive index 1.480 (Dana and Ford).

The crystalline structures of tridymite and cristobalite differ considerably from quartz. In tridymite the oxygen atoms lie mid-way between two silicon atoms, and although the tetrahedra are definite the hexagonal figures are not evident (Fig. 11a). In cristo-balite the tetrahedra lie in a cubic cell with silicon atoms at each corner and in the face centres, the oxygen atoms being again placed midway between two silicon atoms. The main difference is that, whereas in quartz the lines joining an oxygen atom to two silicons form an angle of 155° with each other (Fig. 12), in both tridymite and cristobalite all three atoms are in the same straight line. Wells points out, however, that this linear arrangement in cristobalite gives a distance between the oxygen and silicon atoms of only 1.54 Å, whereas, since the diameter of an oxygen atom is 2.7 Å and that of the silicon atom is .6 Å, the distance between them should be 1.65 Å. He states that Barth suggests that the oxygen atoms actually rotate around the lines joining the nearest silicon atoms, giving a more satisfactory distance of 1.63 Å.
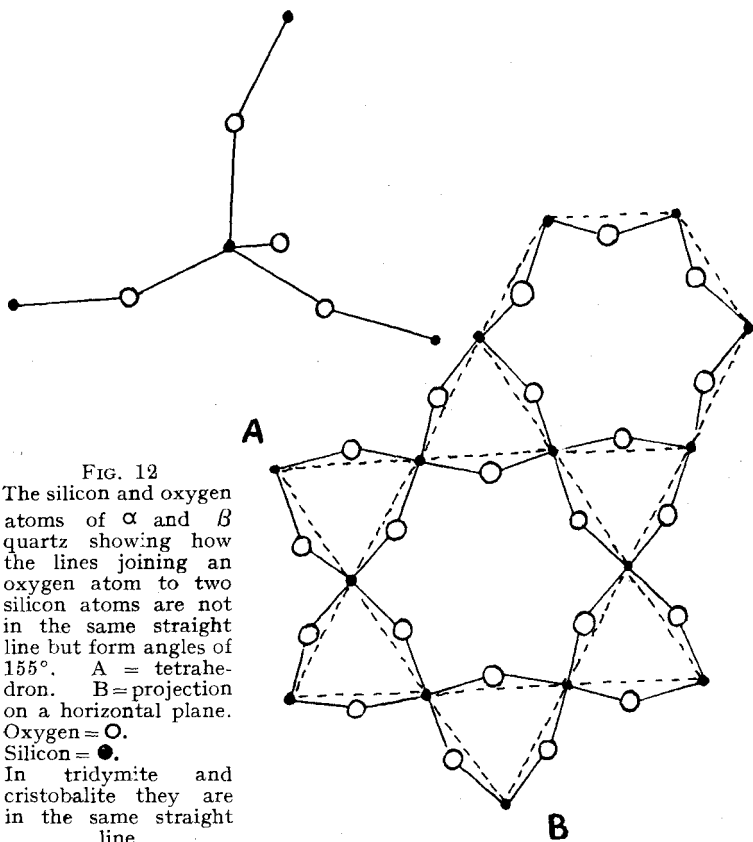
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FIG. 12
The silicon and oxygen
atoms of α and β
quartz showing how
the lines joining an
oxygen atom to two
silicon atoms are not
in the same straight
line but form angles of
155°. A = tetrahe-
dron.   B = projection
on a horizontal plane.
Oxygen = O.
Silicon = ●.
In tridymite and
cristobalite they are
in the same straight
line.

Silica also exists in nature in an amorphous form as opal,
natural glass and sinter, but these are in no sense of the word quartz
and their physical characters are entirely different from crystalline
and massive quartz or from crypto-crystalline chalcedony.

REFERENCES
1. Bragg, Sir William. "An Introduction to Crystal Analysis." G. Bell
   & Sons, Ltd., London, 1928.
2. Dana, E. S., and Ford, W. E. "A Textbook of Mineralogy." Chap-
   man & Hall, Ltd., London, 1948.
3. Evans, J. W., and Davies, G. M. "Elementary Crystallography."
   T. Murby & Co., London, 1940.
4. James, R. W. "X-ray Crystallography." Methuen & Co., London,
   1950.
5. Smith, G. F. Herbert. "Gemstones." Methuen & Co., Ltd., London,
   1950.
6. Ward, A. G. "The Nature of Crystals." Blackie & Son, Ltd., London,
   1943.
7. Wells, A. F. "Structural Inorganic Chemistry." Oxford University
   Press, 1947.

ASSOCIATION
N O T I C E S

REUNION OF MEMBERS AND PRESENTATION OF AWARDS

Dr. G. F. Herbert Smith, the President, described the prize giving held at the Goldsmiths' Hall on November 7th as the climax of the Association's year, when the candidates who were successful at the examinations in June came to receive tangible evidence of their success. The importance of the occasion was, he thought, generally recognized by the large number that were present. Many had come long distances, even as far as Scotland.

It afforded him much pleasure to see present an old friend of his and the Association in Mr. Irvine Jardine. It was thirty years ago that he undertook the very responsible position of official instructor. In those days, when comparatively little was known of gemmology, he had to start the students on the right course.

They were also fortunate in having with them to hand over the Diploma and Certificates, Professor Kathleen Lonsdale, who was well known in X-ray work and crystallography. Due to the brilliant work of early pioneers and the Braggs, father and son, X-rays were a powerful weapon of investigation and Prof. Lonsdale was fortunate in serving her apprenticeship with Sir William Bragg.

Professor Lonsdale then presented the awards and was thanked by the Vice-Chairman, Sir James Walton. He said that she had travelled from Hull to be present that evening. Her wonderful work, he went on, became even more remarkable when it was realized that it was only within recent years that the doors of science had been open to women. She was one of the first women to be made a Fellow of the Royal Society.

Many of those present had heard her lecture on the atomic structure of the diamond. It had made such an impression upon him that now when he looked at a diamond he felt he could almost see its structure. He hoped that Professor Lonsdale would honour them again with a lecture.

To all gemmologists the work of the Professor had been of special value in raising the scientific trend of gemmology. Some might decry that approach and say it was not in accordance with practical gemmology, but the same thing happened in many branches of science and was essential for advancement.

Throughout the ages, Sir James continued, mankind had always been seeking happiness. Some through marriage, wealth or health. Provided one has found a measure of happiness one of the chief ways of gaining a permanent form was to have an interesting, an enthralling hobby. Such a hobby made one impervious to the worries and annoyances of modern life. With such a hobby as gemmology there was no retiring age, though perhaps there should also be a more active hobby to give exercise. To many of

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those present there was the opportunity, the most glorious of all, that they might be able to make of their life work their hobby also.

Professor Lonsdale said she was honoured by the list of her predecessors who had presented prizes and the fact that Sir William Bragg had been a Past President of the Association. She had had the privilege of working with him for twenty years. Sometimes people wanted to know what was the use of pure science. Surely scientists had the same feelings as an artist? His pleasure was great and of the same kind in its reward for the study of the order and beauty of nature. People did not ask what was the use of a violet under a hedgerow. She found pleasure in studying crystals, but of course it did not finish there. Crystals came into every phase of life. Every kind of solid material was crystalline. They were studying the same kind of arrangement in diamonds as in saucepans.

The U.S. Government had recently given her a Fellowship to travel in America under the auspices of a health research scheme because crystals came into medicine. She was now a Professor of Chemistry and knew the importance of crystals in such substances as penicillin. They even came into the study of permanent waving, because hair was partially crystalline and in waving it the arrangement of the atoms had to be changed. Thus the subject had repercussions in almost every field. Gemmologists could feel that they were part of a very great company.

Professor Lonsdale congratulated those who had received the awards for which they had worked so hard. Their work had made them better citizens because they had studied scientific methods. Particularly was this so if they used those methods in everyday life. Many young people could not distinguish between fact and fiction. It was important to be able to distinguish truth from error ; the proved from the unproved ; real from artificial. They had learned how to do this and she hoped they would continue to practise it not only in gemmology but in all the affairs of life.

Miss Elsie Ruff, member of the Council, then presented the Professor with a bouquet, after which the Chairman, Mr. F. H. Knowles-Brown, made another, and surprise, presentation. He said that since the birth of the Association their President had always been closely associated with it, giving it his constant attention and encouragement. In the early days it was difficult to train students because of the lack of a textbook. Dr. Herbert Smith wrote one which had become a standard work on the subject. He also designed his refractometer. From the earliest examinations he was the chief examiner and his influence was such that he set a very high standard to start with. This had been maintained so that the Diploma was desirable to have not only in Britain but throughout the world. Mr. Knowles-Brown said he was, therefore, glad to offer a tribute to the services of the President, who had recently given up work as senior examiner to the Association, in the form of a portrait of him. As he said this he lifted a piece of velvet to reveal a portrait of Dr. Herbert Smith, wearing his University robes and C.B.E. decoration. The painting had been done, unknown to the President, by Miss Betty Byrne, working from photographs.

In his thanks, Dr. Herbert Smith said it had been laid down that virtue was its own reward, but the pleasure of it was enhanced when it was recognized in such a manner.

COUNCIL MEETING

A meeting of the Council of the Association was held at 19/25 Gutter Lane, London, E.C.2, on Wednesday, November 7th, 1951, at 5.15 p.m. Mr. F. H. Knowles-Brown presided.

The following were elected to membership:—

FELLOWS

Alexander, D., Glasgow.
Armstrong, A. H. G., Stirling.
Belton, C. G., Southend-on-Sea.
Bishop, E. A., Southend-on-Sea.
Breebart, A. J., Arnhem,
               Netherlands.
Broadbent, Miss S. A., Farnham
Bridges, R. J., London.
Browne, P. C., Nottingham.
Caffell, E. W., Woking.
Cater, C. W., London.
Cohen, S., Utrecht.
Crook, Miss W. E., London
Davis, G. W., Birmingham.
Denyer, B. C., Harrow.
Dew, R. G. J., Croydon.
Fine, H. D., London.
Goodbody, R. F., Petersfield.
Harris, D. I., London.
Hogervorst, Mrs. T., The Hague,
               Holland.
Instone, I. N., Bexhill-on-Sea.
Kibe, V. R., Indore, India.
Kirkpatrick, M. R., Harrow.
Kolb, H. F., London.
Knowles-Brown, P., London
Leech, R. A., Ilford.

Lumsden, J. G., Edinburgh.
Miller, L. R., San Rafael,
               California.
Myers, G., Wembley.
MacDonald, H. F., Glasgow.
Mackenzie, I., Greenock.
Oostwegel, L., Heerlem, Holland.
Palmer, J. V., New Westminster.
               British Columbia.
Perry, J. A., Southend-on-Sea.
Rae, J. W., London.
Russell, B. T., London.
Russell, W. E., Port Alberni,
               Canada.
Stockwell, J. C., Middlesbrough.
Towe, E. G., Edinburgh.
Turnbull, K., Romford.
Wacker-Wakelin, R. J. G.,
               Birmingham.
Wade, C. D., Paisley.
Wade, J. D. S., Glasgow.
Walker, J., Edinburgh.
West, Miss M. D., Theale, Berks.
Wood, E. A. A., Edinburgh.
Wright, T. J., London.
Wyatt, J., Bromley.

FELLOWS TRANSFERRED FROM PROBATIONARY

Bartram, Miss E. M.,
  West Woodville, South Australia.
Clarke, Miss H. A., London.
Doulis, L., Detroit, U.S.A.
Ekanayaka, F., Colombo.

Gush, Mrs. I., Johannesburg.
Lynch, D. K., London.
Myhre, H., Ljan, Norway.
Scott, J. F., Lincoln.

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Hessling, F., Birmingham.   Spiro, F., Indonesia.
Light, D. A., Sutton Coldfield.   Andriessen, D. J., Bergen, Holland.
Rogers, D. S., Belmont.

ORDINARY

Sheehan, W. W., Brazil,   Jardine, I. G., London.
    South America.

An invitation from the British Standards Institution asking the Asso-
tion to appoint a member to serve on a diamond tools and powders
committee was received. Mr. B. W. Anderson was invited to represent the
Association.

Correspondence concerning the two Swedish Gemmological Associations
was considered, the Council expressing the opinion that the cause of gem-
mology would best be served if a satisfactory means of amalgamation could
be agreed.

TALKS BY FELLOWS

R. H. Corfield: " Gemstones." Mill Hill Rotary Club, October 30th,
1951.

P. Knowles-Brown: " Gemstones—their origin and use in jewellery."
Twenty Club, Temple Fortune, November 21st, 1951.

J. F. Croydon: " Gemstones." Woodbridge Rotary Club, January
12th ; Ipswich Inner Wheel, February 5th ; Leiston Women's Institute,
July 10th ; Southwold Women's Institute, September 20th ; Ipswich Round
Table, November 19th.

MEMBERS' MEETINGS

January 23rd: British Council Cinema, Hanover Street, London, W.1,
7 p.m. " Art of the lapidary and the problems of cutting and polishing,"
by C. L. Arnold and G. E. Bull-Diamond of Messrs. Charles Mathews, Ltd.

March 26th: Twenty-second annual general meeting, Goldsmiths' Hall,
Foster Lane, London, E.C.2., 6.45 p.m.

NORWEGIAN GEMMOLOGICAL ASSOCIATION

On September 14th, 1951, the Norges Gemmologiska Selskap arranged a
lecture for their members at which Mr. Pike, of Messrs. Rayner & Keeler,
Ltd., was the speaker. Members of the Goldsmiths' Association of Oslo
were also invited.

Mr. Pike read a paper which dealt with the simplest and more compli-
cated gem testing instruments, and a demonstration which followed greatly
interested the audience. The lecture was translated by Mr. Hans Myrhe,
Oslo.

The Chairman of the Association, Mr. O. Modahl, in thanking Mr. Pike,
said that the lecture would further increase the interest of gemmology in
Norway.

The following day members of the Association were shown the mineral
collections at the Museum of Natural History in Oslo.

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