THE JOURNAL OF GEMMOLOGY
AND PROCEEDINGS OF THE
GEMMOLOGICAL ASSOCIATION
OF GREAT BRITAIN

Vol. V No. 3 JULY 1955

Mr. CLAYTON'S DIAMOND

by

JESSIE M. SWEET, B.Sc., and A. A. MOSS, B.Sc., Ph.D., F.S.A.

IN the autumn of 1663 Robert Boyle heard that a certain Mr. Clayton, newly returned from Italy, possessed a diamond which became luminescent when rubbed in the dark. This information so intrigued him that he set off at once to find its owner. As Mr. Clayton was preparing to go out and the luminescent effects were not visible in broad daylight, Boyle borrowed the diamond for the night. He described it as " a Flat or Table Diamond, of about a third part of an Inch in length, and somewhat less in breadth, that it was a Dull Stone, and of a very bad Water, having in the Day time very little of the Vividness of ev'n ordinary Diamonds, and being Blemished with a whitish Cloud about the middle of it, which covered near a third part of the Stone." This rather unprepossessing gem was set in a ring.

In a long letter to Sir Robert Morray, F.R.S., which was also intended for the information of a certain Monsieur Zulichem, he gave an account of previous reports of luminescence in stones, most of which he regarded with scepticism. Many of them were referred to as " carbuncles " which in those days meant any red stone (ruby, spinel or garnet). The only one he examined was a vivid ruby which was supposed to have this property, but nothing he did to it could induce it to shine in the dark.

He was so anxious to start his experiments with the diamond that he could not wait for the evening, but got into his four-poster bed straight away and drew the curtains, but no effect was observed until twilight. In the first place he was not absolutely convinced that the stone was a diamond, but after finding that it scratched both quartz and glass, he felt a little more confident about it. He also found that it had electric properties and would attract in the same way as amber or jet when rubbed, though after heating near a candle-flame it attracted nothing. But the real interest lay in its luminescence and this was not visible until the diamond was actually rubbed or heated, when, as he says, it shone in the dark like the scales of whiting or putrefied fish. He did realize, however, that the light was not caused by the destruction of matter as in organic bodies, but by a mechanical operation.

Boyle used various means to excite the diamond and increase its luminescence. He rubbed it with cloths of different colours (of which apparently black gave a poor result) and then with transparent horn, a white wooden box and white porcelain, all of which gave good results, but he would not deduce from that that the colour of the medium used had any influence. After rubbing it with a cloth he covered it with blue glass, but the luminescence was not sufficiently strong to penetrate it. He then held it near a candle-flame, but the effect was not good although he kept his eyes averted from the light. When pressed with a white glazed tile, it seemed to luminesce ; and it gave a vivid reaction when pressed with a steel bodkin, and eventually even with his finger. Finally he took it to bed with him and held it against his body, the warmth of which was sufficient to cause it to glow.

He then tried to quench the luminescence by immersing it in water and other liquids and also by covering it with saliva, in spite of which treatment it still shone. He thought that warm water excited it and that it glowed more brightly when removed, but he could not see the effect when immersed owing to the escape of air bubbles. He did, however, think that the rate of decay of the luminescence was thus accelerated and the visible luminescence would, in any case, appear to have been of short duration.

The results of these experiments were communicated to the Royal Society on 28th October, 1663, when the stone was exhibited, after which it was returned to Mr. Clayton, who presented it to Charles II. Boyle regretted that he was no longer able to demonstrate its properties to Sir Robert Morray or Monsieur Zulichem. but suggested that it might be possible for them to see it, "though it be now in the hands of a Prince that so highly deserves, by understanding them, the greatest Curiosities ; yet he vouchsafes you that access to him as keeps me from doubting, you may easily obtain leave to make further Tryals with it, of such a Monarch as ours, that is not more inquisitive himself than a favourer of them that are so." Eventually he discovered that several other diamonds exhibited a similar luminescence, but none so well as Mr. Clayton's.

We may infer from these observations that, during exposure to daylight, Mr. Clayton's diamond absorbed radiation which it could emit under the stimulus of heat, applied either by "affriction" (as Boyle called it) or by immersion in hot water—a phenomenon known as thermoluminescence. We have repeated these experiments of Boyle under more controlled conditions and the following is a brief account of the results obtained and the conclusions drawn.

Mr. Clayton's diamond not being available, it was first of all necessary to select a suitable diamond. Accordingly, since it seemed probable that a diamond that fluoresced strongly under ultra-violet light would be likely to exhibit thermoluminescence, a set of diamonds from the Belgian Congo, presented to the British Museum by Sir Ernest Oppenheimer, was placed under a high pressure mercury discharge tube, the radiation from which was caused to pass through a Wood's filter.[1] One of this set (B.M. 1946, 1a)—a rough spinel twin, which fluoresced (bluish-white) much more than the others, was chosen for the experiments. After exposure to ultra-violet light, the diamond was removed to a dark room, where for about 2 hours it was easily visible to an observer that had accustomed his eyes to the darkness. When it was no longer visible, the diamond was placed in a beaker of hot water (temperature between 70 and 80°C) and the diamond again glowed brightly. It has been customary to call the former phenomenon phosphorescence,[2] and the latter thermoluminescence. The two phenomena are in point of fact the same in that phosphorescence and thermoluminescence denote the flowing out of energy that has been stored during the period of activation, the only difference between them being that in the former instance only is the rate of emission of light energy at room temperature sufficiently great to be detected by the eye. As the energy contained in the diamond decreases, the rate of emission of this energy also decreases (just as the rate of flow of liquid from a vessel decreases as the level of liquid in it falls), until this rate is too low to be visible. This emission of energy is still, however, taking place and, in the case of diamond, the rate can be increased by elevating the temperature, whereby the luminescence can once again be seen. It was further discovered that this low rate of light emission continued for several days : thus, the diamond, after exposure to ultra-violet light for 3 minutes, followed by 10 days in darkness, glowed quite brightly when placed in water at 70–80°C. The luminescence could, however, soon be thermally quenched and after maintaining the diamond at 100°C for a few minutes, visible luminescence at this temperature ceased.

Although these experiments show clearly that this diamond can absorb energy in the form of ultra-violet light and emit it later as visible light, they are not exactly analogous to those of Boyle, whose diamond was exposed only to daylight. The diamond, therefore, after heating at 100°C to remove the absorbed light-energy, was allowed to lie near a north window (the day was dull and rainy) for 4 hours. When it was placed in water at a temperature of 70–80°C it was observed to luminesce. It seemed probable that the source of luminescence of the diamond was the absorption of ultra-violet light, and this was confirmed in the following manner. The diamond was placed in a light-tight box and heated to 100°C as before. The box was removed to the dark room where the diamond was transferred to another box in which it could be illuminated through an ultra-violet filter.[3] This box was then placed near a window so that daylight could fall on the diamond and left for a day. When the diamond was examined in water at 70–80°C, it produced no visible luminescence.

Having shown that there was sufficient ultra-violet radiation in north daylight to activate the diamond, it was next necessary to find what wave-length of ultra-violet light was being absorbed. Accordingly it was decided to repeat the experiments using a tungsten filament lamp instead of daylight. This source of light was chosen for two reasons : firstly, it is known that the tungsten filament lamp emits only a very small amount of ultra-violet light,[4] and secondly, it was an easy matter to determine the lower wave length limit of this ultra-violet light. It was in fact 3130 Å.[5] By illuminating the diamond with this filament lamp we were trying to ascertain whether there was sufficient energy in the very weak ultra-violet radiation between 3130 and 3910 Å,[6] to activate the diamond. The results of the experiments were the same as when daylight had been used. Finally the radiation from the tungsten filament lamp was caused to pass through the ultra-violet filter before striking the diamond. The results were the same as when daylight had been the source.

Diamonds are usually classified as type I and type II, a characteristic difference between the two types being that type II diamonds do not absorb ultra-violet light of wave lengths greater than about 2250 Å whereas type I diamonds absorb strongly below 3000 Å. It may be concluded from this that the diamond used in the above experiments should be a type I diamond, since, as we have shown, it is activated by, and presumably absorbs, wave lengths between 3130 and 3910 Å, and this was confirmed by examination of the spectrogram of an iron arc[7] taken with the diamond placed before the slit of the spectrograph which showed that the absorption of ultra-violet light by the diamond was strong below about 3000 Å and complete beyond 2940 Å.

We have shown that the active ultra-violet wave-lengths in the production of luminescence lie between about 3910 and 3130 Å, and it would appear probable that this band of wave-lengths would also be mainly responsible for the fluorescence. This was shown to be so in a qualitative manner by holding the diamond in the focal plane of the spectrograph, when illuminated by an iron arc, and moving it slowly from the visible to the ultra-violet end of the spectrum. The fluorescence was most intense in the region just below 3900 Å, and diminished as the diamond was moved to a position illuminated by ultra-violet light of wave-lengths less than 3000 Å, although fluorescence could just be detected at 2000 Å. It would seem, therefore, that although the absorption of ultra-violet light below 2940 Å is complete, the energy so absorbed is largely dissipated in other ways than by light emission.

A considerable amount of work has been done in an attempt to discover the cause of the different behaviour of the two types of diamond, but it is not our purpose to discuss these here. It will suffice to say that, in general, fluorescent and luminescent diamonds are type I, if the absorption of ultra-violet light be accepted as the distinctive characteristic,[8] and, from the experiments we have carried out, some of these type I diamonds, to which category Mr. Clayton's diamond must also belong, are activated by absorption of long wave ultra-violet light (3910–3130 Å) of very low intensity, the energy so absorbed being slowly emitted over a period of several days, a fact that could be made visible, as Boyle demonstrated, by increasing this rate of emission by raising the temperature.

REFERENCES.

1. This filter absorbs visible light, but allows ultra-violet light of wave lengths between about 4000 Å and 3000 Å (Å = Angstrom Unit = 10^{-8} centimetres) to pass.
2. Luminescence is a better term and will be used in this article.
3. An ultra-violet filter transmits visible light, but allows no ultra-violet light to pass. The filter used was found by experiment to absorb all wave lengths below 3910 Å.
4. 88% of the output is infra-red radiation.
5. The limits of this radiation were determined experimentally for a 150 watt (230 volts) lamp working at 230 volts exactly.
6. See footnote 3.
7. The iron arc is a strong emitter of short wave ultra-violet light.
8. Sir C. V. Raman, Proc. Ind. Acad. of Sci., A, 1944, **19**, 199.

SYNTHETIC DIAMONDS

Since the publication by the General Electric Company of America of the production of synthetic diamond, two other reports of manufacture have been received.

The Swedish A.S.E.A. works are stated to have produced synthetic diamond in February of 1953. Using a pressure of 80,000–90,000 atmospheres and temperatures up to 5,400°F. and on principles discovered by the Swedish scientist Baltzar von Platen, the company made 40 minute colourless or faintly greenish stones at that time. It is stated that stones up to a 2mm. size can now be made.

The N.V. Bronswerk laboratory, in the Netherlands, is also reported to have produced synthetic diamond, with results similar to those produced by G.E.C. (*Journ. Gemmology*, Vol. V (2), 1955). The first " fields of crystals " were produced in January, 1955.

NOTES on the OCCURENCE of TWO-PHASE INCLUSIONS in SYNTHETIC SPINEL

by Dr. J. W. BRINCK and Dr. P. C. ZWAAN, F.G.A.

IN " A letter to the Editor " of *Gems and Gemology* (Vol. VIII, 1954, No. 2) some synthetic spinels showing distinct two-phase inclusions were described by Aldert J. Breebaart, F.G.A., Nijmegen, Holland.

A short review of the contents of this letter is given here :—

The writer reports the occurrence of many inclusions with a distinct two-phase appearance in a yellow-green synthetic spinel. This spinel was part of a delivery of cut synthetic from Germany. The stone was sent to England for further examination. There the occurrence of two-phase inclusions of a hydrothermal type was stated ; the first phase being a liquid one, the second phase a vapour. These liquid and vapour phases of the inclusions might have been introduced in the stone during its growth in the Verneuil furnace. Here the water might have been formed under certain ideal circumstances occurring when the hydrogen and oxygen of the blowpipe fused at a ratio of 2 to 1. Due to the terrific heat in the furnace, this water would be evaporated immediately and perhaps it was included as vapour during the growing of the boule, and on cooling partly condensed into water in the thus formed cavities.

Seeing the photographs published in the article, we were convinced that the real character of the inclusions might be other than supposed. Some of the features displayed by the inclusions make it difficult to interpret these inclusions as of a hydrothermal type, containing water-vapour phases.

The hydrothermal type of inclusion is a very common one, reported and studied by many authors in different kinds of natural crystals. (G. A. Deicha, 1951, and E. Ingerson, 1947.)

Ingerson concluded there is a certain ratio between the volume of the liquid- and the vapour-phase (" bulle de retraite " of Deicha), controlled by the P/T ratio at time of forming.

Supposing the circumstances during the time of formation of the growing boule in the Verneuil furnace being about atmospheric pressure and rather high temperature (> 200°), the evaporated water would have a very low density, resulting on cooling in a very small liquid phase and a corresponding rather large vapour phase.

Since the reverse is the case, as was shown by the photographs, this constitutes a strong argument against the hydrothermal character of the inclusions.

A second argument was indicated by the kind of differences of the refractive indices of the three phases (crystal and two-phase inclusions) in respect to each other. This, however, necessitated proof by microscopic examination of the stone itself.

Mr. A. J. Breebaart was so kind as to send us the described synthetic spinel to be re-examined together with some other synthetic spinels of the same delivery.

Description of the stone :

It is a brilliant cut stone weighing 2·10 carats with a yellow-green colour. The refractive index is 1·731 measured on the table. Its specific gravity has the average value 3·643. Under the Chelsea colour filter the stone has a greenish colour. Microscopic examination indicates curved structure lines and typical inclusions. In addition anomalous double refraction occurs.

Inclusions :

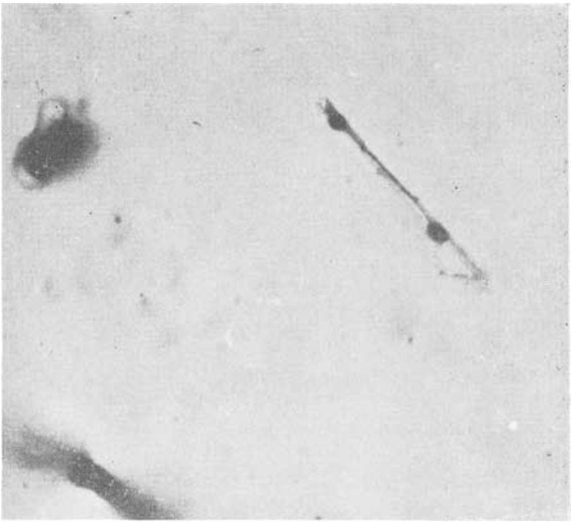
The inclusions of the synthetic spinel were found to be visible at low magnifications. They were studied by the writers at magnifications up to about 500 ×, by observation through the table.

There are one-phase inclusions in the spinel, showing a refractive index considerably different from that of the stone. Their morphology shows rounded form while sometimes elongated bodies meander through the spinel. They appear as black or nearly black inclusions and were identified as air bubbles, introduced in the stone during its growth in the Verneuil furnace. (Profiled air bubbles of Gübelin, 1953.)

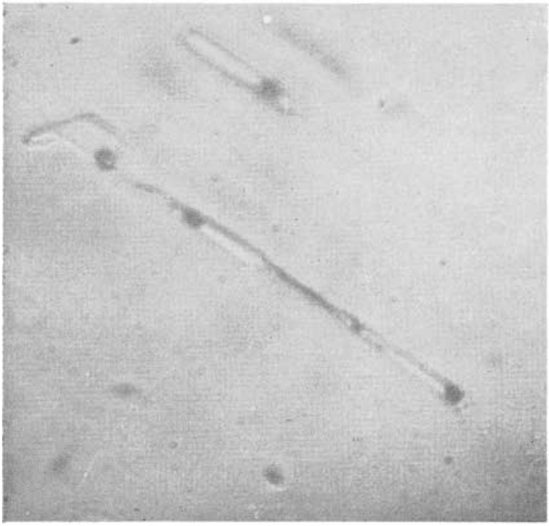
Besides these air bubbles there are also many of the interesting inclusions, of the type described by A. J. Breebaart, being certainly two-phase inclusions.

They often show negative crystal faces. Needle-shaped forms predominate, but sometimes broad and flat forms occur. One of the two phases, filling most of the inclusion, shows by its transparency that it has a refractive index similar to that of the spinel, while the Becke line shows that it is slightly smaller.

The other phase observed in the inclusions consists of rather



Two-phase inclusion, with negative crystal form Two bubbles of gascous phase in the same inclusion—different ratio between vitreous and gascous phase volume



Two-phase inclusion with negative crystal form

small rounded bodies, with a much smaller refractive index than the spinel.

In many inclusions, mostly the smaller ones, there occurs only a single body of this second phase. In the bigger ones, however, we see two and even more, of varying size.

None of the second phase bodies found in the inclusions show any Brownian movement. This proves they are in a fixed position, being controlled by the first phase of the inclusion.

The ratio between first and second phase in the inclusions, as was seen in many of them, is not always the same.

These observations render it impossible that the inclusions are of a hydrothermal character, but make it almost certain that the first phase in the inclusions is a vitreous one, whereas the second phase is a gaseous one, and is probably air.

The occurrence of vitreous inclusions in crystals (natural) was stated by H. Vogelsang (1867), and has been studied and proved recently by Dr. G. A. Deicha (1951).

Deicha describes quartzphenocrysts, having vitreous inclusions. These inclusions show beautiful negative hexagonal bipyramids, proving that at the time of formation the quartz was in the β-phase (> 573°). Natural spinel being isometric hexoctaedral shows isometric negative crystal forms, as was described by Dr. E. Gübelin (1953). The needle-shaped negative crystal forms point to some unknown crystal-phase of $MgAl_2O_4$ at the time of formation of the boule.

The same type of two-phase, vitreous inclusions was found in two other synthetic spinels of the same delivery. They are dark green stones, with many inclusions that appear as shadowy streaks to the naked eye.

At magnifications up to 500 ×, they show two types of inclusions The first type consists of profiled air bubbles. These inclusions are rather large compared to the inclusions of the second type, which are also less abundant.

They are of a vitreous two-phase type, being glass and probably air, as in the case of the stone described above.

REFERENCES.

H. Vogelsang, *Philosophie der Geologie und mikroskopische Gesteinsstudien*, 1867, Bonn.

E. Ingerson, *Liquid inclusions in geologic thermometry*, Am. Mineralogist, 1947, **32,** 375.

G. A. Deicha, *A propos de reliquats magmatiques dans les quartz de première consolidation des roches à deux temps de cristallisation*, Bull. Soc. franc. Minér. Crist., 1953, **LXXVI,** 457–463.

G. A. Deicha, *Neue Methoden zur Erforschung der hydrothermalen und pneumatolitischen Einschlüsse in Mineralien und Gesteinen*, Neues Jb. Mineral., Mh., 1951, **9,** 193–203.

K. F. Chudoba and E. J. Gübelin, *Schmuck- und Edelsteinkundliches Tachenbuch*, Bonn, 1953.

A. J. Breebaart, Letter to the editor, *Gems and Gemology*, Vol. **VIII,** Summer, 1954, No. 2.

ORIENTING BLUE TOPAZ with ULTRA-VIOLET LIGHT

by HUGH LEIPER

OVER a considerable period of time, I have been faceting blue topaz, to me, a very fascinating and beautiful gem. But I must admit that many of my earlier attempts did not result in a finished gem of the depth of colour that the rough material seemed to promise.

This puzzled me a great deal. I sought accumulated examples of the gem rough from every available country of occurrence—Russia, Brazil, Australia, Ceylon, Nigeria and the United States ; particularly, in the latter case, from Mason County, Texas, which was fairly near my home and from which a wealth of varied material was available at the cost of many hours of back-weary digging.

By ordinary methods of orienting the preforms, I was able to secure, at times, a satisfactory flooding of the finished gem with the beautiful sky-blue for which this material is known. At other times, the finished gem would show this blue colour only when tilted to certain angles away from the perpendicular line of sight (to the table). I realized that something was definitely wrong with my method of orienting the preform but I was, at that time, guided only by such areas of strong colour as could be seen by ordinary daylight.

One evening while in my home workshop showing visitors some of the various fluorescent minerals I had accumulated, I happened to pass the short-wave ultra-violet light over a tray of large topaz crystals, some from Australia, the majority from the Texas area. My eye caught a *lemon-yellow* fluorescence from a large cleavage of Australian topaz. On closer examination, this showed as an " hour-glass " shaped area extending from two opposite corners of what had been a practically square crystal before it had been fractured and cleaved. After the visitors departed, I got out my entire collection of rough gem topaz, and went over it carefully.

I discovered that there were three distinct patterns of fluorescence present in this topaz rough.

TYPE 1

Zones of lemon-yellow parallel to the " C " axis of the crystal, but in hour-glass shape when viewed from the basal cleavage, and extending the length of the crystal. I have called this Type 1-A.

Zones of lemon-yellow parallel to the " C " axis, but lying parallel also to *four* of the eight *sides* of the crystal. I have called this Type 1-B.

Zones of lemon-yellow parallel to the larger of the terminations of the crystal ; generally two, in a few instances three, and rarely four zones being visible. These zones are not on the surface of the terminations but are generally found to be from 2mm. to as much as 8mm. below the surface, and are *joined* at the apex—a very important point. This type of zoning appears to be the most common of the three, and, since a great many of the water-worn pieces found are simply terminations which have been broken from their attachment, rolled and eroded until they have often entirely lost their former crystal form, the discovery is very helpful. I have called this Type 1-C.

TYPE 2

These specimens are perhaps the most spectacular when first viewed. They are suffused all over with a cloudy lemon-yellow glow, rather than having definite colour bands. They do not, however, yield the depth of colour when faceted that can be expected from zoned crystals properly oriented.

TYPE 3

When first examined these were not apparent. But, after all zoned specimens had been graded out, it then became evident that the remaining crystals were of two colours under ultra-violet light. One of these showed crystals of apparent deep indigo-blue, while the remainder were a much lighter blue in colour. Upon separating the two and later comparing them in daylight, it was found that the first (indigo-blue under U.V.) were homogeneous blue all over by daylight, while the lighter blue specimens (under U.V.) turned out to be the common white topaz. I have called the first Type 3-D, and the latter simply white topaz.

These simple methods of grading blue-zoned topaz will be of material assistance to faceters, both in the purchase of suitable gem rough for faceting and in evaluating that which they may dig for themselves. Likewise it makes possible more accurate orienting of the colour zones in the preform and makes more certain the cutting of a finished gem that will take maximum advantage of the colour available in the material. (Be sure your rough is free of oil or detergents before examining under U.V. light. Work in complete darkness.)

My examination of topaz rough from various sources leads me to the following conclusions about topaz from various countries.

Russian topaz crystals that I have been able to examine appear to be uniformly of Type 3-D, homogeneous with colour distributed throughout. Some of the splendid examples of this topaz in our various museums, notably in the American Museum of Natural History in New York, the U.S. National Museum, Washington, and the Chicago Natural History Museum, show this quality of colour to perfection and there are few from other areas that can match them.

Brazilian crystals appear to be of both Type 2 and Type 3-D ; inclined to have numerous veils and feather-like inclusions. I have observed none of Type 1 in any of its zoned forms among the Brazilian material although my examination has not been thorough for want of sufficient material.

Australian topaz which I have been able to examine shows material of Types 1-A and 1-B, one example of Type 1-C, several of Type 3-D, also white topaz. It is probable that the missing Type 2 will likewise show up from this area upon examination of a larger selection of crystals.

Topaz crystals examined from Nigeria have shown themselves to be of Type 3-D and white topaz—no zoned specimens having come to my attention. They average very light blue to blue-white.

Such specimens as I have been able to examine from Ceylon have been native-cut small gems, and all those examined have been of Type 3-D or white topaz. The blue topaz from this area is usually of very light, blue-white colour, possibly due to the lack of orienting of the rough by the native cutter—a very common failing in all gems from this area where they seem to cut for weight alone.

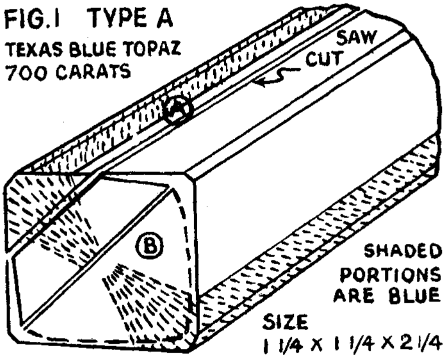
Topaz of the blue variety has been known to occur in the United States in various localities—Maine, New Hampshire, Massachussetts, Colorado, California and Texas. I have not been able to procure specimens from all of these areas yet, hence my own examinations of material have been largely confined to the Texas material, where all of the various types occur, with a marked predominance of the Type 1-A, 1-B and 1-C noted, also a large number of beautiful pieces of Type 3-D. The ratio of the " blues " of various types to white topaz in the Texas area seems to run almost 50-50. A very large percentage of the large crystals found are blue-zoned—relatively few large white topaz crystals showing up.

The drawings accompanying this article show the proper manner of orienting the preform to the prevailing type of colour in the topaz rough. Note that in Type 1-A, illustrated in Fig. 1, the transverse " hour-glass " blue zones, extending from two opposite corners, have been placed so that the zones are vertical to the table of the gem. A saw cut made with a very thin diamond saw first separated the crystal lengthwise parallel to the C axis.

The preform was then ground accurately to rectangular shape, the corners of the rectangle were ground off, and the immense table polished. After this the pavilion was cut into six steps, each pair of which was then skew-cut. The crown was cut into four steps and these pairs skewed, after which a fifth step, quite narrow, was cut around the edge of the table. The rough weighed approximately 700 carats. Sawing removed a piece of approximately 100 carats, with a sawing loss of approximately 23 carats. Out of the remaining 577 carat rough, a preform of approximately 410 carats was made and from this a finished gem of 333·5 carats resulted, a " save " of 57·8% of the rough. Several nice gems could be cut out of the 100 carat slice.

Fig. 3 shows how two or more preforms may be cut from a crystal having Type 1-B colour zoning. It often happens that a crystal will have both Type 1-B and Type 1-C zoning. In such a case it is wiser to make use of the termination for the larger gem with its Type 1-C zoning as this type has the zoning joined at the apex. This is then placed in the culet area of the pavilion so that no light may pass into the gem without being reflected through this portion of the culet. With Type 1-B, carefully notice that the colour zones that are parallel to the sides of the crystal are often not joined at the corners. There is, therefore, a small amount of area in the

FIG.1 TYPE A
TEXAS BLUE TOPAZ
700 CARATS



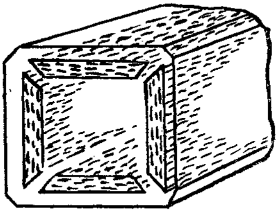


FIG. 2. TYPE.B. SHOWING BLUE ZONES PARALLEL TO C.AXIS

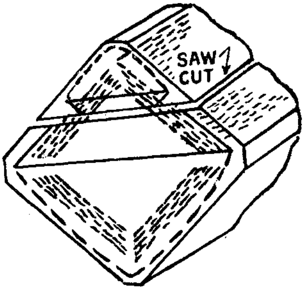
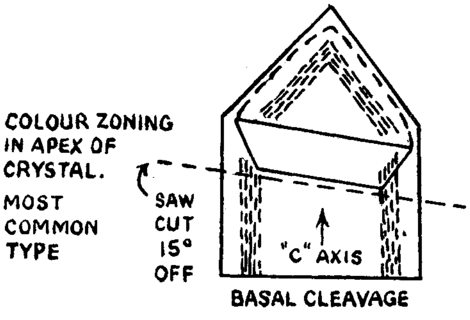


FIG.3 TYPE.B
ORIENTING PREFORMS TO TAKE ADVANTAGE OF COLOUR ZONING.



culet that will not be blue-zoned. By throwing the table cut slightly off to the left or right, it may be possible to place a portion of one of these blue zones into the culet area where it does its best work. A smaller gem or two can often be cut from the upper portion which is sawn off, provided it is cut deep enough.

Figure 4 illustrates a cross section through a terminated topaz crystal and the usual placement of the joined blue zones. This is an idealized drawing—your piece of gem rough may be, and probably will be, only the tip of a crystal, tumbled and water-worn almost completely out of shape. The terminal zoning under short-wave U.V. will, however, give an accurate clue to the grinding of the preform. Note carefully that the table must be placed at least 15 degrees off the plane of basal cleavage and, when polishing the table, it is best to polish " down-hill " away from rather than into the grain.

Other gems may be cut from the remainder of the crystal by placing the side-zoning in the greatest diameter of the girdle. Such preforms are cut parallel to the " C " axis or nearly so. By turning the table so that it comes from the interior portion of the material, it is sometimes possible to place the blue-zoned area well down in the culet area where it will do the most good in flooding the gem with colour.

All blue topaz should be cut with a fairly shallow crown, about 25% of the height, and the pavilion made as deep as the rough will allow if colour is to be enhanced. The final facets in the culet must never go below the critical angle for topaz, given as 39 degrees for this facet by some authorities, but my personal experience has shown that a final set of facets at 40·5° is much better and more brilliant.

Topaz that is of Type 3-D, homogeneous and apparently blue and uniform, can usually be cut in almost any direction that the rough will allow except, of course, the table must be at least 15 degrees off basal cleavage. I have tried as low as 5° and had real trouble.

In general, the apex of a crystal will yield an excellent brilliant with the smallest waste of rough, while a step cut gem may often be laid out best parallel to the " C " axis, or lengthwise to the crystal.

(*Reprinted, with permission, from " Gems and Minerals " Magazine, California.*)

JADE STORY — EUROPEAN

(*The third part of the Story of Jade in Europe*)

by ELSIE RUFF, F.G.A.

THE study of jade—in particular its symbolism and early use—has long been considered one for the specialist alone. And this particular specialist has hardly ranked as a gemmologist. Gemmology itself has had a tendency to shelve the jade question, again, regarding it as a subject for the specialist. Most gemstone textbooks deal with the material very perfunctorily. To study jade in its widest sense is to leave behind the field of the specialist. For the difficulty of digging in the jade hole is that it goes so deep, and has so many ramifications, it unavoidably cuts through into other holes.

To establish the term *lapis nephriticus* (see JOURNAL OF GEMMOLOGY January, 1955, p.16) is not difficult, but it will be obvious that the question is not a long one for etymology alone. Bright's disease is a disease of the kidneys, known as nephritis. The Spanish for *lapis nephriticus* is *piedra nefritica*—nephrite stone. A modern Spanish dictionary combines two terms *piedra nefritica o jade.* The French *pierre néphrétique* is of course the same thing. And the Latin *nephriticus* stems from the Greek, *nephros,* νεφρός, kidney There seems no doubt whatever that this word has always been associated with the kidney. More than one student has felt that the occurrence of nephrite boulders in kidney form might be responsible (long since) for this expression, but as the term could as aptly apply to boulders of other materials, similarly shaped, it would seem a suggestion we may confidently discard.

As it is not possible to quote every source, or even necessary or advisable from the point of this enquiry, we may confine ourselves to various authorities over the past few hundred years. What must come as a surprise to all researchers is the enormous amount of literature available on this subject (provided one is intent enough on the search) and the vast number of people concerned or intrigued with the story of jade.

The nineteenth century, which is late enough to begin the inquiry, was the era of *The Jade Question.* It was the century too, for the discovery of the Jordansmühl and Reichenstein occurrences.[1] American gemmologists were now in the picture; men who have given their names to gemstones with which every gemmology student is familiar. It was the era of Dr. A. B. Meyer, of Dr. F. W. Rudler, of Mr. James Hilton, F.S.A.A., and of Jean Pierre Abel Rémusat, of whom we shall hear later. There was also Dr. Heinrich Fischer, who differed strongly with Dr. Meyer on the occurrence problem. There was Dr. Schliemann as we have seen[2], and a host of other authorities. Not least among them was A. Damour of Lyons, considered the leading mineralogist of his day, who investigated this subject extensively and was responsible for the segregation, in 1863, of the two distinct minerals—suggesting the term jadeite for the jade of the pyroxene group. This term was adopted, used, and more recently questioned. (We are told by Dr. Rudler (*Journal of the Anthropological Institute*, Vol. XX, 1891) that M. Damour felt the old mineralogical term nephrite should be confined to the strictly oriental jade.) There was also the American geologist, Mr. Pumpelly, who spent many years in the East and became an enthusiastic contributor to *The Jade Question.*

In 1879, before the discovery by Traube (see the JOURNAL OF GEMMOLOGY, October, 1954, p. 344) Dr. F. W. Rudler's article appeared in *The Popular Science Review* (Vol. 3). Dr. Rudler, who died in 1915, needs little introduction. He was Registrar of the Royal School of Mines and one of the founders of both the Ethnographical Society and the Anthropological Institute, apart from holding many other public offices. His article, entitled *On Jade and kindred stones*, is too long to quote in its entirety. The following extract will, however, express the author's approach to the subject.

" Much of the esteem," wrote Dr. Rudler, "which the ancients set upon precious stones was due, in like manner, to the superstitions by which such minerals were liberally surrounded. No doubt the properties which we prize at the present day—such as colour, brilliancy, and hardness—were equally prized in the remotest times at which precious stones were used; but above and beyond these obvious characters, overarching all these physical properties, there was the higher value derived from their metaphysical virtues. Some of these values were of a purely spiritual character, such as the power attributed to so many gems of dispelling vicious propensities and of inspiring purity of life in the owners. Others, however, were of less subtle nature, and were in fact medicinal rather than metaphysical. In order to cure disease, it was in most cases considered sufficient simply to wear the stone, when its sympathy with the affected part brought its curative powers into play. But in other cases recourse was had to the grosser method of internally administering the powdered gem. These superstitions naturally led men to seek eagerly for stones so marvellously endowed, and thus our knowledge of such minerals and their mode of occurrence became widened. Such stones which were reputed to possess therapeutic virtue were carefully preserved and studied in their minutest details. Who indeed would not diligently seek and fondly cherish an object which was at once a personal ornament and a specific against disease?

Science is unquestionably the arch-foe to superstition; yet superstition, it must be conceded, has unwittingly rendered an occasional service to the cause of science. How ill, for instance, might it have fared to-day with the student of prehistoric archaeology if our ancestors had been free from any superstitious regard for those implements of stone—unknown alike in origin and use—which they occasionally brought to light with the help of spade and plough. As long as the flint arrow-head was regarded as a "fairy dart" or the stone axe as a "thunderbolt" it stood in little danger of being heedlessly destroyed; shielded by the supernatural origin to which it was referred, generation after generation, until, in these later days, it has come to grace the cabinet of an archaeologist. The time of real danger was not when there was too much superstition abroad, but when there was too little superstition, yet not sufficient science—when men had ceased to value a stone implement as a talisman, or amulet or charm, but were not sufficiently enlightened to recognize its true meaning and to value it on scientific grounds."

This clarity of thought—all the more remarkable when we consider the date—finds an echo in the words of a famous contemporary physicist: " Science has given back to the universe that quality of inexhaustible richness and unexpectedness and wonder which at one time it seemed to have taken away from it . . ."

During 1892, in the Journal of the Anthropological Institute, p. 319, Dr. A. B. Meyer was perpetuating an early blunder. He wrote: " The occurrence of raw jade in Silicia (Germany), viz., near Reichenstein, was already known to Linnaeus (*vide* the 12th

Latin edition of Gmelin, Nuremburg, 1777, Vol. 1, p. 458), and has only recently been rediscovered by H. Traube[3]." While it seems to have been established that the jade occurrences had been worked in pre-historic times, it has not been established that the Swedish Linnaeus ever knew of these occurrences. Gmelin was writing of *Lapis Nephriticus*, a term it transpires that in his day covered other substances, such as Steatite and Serpentine[a]. Hence Gmelin's occurrences for *lapis nephriticus* are invalid, or doubtful, from our point of view. Several countries he quotes have recently denied such occurrences, including Sweden itself[b].

In the second edition of the *Encyclopaedia Britannica* (1777), a date coinciding with Gmelin's work just quoted, the same confusion exists:—

"*Lapis Nephriticus*, SEE Steatites."[c] Yet, under NEPHRITIC STONE there is further doubt. This is described as a "soft, opaque stone not susceptible of a good polish; smooth, and as it were, unctuous to the touch; variegated with several colours of which green is the principal. It is found in Saxony, Switzerland, Spain, and Mexico; and from the imaginary virtues ascribed to it in nephritic disorders, has been ranked among the precious stones, but differs exceedingly from them in all its sensible qualities. Neumann finds fault with some authors for referring this stone to the jaspers, agates, or marbles, from all of which he says it widely differs: it wants the red specks of jasper, the hardness and compactness of the others, and all of them want its unctuosity or soapiness." Except for the occurrences, this description could refer to what we know to-day as nephrite, but later in the article doubt increases. "Dr. Lewis," it runs, "tells us that the nephritic stone is a species of indurated clays, called from their unctuosity, steatitae. With these it agrees not only with its obvious properties but likewise on burning hard, the peculiar character of the argillaceous earths. Its green colour seems to proceed from copper . . . . The nephritic stone is considerably the hardest of all the substances of this class." Again, the last sentence suggests that while the word nephrite or nephrite stone or nephritic stone includes these lesser minerals it also applies to the nephrite we accept to-day.

(*a*) Even up to recent years a form of serpentine has passed under the misnomer Jade.

(*b*) For this information we are largely indebted to Sir Charles Hardinge, Bart., who has taken the trouble to communicate with responsible people in the countries involved.

(*c*) Under this heading, the article reads : ". . . a name given by late authors to a substance called in English soap-earth, for making porcelain . . ."

Although the above quotation is a century earlier than the one we are at the moment examining, it is included here for obvious reasons. In the first edition of the *Encyclopaedia Britannica* there is no mention of jade.[a] That was in 1768. In the third edition, 1788, eleven years later than the one quoted above, there is an item headed JADE-STONE. Under this we read: "Jade-stone, Lapis Nephriticus, Jaspachates,[b] a genus of siliceous earths. It gives fire with steel, and is semi-transparent like flint . . . . A kind brought from the river of the Amazons in America is called CIRCONCISION STONE . . . . The jade stone is unctuous to the touch; . . . . Mr. Kirman seems to suggest that it contains a portion of argillaceous earth, or rather magnesia. The specific gravity is from 2·960 to 3·389; the texture is granular, with a greasy look, but exceedingly hard, being superior in this respect to quartz itself . . . . Mr. Saussure seems to have extracted iron from it. Sometimes it is met with of a whitish milky colour from China, but mostly of a deep or pale green from America. The common lapis nephriticus is grey, yellowish, or olive colour. It has its name from a superstition of its being capable of giving ease in nephritic pains by being applied externally to the loins. It may be distinguished from all other stones by its hardness, semi-pellucidity, and specific gravity."

To this excellent contribution, the name of the author has not, unfortunately, been attached. Credit should, however, go to the Swedish mineralogist, Axel Fredrik Cronstedt, a translation of whose work was published by J. H. de Magellan in 1788 (second edition). It was entitled *Essay towards a system of Mineralogy.* The *Encyclopaedia Britannica* version is an excerpt, almost word for word, from this work. As a contribution this is outstanding, if only for the great strides made in no more than eleven years and at a period nearly two hundred years ago. And more. It uses the word JADE as we today understand it. It included under this heading the term we are concerned with, *Lapis Nephriticus.* (The term Jaspachates, to be met with from time to time, here suggests jasper of an agate-like formation.) At this time there was no separation of nephrite and jadeite, consequently the CIRCONCISION STONE from the river Amazon was classed merely as jade. Yet the specific gravity tells us plainly that the two species were being

---

(*a*) Under Nephritis, medicines for dealing with diseases of the kidney include nephritic stone.

(*b*) Jaspachates or iaspachates was for a long a general name for agate. It is to be found as far back as Pliny.

examined. (Sp.G. for nephrite 2·90-3·03, for jadeite 3·33.[a]) Its hardness has obviously been confused with its toughness—a common error in early times and not unknown today. To the point of our enquiry, its curative properties for nephritic pains has also been recorded.

Little advancement on this contribution appears during the nineteenth century, as far as the *Encyclopaedia Britannica* is concerned. (And they have drawn on the experts of the day.) In 1801 there is the item: (4th edition). "Jade-stone or Lapis Nephriticus, a species of Mineral. See Mineralogical Index. *Genus V. Magnesian Species. Nephrite or Jade.*" The species is divided into two sub-species. 1. *Common Nephrite*, with a Sp. Gy. 2·97—4·38(!), of the following constituents:

Silica	47%
Magnesia	38%
Alumina	4%
Lime	2%
Oxide of Iron	9%
	100

"The repository of nephrite is unknown," the article goes on. "It was originally brought from the Levant, East Indies, and China. It is found also in the Alps, in Switzerland, and in Piedmont. The water-worn pebbles which are collected on the banks of Lake Geneva often contain this mineral. It is found also in a similar form at a particular place on the shores of Iona, one of the Hebrides in Scotland."[4]

"Oriental nephrite," is the final word on this section, "long known under the name of jade, is held in considerable estimation on account of its hardness and tenacity. It was employed by the Turks for the handles of knives and sabres, and frequently by others for various ornamental purposes. The property of curing diseases of the kidney is ascribed to this mineral by ancient authors, and hence the name Nephritic-stone or Nephrite."

The second sub-species in this article takes the heading of *Axe-stone*. "La Pierre des haches . . . Beilstein of the Germans. *Exter. Char.* This is also found massive, but most frequently in rounded pieces; lustre glimmering or weakly shining; fracture in

---

(*a*) B. W. Anderson.

large masses; slaty, in small splintery fragments in the form of plates. *Colour.* Deep meadow green, sometimes olive-green; translucent; semi-hard; not very brittle and more difficultly fusible than the preceding variety.

Localities, etc. The mineral is found in China, the East Indies, and South America, on the banks of the river Amazon. It is found also in some of the islands of the South Sea, as well as in Corsica, Switzerland, and Saxony.
Uses. Axe-stone is employed as hatchets and other cutting instruments, by the natives of the countries where iron is little known."

So satisfactory and up-to-date, apparently, was the above information that the next edition of the Encyclopaedia (the 5th, published in 1815) carried the article without alteration.

Until we come to the 8th edition (1853) there is little to record. Here JADE is classed as: " An ornamental stone of which there appear to be two varieties, common jade or nephrite, and saussurite, or jade tenace. Common jade is a silicate of magnesia, oxide of iron, and alumina. Its specific gravity varies from 2·9-3·0. Hardness 7·0. Its colour is leek-green, passing into grey. It is very tough and scarcely fusible before the blow-pipe. Nephrite was formerly worn as a charm, and was supposed to be a cure for diseases of the kidney, whence the name from νεφρός kidney. From its toughness it has been used for the blades of hatchets by the New Zealanders and other savage nations . . . In China the jade is of a whitish colour and is called YU . . . A great variety of jade ornaments from India and China appeared at the Great Exhibition of 1851 . . . Jade is polished like cornelian but it takes only a greasy, not a brilliant, polish. Saussurite is a double silicate of magnesia, lime, and oxide of iron, with a silicate of alumina. Specific gravity 3·2. Hardness 5·5. Its colour is greenish-white, or ash-grey; . . . it is extremely tough, and is fusible before the blow-pipe."

This article was written by Charles Taylor, D.D., Hon. LL.D. (Harvard), Master of St. John's College, Cambridge.

In 1875 the 9th edition of the *Encyclopaedia Britannica* arrived, with a long article on jade by F. W. R., the Dr. Rudler of an earlier quotation. Apart from his reference to Chinese jade " often described by early mineralogist as 'jaspis viridis' " (see JOURNAL OF GEMMOLOGY, January, 1955, p. 13) there is little we need quote here.

In the summary he gives a number of chemical analyses under no less than nine varieties, with the following Sp. Gy. constants:—

"White Jade. China. Damour. Sp. G.2·97.
White Jade. Turkestan. L. R. von Fellenberg.[5] Sp. G. 2·96.
Green Jade. New Zealand. L. R. von Fellenberg. Sp. G. 3·02.
Green Jade. Swiss Lake Dwellings. L. R. von Fellenberg. Sp. G. 3·02.
Oceanic Jade. Damour. Sp. G. 3·18.
Jadeite. China. Damour. Sp. G. 3·34.
Chloromelanite stone celt. Damour. Sp. G. 3·31.
Saussurite. Lake Geneva. T. Sterry Hunt[a]. Sp. G.3·30.
Fibrolite celt from Morbihan. Damour. Sp. G. 3·18."

As the 10th edition of the *Britannica* contains only supplementary volumes to the 9th edition and does not supersede it, we find no further information here. In the 11th edition (1910) Dr. Rudler again contributes at length, and in 1950, a supplement to the 14th edition, we have W. A. Wooster, Ph.D., Demonstrator in Mineralogy at the University of Cambridge, and Dr. G. F. Kunz, the late American gemmologist. These contributions are actual copies of the articles included in the 14th edition first published in 1929.

Another author who should certainly be included in the 19th century is the Frenchman, S. Blondell, whose publications, *Jade, Historical, Archaeological and Literary Study of the mineral called Yu by the Chinese*, first appeared in Paris during 1875—twelve years after Damour[b] had published the result of his investigations and had separated the two species.

M. Blondell, of whom we shall hear more later, points out that the separation of jade and jasper (perhaps more important than that of jade and nephrite) is somewhat modern, though this is by no means the first indication.

There are several outstanding contributors to *The Jade Question* during the 18th century. A. G. Werner, of Freiberg, locally known as the father of German geology, is credited with having

---

(*a*) Thomas Sterry Hunt, 1826–1892, American Geologist and Chemist.

(*b*) Dr. G. F. Kunz wrote, in 1903 (Jade—nephrite—German New Guinea, Silesia, and elsewhere) : "Dr. Meyer has published in all no fewer than 36 articles on the general subject, and, as is well known, has clearly shown that the subject is a chemical rather than an ethnological problem."

Englished *Lapis Nephriticus*, giving us NEPHRITE, in 1789. In 1779 Antoine Grimoald Monnet published *Nouveau Systeme de Mineralogie.* On p. 217, Part VIII, is a long paragraph on *Le Jade, ou pierre néphrétique.* (Again, two terms to describe the same material.) Here the author separates nephrite from chalcedony. He speaks of its " greasy " look, " like oil." He observes that jade is dearer than it is precious because of the superstition attributed to it, but adds that he has not observed sufficient varieties to establish the various qualities. He doubts whether M. de Bomare (see below) is qualified to establish the three types he suggests. Finally he mentions the " very coarse texture " of jade, noticeable in a fracture. And, like a well behaved scientist, he repeats that he will make no decisions.

Monsieur Wallerius (Johan Gotsch Wallerio) has been quoted as introducing nephrite, that is, the pierre néphrétique, into mineralogical nomenclature, yet there are several others of his century who have done more to classify nephrite. In his publication of 1772, Wallerius quotes various experiments made by various workers in this field with which he does or does not agree. That one experiment with *lapis nephriticus*, if powdered and mixed with water, " brought it back . . . . to the state of steatite." He writes: " I prefer to offer no comment." He does, nevertheless, classify it under the general heading of *jaspis*, greasy in appearance. And he lists (almost as Bomare, 10 years earlier):

" (a) *Lapis Nephriticus*—whitish. Faintly milk-white, at times quite transparent. China.

(b) *Lapis Nephriticus* of green undertone. " Lapis Divinus " (Holy stone) is less transparent. Oriental.

(c) *Lapis Nephriticus*, not transparent. Of green shade. Lapis Amazonicus. Colour similar to prasius (Prase). From America."

In the same year, viz., 1772, we have *Antiquitates Medicae Selectae* by Johann Ernst Immanuel Walch, published in Latin. This author mentions *Lapis Nephriticus* and the " very great powers " attributed to it by the doctors of old. Dealing with a number of stones and their cures he first observes, under the heading *Use of Stones in antique medicine:*

" As we have found, they made a special use of a certain kind of their erudition in their ponderous way. We must confess that we hold this as an unpleasant task. It must not have been easy for them to suggest that a stone could exert its high powers by its own strength, even if it was reported that some stones had a healing power in their litholatry, which as a rule meant a sanitary cleaning of wounds and remaking of the wounded body and members . . ." He concludes, after much quoting: " Whatever it may be, and we do not want to deny it, the surgeons of old must in the presence of the suffering have used all their ingenuity, while having only less efficacious medicaments of inferior composition they contrived psychological means." (A refreshing observation made nearly two hundred years ago.)

A year earlier, in 1771, M. Bucquet had published, in French, *Introduction à l'étude des Corps Naturels tirés du Règne Minéral.* Of jade, he writes of its colour " green . . . . more or less dark, olive or brown," and of its greasy appearance, of its toughness, rendering it difficult to work. He separates it from the agates, as others have done, " because jade reddened in fire and thrown into water, does not break." In the fire " it loses its colour," a fact long known in China.

In 1762 appeared *Minéralogie ou Nouvelle Exposition du Règne Minéral.* By M. Valmont de Bomare. On the subject of *Jade ou Agate Verdâtre, ou Pierre Néphrétique,* he quotes a number of writers who " consider this stone differently. Be that as it may, after our experiments in the stone which they name today nephritique stone, we have arranged it in this order . . ." Bomare goes on to speak of the nephritique stone as " rough grained . . . compact . . . . oily to the sight and touch like the lard stone of China, of a green colour, or olive, or more or less milky . . . . difficult to polish highly, because of its extreme toughness . . . . it makes fire with steel . . . . one attributes to it many properties which are fictional, also they have decorated it with many different names . . ."

In his classification he gives:

" (1) White jade . . . . the true jade of the Orient, which is no onger known to be quarried.

(2) Jade . . . . a clear green . . . . excellently named *divine stone* or nephritique stone.

(3) Jade of a dark green . . . . its colour resembles a piece of dark emerald; it is called Stone of the Amazons.

Note 1.—The nephrite stone which many of these authors recognise to be the green jasper of the ancients . . . . its green comes from copper, one notices that that from China is of the same species but more transparent and clearer; that from Saxe (Saxony) is opaque and dark."

He speaks further of the Indians and their art of cutting this stone " with holes sometimes six to seven inches long, and without any iron tools." Later, an apparent contradiction of his title, he says: " . . . . some workers admitting themselves that jade surpasses in toughness, the agate, the jasper, and the porphyry . . . . It is also this extreme toughness of the jade which has rendered it so precious and of such great esteem with the ancients . . . . It is highly esteemed for warming the kidney-stone, and for epilepsy, and often worn as an amulet on the collar or arm, on the kidneys, and on all afflicted parts." Later he quotes Voiture[6] in the 23rd of his letters to Mlle. Paulet, " the jade stone is a remedy in a country where there is not another . . . ."

Dezallier D'Argenville also wrote of the *néphrétique stone*, published in French during 1742. " . . . . a species of jade of a dark green; spotted black, sometimes yellow; this stone is tougher than ordinary jasper . . . . and does not polish perfectly, they believe it has the property to cure nephritique colic." And later: " The green and white jade which borders on the green, on the yellow, and sometimes in the blue, is often called Divine Stone and Nephritique, because it is imagined that worn over the kidneys it cures colic . . . ."

Finally, in 1704, we come to Langius or Christianus Joannes Lange. Here in the beginning of the eighteenth century we find one with an almost complete mastery over the subject, far more convincing than many who came after him in his own times, as well as those in the nineteenth century. He describes *Lapis Nephriticus* as: " A gem neither transparent nor opaque, nor green only, now mixed with colour, which means to say, showing from a green undertone, white or yellow, azure or black, in such a way that the green always predominates, somewhat greasy on the surface, as if dipped in oil, on which account it cannot be very well polished." " The rarest is white all over," he states. Under Etymology he writes: " The reason for its name originates from its effectiveness, in fact it is called NEPHRITICUS from the Greek word νεφρός which means a kidney, as in kidney pains it frees them in forcible style from the calculi and thus it originates the cure." It is noticeable here that he does not say whether or not he agrees with this *cure*. He merely states what is common in his day.

Lange then goes on to describe its differences compared with other stones. He writes of one who believed it to be a kind of dark smaragdus and of others who thought it to be a species of jaspis. "Nevertheless," he continues, "there are differences between the true jaspis and nephriticus. (1) Harder than jaspis if anything. (2) It does not show any red lines " (earlier he had spoken of the red spots of jaspis, referring doubtless to our bloodstone). " (3) It does not allow of any exact polishing by reason of its oiliness. (4) It shows two distinct colours but nearly always one of them is whitish green. We can therefore say that Laet is right. Nephriticus is a species of its own, neither prasius (prase) nor jaspis (jasper)." Later, he speaks of what is thought to be an artificial Nephriticus that comes from New Spain, viz., South America. Even here, Lange suspects, at any rate, that the species is different. And in the various beliefs of the Americans he quotes Monardes[7].

To gather up the evidence of these two important centuries (the 18th and 19th), it seems clear that the words JADE and NEPHRITE—or nephritic stone or *pierre néphrétique* or *lapis nephriticus*—were one and the same material. That the South American jade was included under this general heading(until Damour separated the species) is also clear, whether it was called CIRCONCISION STONE or Divine Stone. A single exception is the " artificial Nephriticus " of New Spain, that is, material differing from the known nephrite. It is generally understood also that this jade or nephrite was not jasper, though earlier believed to be so. Furthermore that the term *lapis nephriticus*, while it covered other substances such as steatite, confusing the occurrence issue, the gemstone material was still the major portion of such classifications. Finally, of great assistance in establishing *lapis nephriticus*, it is in every case used as a curative for nephritic disorders.

REFERENCES

1. *Journ. Gemmology*, Vol. 4 (8), 1954, p. 344.
2. *ibid.*, — p. 339.
3. *ibid.*, — p. 344.
4. *ibid.*, — p. 346.
5. *ibid.*, Vol. 5 (1), 1955, p. 13.
6. *ibid.*, — p. 338.
7. *ibid.*, — p. 13.

GEMSTONES in BIRMINGHAM MUSEUM

by VINCENT C. SMITH, F.G.S., E.M.A.

WITH Birmingham as one of the main centres of the jewellery trade, it has always been the policy of this Department to display a portion of the extensive series of gemstones in our possession.

However, additions in recent years to this collection have necessitated rearrangement of the existing exhibit and a new case has recently been put on display in the Geological Gallery of this Department.

It is hoped that this case will also be of interest to the general visitor and specialist. The range of stones is as comprehensive as we have been able to make it and practically every variety of Corundum, Spinel, Beryl, Topaz, Garnet, etc., is represented, together with the rarer gems like Spodumene and Iolite. There are also displayed stones which have been chosen for their educational value rather than their intrinsic worth and an example of this is the very fine Citrine weighing 1 lb. 12 ozs. avoirdupois, which forms a centre piece to a selection of the varieties of Quartz.

As the Geological section caters primarily for the mineralogist many stones not normally utilized by the jeweller are included. Fluorspar is a typical example, for although this mineral can be very beautiful when cut and polished, its softness and low refraction make it unsuitable for the trade ; nevertheless this type of specimen can often be of especial interest to the geologist.

Adjoining the gemstone case is a display of precious and semi-precious stones in their natural state, and it is hoped that this will be of interest to jewellers, augmented as it is by comprehensive reference collections of cut and uncut gems which are available to students and specialists on request.

The gemstones are mainly from the collection formed by the late Mr. A. S. Wainwright, a name well known to the trade in Birmingham, the late Mr. William Bragge, whose collection was purchased and presented to the Museum by the Rt. Hon. Joseph Chamberlain, and lastly the Bernard Senior Collection which was purchased by Ansell's Brewery and presented to this Museum and Art Gallery in 1928.

ANOTHER MINERAL in GEM QUALITY

by JACK E. SCHUNK, B.A., F.G.A., and NEVILLE DEANE, F.G.A.

THE discovery of another mineral in a form which will provide a cut gem is always an event, and this is a short account of such an occurrence.

Early in January, 1955, one of the authors (N. Deane) received a letter from the other from Brazil, stating that he was sending a piece of potentially useful material which might provide some entertainment. The sender stated that he thought he knew what it was, but left it to the recipient to discover. The colour varied from pale to rather less pale yellow, and he had about 100 grams of the material and thought he might be able to secure more of it.

When received the piece was about 16 carats in weight, light yellow, but obviously dichroic in two shades of yellow and, although it did not show an obvious crystal face, was rather flat and appeared to have one good cleavage and another less clear. It was quite transparent, and looked cuttable, although with new material there is always a risk that it will crack with the heat of dopping, or cleave when ground with abrasives.

As one face was almost flat, it was decided to grind and polish it, to determine the refractive index and also the density, but otherwise to leave it as it was. This was done and the selected face was not too difficult to polish.

Laboratory tests were carried out, although at this time there was a cold spell and the temperature of the toluene used in the S.G. test was only 8°C. and the lens of the refractometer had to be well wiped as it soon misted up by moisture in the breath. However, the density was determined as 3·03, and the R.I. as a minimum of 1·608 and a maximum of 1·637. The hardness was less than quartz and about 6. These constants did not agree with anything in the list of gemstones. It had been thought it might be

Brazilianite although its behaviour was different, and the only gemstone with somewhat similar constants appeared to be Nephrite and it was obviously not that. This was as far as the writer could go, and the specimen was sent to the Gem Testing Laboratory in London for examination.

By return of post, Mr. R. Webster wrote that he and Mr. B. W. Anderson had examined the material, and found it to be Amblygonite, composition $(LiNa)Al(PO_4)F,OH$, isomorphous with Montebrasite and having the constants S.G. 3·029, R.I. 1·609, 1·626, 1·637, and that according to the new edition of Dana one of the places in which it was found was Mogi das Cruzes, Sao Paulo, Brazil. The spectrum showed a very vague and unmeasurable band in the blue and a cut off in the violet. Fluorescence was weak, if any, under Long Wave ultra-violet, possibly a weak orange under short wave ultra-violet and a brightish bluish-green under X-rays, with no phosphorescence. Phosphate was determined by micro-chemical test and lithium by flame test, which also confirmed phosphate.

The rough material being a phosphate, similar to Brazilianite and apatite, it was thought possible that it might easily fracture with the thermal shock of " dopping " in the ordinary way, so it was decided to be careful and dop by the " under water " method in which stone, cement and dop stick are all put in water at room temperature, warmed till the cement softens, assembled and then removed from the water and cooled slowly.

But first the rough had to be sawn to shape, as, although it could be ground to shape, it was wished to reserve a projecting piece in case of further examination, and in the operation of cementing for sawing the indications were that the material would fracture with thermal shock. Sawing was easy, using a metal-bonded diamond saw. The material was moderately hard—about as hard as feldspar—and showed no signs of flaws appearing on cleavage planes (as does spodumene), although amblygonite is stated to have an excellent cleavage. Grinding to shape was also easy. There was a slight odour apparent when grinding, as there usually is with apatite, and no cleavage flaws developed. Cutting the facets on a diamond-charged bronze lap was also easy, although, as the material is softer than quartz, it is very easy to overcut a facet. Polishing was moderately easy. A lap of 18% tin, 82% lead, was used, with " ruby powder," and gem polish came readily, but with a tendency to leave polish marks or very slight scratches rather than to leave an absolutely flawless mirror polish. The lustre is quite good for a stone softer than quartz and better than the writer (N.D.) has obtained on apatite. At the end, the finished stone was a step-cut, cut-corner rectangular shape of 4·6 carats, not completely flawless, but transparent and a nice bright stone of a pale yellow colour.

It is obvious that the material, being softer than quartz, and of a not uncommon colour amongst stones, is not likely to be amongst the most popular and useful stones as regards jewellery, but nevertheless if supplies of rough are made available, stones will undoubtedly be cut from it and amblygonite and its constants should be listed as one of the stones which may occasionally appear.

A second lot of amblygonite has now been received by one of the authors (J. E. Schunk) in Brazil. There was an equal amount of excitement on the examination of this second lot, the main reason being the presence of several pale blue and greenish specimens, and these are known colour-varieties of amblygonite. But on a more careful examination all of the blue and green pieces turned out to be beryl. The rest of the parcel was amblygonite. The colour, as compared to the first lot received, was much lighter, the majority of it being colourless or almost so. The quantity was as limited as it was in the first parcel. Almost every piece showed one excellent cleavage surface. The inclusions had a white mossy texture plus some of a bright green colour. No good crystal shapes were found although some pieces showed a flat moulded-glass appearance on one surface. Once it has been seen in its rough state it is fairly easy to separate from other gem materials. Brazilianite, which has a similar refractive index, almost always has numerous crystal faces present and has a more intense colour. Amblygonite is perhaps most similar to beryl, but the obvious cleavage surfaces plus strong birefringence eliminate beryl. In all specimens this strong birefringence, resulting in the doubling of inclusions and of opposite edges, is easily seen by the unaided eye.

The source of this new find is in the north-eastern part of the State of Minas Gerais, Brazil.

Gemmological Abstracts

ANON. *California Jade.* Mineralogist (Oregon), Vol. 23, 4, April, 1955, p. 178.

A further reference (*Journ. Gemmology Abs.*, Vol. V (1) 1955, p. 34) to the occurrence of green to white jadeite at Clear Creek, San Benito Co., California. According to a report of the U.S. Geological Survey, the jadeite is found in small veins cutting albite-glaucophane, acmite schist, and as larger lens-shaped pods with serpentine. The vein jadeite is associated with albite, analcite, natrolite and thomsonite. The white jadeite vein material is almost pure jadeite. The average specific gravity is 3·43, and chemical analysis of the green variety shows that it carries about 10% of the diopside molecule and 14% of the acmite molecule.

J.S.

PARSONS (C. J.). *How to use a quartz wedge.* Gemmologist, Vol. XXIV, No. 284, pp. 39–42, March, 1955.

This is part 3 of the series on the quartz wedge started by K. Parkinson and carried on by the above-named author. (*Journ. Gemmology Abs.*, Vol. V (2), 1955, pp. 94-95.) The method of obtaining an optic figure is briefly described. The use of a small drop of liquid on a plane facet of a stone is advocated in order to give the necessary curved surface for convergent rays. The spherical end of a small glass rod is mentioned as being suitable for a similar use. The different types of optic figures are given and determination of the *sign* by the use of the quartz wedge is fully discussed.

12 illus. R.W.

LEE (H.). *Further notes on American artificial turquoise.* Gemmologist, Vol. XXIV, No. 284, p. 56, March, 1955.

A short note on the examination of another specimen of the plastic bonded imitation turquoise (*Journ. Gemmology Abs.*, Vol.

V (1), p. 36). These are now known to be made by Harold Maryott, of Arizona, U.S.A. This improved version is slightly harder and the density is higher, being 2·39. The maker mentions that a newer plastic bonding will be used in later manufactures.

R.W.

NEUHAUS (A.). *Theoretical principles of diamond synthesis.* Gemmologist, Vol. XXIV, Nos. 284/5, pp. 47–48 / 72–73, March/April, 1955.

A technical article explaining the difficulties in the synthesis of diamond. Earlier attempts at diamond synthesis did not fully realize the high pressure needed, as deduced from the specific gravity of diamond. In Moissan's experiment a real high pressure was not possible and he took refuge in the expectation of a production as a metastable synthesis. The chance production by metastable formation is said to be remote and is fully discussed. The work of nucleation, undercooled viscous melts and the kinetic theories involved are discussed. The work of Bridgeman on high temperatures and pressures is mentioned, and the article concludes with a general summing up.

2 illus. R.W.

McLEOD (H. L.). *More about Stichtite.* Gemmologist, Vol. XXIV, No. 285, p. 74, April, 1955.

Mention is made of the use of stichtite from Kaapsche Hoop Transvaal, South Africa, a source now said to be exhausted, for the production of cabochons.

R.W.

ANDERSON (B. W.) : PAYNE (C. J.). *The spectroscope and its applications to gemmology.* Gemmologist, Vol. XXIV, Nos. 284/5/6, pp. 43–46/68–71/92–95, Mar./Apl./May, 1955. (Parts 19, 20 and 21.)

Continuation of this important serial. Discussion is now made of those stones which owe their absorption spectra to iron. There are two categories, the ferrous corresponding to FeO, almandine, peridot and blue spinel being examples, and ferric, corresponding to Fe_2O_3, illustrated by chrysoberyl, yellow orthoclase and green sapphire. Ferrous iron often replaces magnesium (even in almandine, which always contains a small quantity of Mg) and gives red or blue colours. The absorption spectrum of almandine was first noticed by Church, and this spectrum is the first discussed. This spectrum is characterized by three strong wide bands at 5760A, 5260A and 5050A, the last having a " core." A number of weaker bands are also present. All red garnets show the almandine spectrum to a greater or lesser degree, even hessonite (grossular), spessartite and pyropes, which usually have a trace of the almandine molecule. An almandine spectrum may be seen in the case of almandine-garnet-topped doublets and this may well deceive the unwary. The absorption spectrum of blue spinel is less easily recognized and may be confused with the cobalt spectrum of the synthetic blue spinel, but the strongest band in the natural stones is in the blue where there are no bands in the cobalt spectrum. This strong band is at 4580A and there is a weaker band at 4780A—these two making a distinctive pattern. There are other weak bands in the green, yellow and orange. The rare gem taaffeite is the only gemstone to have an absorption spectrum in a marked degree similar. Mention is made of the absorption spectra of green tourmaline and blue/green sapphire for comparison. The bright colour of the synthetic blue spinel as against the rather sad blue of the natural stones and the strong red of the synthetic as seen through the Chelsea colour filter (the natural blue spinel also shows a reddish colour through the filter but it is unlike the strong red of the synthetic) are diagnostic if the absorption spectrum is in doubt. The absorption spectra of peridot and sinhalite are discussed, reference being made to the similarity of composition and atomic structure of these two minerals. Peridot has three main bands in the blue centred at 4930A, 4730A and 4530A. The 4930A has a distinct narrow " core " at 4970A ; the 4730A is fairly narrow, while the 4530A is broader and less well-defined. There is some variation with optical direction, and the bands seen in the three optical directions are given. The bands for sinhalite are given as 5260A (weak and vague) ; 4930A (mod. strong and narrower) ; 4750A (mod. strong and narrow) ; 4630A (mod. strong and broader) ; 4520A (mod. and narrow) ; 4350 (strong and as a cut-off). The extra band at 4630A in sinhalite may be used to distinguish from peridot.

5 illus. R.W.

WEBSTER (R.). *X-rays and their use in gemmology.* Gemmologist, Vol. XXIV, Nos. 285/6, pp. 63–67 / 87–91, April/May, 1955.

This new series commences with the historical aspects of the experiments which led to the discovery of X-rays by Rontgen in 1895. The effects seen when a high-tension electric current is discharged between electrodes at atmospheric pressure, and under reduced pressures, are described. The story of Rontgen's discovery is given, and the part played by Sir J. J. Thompson in identifying cathode rays as streams of electrons is referred to. The opacity of a substance to X-rays is a function of the atomic weight of that substance. Until the classic experiment of von Laue in 1912 proof of the nature of X-rays was in doubt. The story of this experiment, which gave experimental proof of the theory that X-rays were *light* of short wave-length, and that crystals have an orderly arrangement of their atoms, is told. The apparatus employed for the production of the necessary high-tension current is briefly mentioned. The earlier types of " gas tubes " used to produce X-rays, and the modern " hot-cathode " tube devised by Coolidge, which employs the " Edison effect," that is, the formation of electrons from a heated filament, are discussed.

8 illus. P.B.

WEBSTER (R.). *New Italian gem-testing laboratory.* Gemmologist, Vol. XXIV, No. 286, pp. 79-83, May, 1955.

Description, from photographs, of the new gem-testing laboratory opened in Florence. The laboratory is well equipped for pearl and gemstone testing, and has, unusual in such laboratories, a well-appointed chemical department. Apparatus for absorption spectroscopy not evident. The laboratory is operated by the Cassa di Risparmio di Firenze (Florence Savings Bank) and the local Chamber of Commerce.

3 illus. P.B.

GOODWIN (PETER). *Ten points about pearls.* Printed by the South China Morning Post Ltd., Hong Kong. 1955.

A well-printed, paper-covered booklet of eleven pages. The author states that the pages are written to help those who are interested in pearls. He discusses ten points :—shape, colour, blemishes, lustre, matching, graduation, drilling, clasp and threading, size and weight, and value and price. A test for the roundness of pearls is said to be the ability of a pearl to roll straight across a polished surface. Best colour is rosée, other colours being mentioned. Variations of colour are best seen when a necklet is coiled-up in the palm of the hand, a procedure better than observing on black velvet. One spot or blemish may not matter as the drill canal can be drilled through it, but 10% of the value may be lost by each other blemish. Lustre is defined as the natural polish of the pearl, and orient is said to be connected with the colour of the nacre lining the shell. The orient of cultured pearls is said to be stronger than natural pearls. Matching for colour and graduation are discussed. Holding a necklet out straight and shaking it gently will show any off-centre drilling by such pearls tending to rotate so that the heavier side turns to the bottom. A good clasp will never be found on an inferior necklet, and thus the nature of the clasp will indicate the quality of the necklet. A note is given on the stringing of necklets and why knotting between each pearl is important. Value and price, and size and weight, as expressed in the booklet, are at variance, for the unit weight given is the *momme*, the Japanese weight equal to 0·13 oz. avoir., a weight used for cultured pearls only, while in the chapter on value and price reference is made to the *base system* which is used for genuine pearls only. Indeed, in the introductory chapter the author states " these points are about cultured pearls only," but much of the text is more in keeping with advice about natural pearls, than the much less important cultured variety.

R.W.

ASSOCIATION NOTICES

SWISS GEMMOLOGICAL ASSOCIATION

The Swiss Gemmological Association held their Annual Instruction Course from 23rd to 25th May. The first day was devoted to the examinations and several members sat for the Diploma Examination and some for the Diamond Examination. These examinations are carried out in a similar way to the British and American gemmological examinations. The Diploma Examination consists of two different written examinations, which must be answered without the help of books and notes and within the period of two hours each. The Practical Examination consists of testing 24 stones within unlimited time. The Diamond Examination consists of a theoretical part—two hours answering questions without books and notes and two hours of more difficult questions with the help of books and notes. For the practical part of this examination five diamonds are submitted for grading (grading of colour, perfection of cut and transparency, as well as measuring depth, angles, diameter of girdle and table).

On the second day the Annual General Meeting was held, in the course of which the following members were awarded Diplomas :—

> Mr. W. Frieden, Thun ; Mr. E. Frischknecht, St. Gallen ; Mr. A. Leicht, Geneva ; Mr. W. Meister, Zurich ; Mr. W. Ruckli, Lucerne ; Mr. E. Seiler, Jr., Basle ; Mr. R. Widmer, Aarau ; Mr. K. Zigerli, Berne ; Mr. J. Ryser, Biel (Bienne) ; Mr. H. Perrenoud, Lausanne.

The rest of the second day as well as the third day consisted of the real course, which this year was theoretical only.

The following lectures were given by the Association's Scientific Instructor, Dr. E. Gübelin, C.G., F.G.A. :—

Introduction to the general knowledge of inclusions ; specialized description of inclusions, particularly with regard to their diagnostic importance.

Diamond grading methods ; artificially coloured diamonds and their identification ; synthetic diamond.

Gem testing without instruments.

New gemstones (Taaffeite, Sinhalite, Amblygonite, Hypersthene-Bronzite, Stichtite, Augelite) ; new synthetic stones (synthetic rutile, synthetic strontium titanate, synthetic lapis-coloured spinel, synthetic red spinel).

Practical application of the immersion method.

Distinction between genuine and synthetic stones by means of transparency in short U.V. light.

The course was a complete success and the members went home with great enthusiasm and with the conviction that there is always something new to be learnt about gemstones.

COUNCIL MEETING

Sir James Walton, Chairman, presided at a meeting of the Council held at Saint Dunstan's House, Carey Lane, London, E.C.2, on Tuesday, 10th May, 1955.

The following were elected to ordinary membership :—

Michael D. G. Breeze, Leicester.
Markson A. Gam-Dede, New York.
Robert Klippel, Sherman Oaks, U.S.A.
Robert S. McGrath, Washington, U.S.A.
George F. de Menasce, London.
Enoch C. Parrott, Vancouver.
Xaver Saller, Munchen, Germany.

The Council discussed the inclusion of diamond in the diploma practical examination and possible damage to instruments, and complications that arise when mounted specimens for the examination are sent abroad.

Mr. J. R. H. Chisholm, M.A., F.G.A., was appointed by the Council as an examiner in gemmology to work with Dr. G. F. Claringbull and Mr. B. W. Anderson.

GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to Mr. R. W. Hester, F.G.A., of Princes Risborough, for providing a new case for the Association's set of historical diamond models, and for a wooden case for sending the models by post.

The Council is also grateful to Mr. George Lindley, F.G.A., for a gift of a piece of coral, for display in the Association's new offices.

Mr. Antonio C. Bonanno, of Washington, D.C., U.S.A., has kindly presented the Association with eighteen American mineral specimens.

TALKS BY MEMBERS

ANDERSON, B. W. : *Herbert Smith Memorial Lecture.* The refractometer and other methods of measuring refractive indices. Association meeting, London, 30th March, 1955.

HESTER, R. W. : "Gemstones." "All Wives" Club, Halton Camp, Bucks. 1st February, 1955.

WEBSTER, R. : "Gemstones." Eastcote Branch, British Legion. 19th April, 1955.

"Some newer problems besetting the jeweller." Midlands Branch of the Gemmological Association. 6th May, 1955.

GEMOLOGICAL INSTITUTE OF AMERICA

At the annual meeting of the Board of Governors of the Gemological Institute of America, which met in Boston, on April 2nd, Dr. Edward H. Kraus, Dean Emeritus of the College of Literature, Science and the Arts, of the University of Michigan, was re-elected President of the Institute for the tenth consecutive year.

GEM EXHIBITION — 12th–30th OCTOBER, 1955

Organized by the Midlands Branch of the Gemmological Association of Great Britain and the City of Birmingham Art Gallery

A Series of PUBLIC LECTURES will be given at **6.30 p.m.** in the LECTURE THEATRE at the CITY of BIRMINGHAM ART GALLERY

THURSDAY, 13th October. HISTORICAL GEMSTONES.

Speaker : TREVOR P. SOLOMON, F.G.A., Chairman of the Midlands Branch of the Gemmological Association.

SATURDAY, 15th October. THE GEM DIAMOND

Speaker : NORMAN HARPER, F.R.G.S., F.G.A., Senior Lecturer in Gemmology at The City of Birmingham School for Jewellers and Silversmiths ; Vice-Chairman of the Gemmological Association of Great Britain.

MONDAY, 17th October. GEMSTONES — THEIR GEOLOGICAL BACKGROUND

Speaker : VINCENT SMITH, F.G.S., E.M.A., Assistant Keeper, Department of Natural History, Birmingham Art Gallery.

THURSDAY, 20th October. THE STORY OF GEM DISCOVERY.

Speaker : B. W. ANDERSON, B.Sc., F.G.A., Director of the Diamond, Pearl and Precious Stone Laboratory of The London Chamber of Commerce.

SATURDAY, 22nd October. THE ROMANCE OF THE PEARL

Speaker : ROBERT WEBSTER, F.G.A., Lecturer in Gemmology at the Chelsea Polytechnic ; Scientist at the London Chamber of Commerce Laboratory ; Author of " Practical Gemmology," etc.

MONDAY, 24th October. RUBY AND SAPPHIRE : GEMS OF THE ORIENT

Speaker : D. N. KING, F.G.A., Honorary Secretary of the Midlands Branch of the Gemmological Association of Great Britain.

THURSDAY, October 27th. GEMSTONES THROUGH X-RAY EYES

Speaker : G. F. CLARINGBULL, B.Sc., Ph.D., Keeper of Minerals at the British Museum (Natural History).

(*Admission Free*)

The Exhibition will be opened by the Lord Mayor of Birmingham on Wednesday, 12th October.

LETTER TO THE EDITOR

The Editor,
Journal of Gemmology.
DEAR SIR,

So long as the " orient pearl " has been known, its principal sources have been (and still are) the various colonies of *Margaritifera vulgaris* off the coasts of Arabia and India. In the first century A.D., Pliny brackets pearls from the Persian Gulf and from India as being of the highest value, while the author of the *Periplus* refers to the pearls of the Persian Gulf, India and the Red Sea. The Red Sea is no longer an important source of pearls, but although India (which for this purpose includes Ceylon) produces supplies of pearls only intermittently, it is still listed as a principal source (e.g. by Herbert Smith and R. Webster.) The Ceylon fishery of 1905 surpassed all records, and Miss Judith Banister will be able to find full information on the subject of her query in the *Book of the Pearl*, by G. F. Kunz and C. H. Stevenson (London, 1908).

By a curious coincidence, Miss Banister's letter[1] suggesting that the Indian fisheries had ceased to be of importance appeared at a time when after a lapse of some years another Indian fishery was actually in progress. It was advertised in time-honoured form in the personal column of *The Times* of 11th March last as follows :—

" *Indian Pearl Fishery.* A Pearl fishery will take place at Tuticorin, South India, on or about the 15th March, 1955—weather permitting. About 2½ crores of oysters will be fished. The fishery may last up to 30th April, 1955. The pearl oysters will be sold in public auction by the Madras Government at Tuticorin daily during the period of fishing. For further particulars apply to the Assistant Director of Fisheries, Tuticorin, South India."

Yours faithfully,

J. R. H. CHISHOLM.

---

[1] Journ. Gemmology Vol. V, No. 2, 1955, p. 112

HERBERT SMITH MEMORIAL LECTURE

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

The Refractometer and Other Refractive Index Methods

WHEN I was asked by the Gemmological Association to give the first Herbert Smith Memorial Lecture I accepted the offer without hesitation although I knew it would involve me in a good deal of work, since I welcomed the opportunity to pay tribute to a man who has done more than any other to further the cause of gemmology.

Though mineralogy was his profession, G. F. Herbert Smith, in the course of his long and active life, had many other interests and worked in many other fields. In each of these fields he has left friends who will gratefully remember his work. To us, as gemmologists, his name is held in honour for many reasons. We will remember his keen interest in our Association, of which he was President from 1942 until his death in April, 1953 ; we remember him as an examiner who initiated and maintained the high standard which has made the " F.G.A." the most coveted gemmological qualification in the world. But most of all we remember him as the designer of the first trustworthy jewellers' refractometer and as the author of a book on gemstones which, ever since its publication, has been the standard work on the subject in the English language.

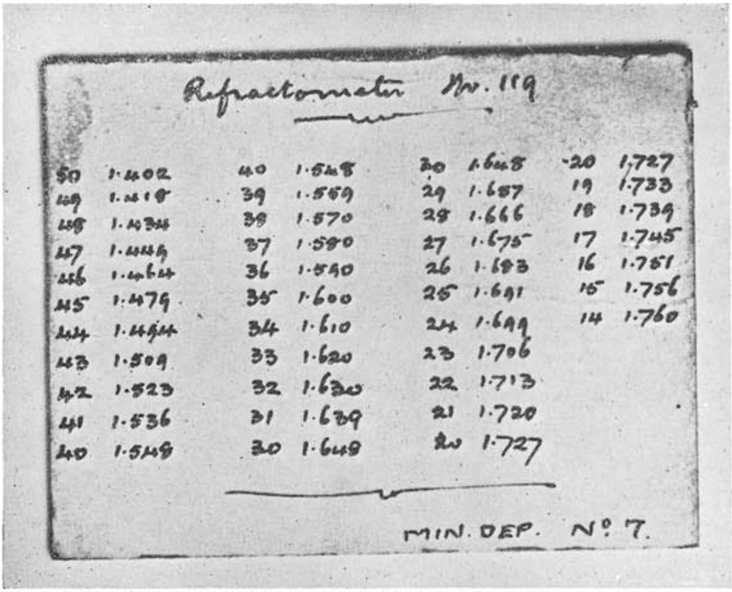
Since it is exactly fifty years ago that the first model of the famous Herbert Smith refractometer appeared, it is appropriate that the refractometer and its use should be the main burden of this Memorial Lecture. The book " Gemstones " was first published in 1912. The refractometer, the book, and the classes which began as " Mineralogy for Jewellers " under Mr. I. G. Jardine at Chelsea Polytechnic just before the first World War, all worked together to create that British School for Gemmology of which we are so pardonably proud.

I must now, without further delay, come to grips with the main subject of my lecture—the origin, development and powers of the jewellers' refractometer. I will also touch briefly on other methods of refractive index measurement which may be resorted to in cases where a refractometer, for one reason or another, cannot be used.

THE BASIS OF THE REFRACTOMETER

When a ray of light passes obliquely from one transparent substance to another of lower optical density, the ray is refracted away from the normal to the surface of contact. As the incident angle is increased, a critical point is reached where the refracted ray forms an angle of 90° with the normal. This is known as the *critical angle* between these two media, and rays of light impinging on the intersurface at angles greater than this are totally reflected. The size of this critical angle depends entirely upon the relative refractive indices of the two media. The British scientist W. H. Wollaston was the first to point out that if a standard block of dense glass were used as the medium of high index, the refractivity of substances of lower index could be assessed by measuring the critical angle between them and the block when placed in optical contact with it. On that principle, elaborate instruments designed to measure this critical angle with great accuracy, employing a prism, cylinder or hemisphere of very dense lead glass, were developed later in the nineteenth century. We are happy to have an Abbé Zeiss-Pulfrich refractometer of this kind in our Laboratory. In the hands of a trained scientist it is an invaluable instrument where there is a need for refractive index readings accurate to within one or two units in the fourth place of decimals—but it is quite unsuitable for the jeweller, besides being very expensive.

In 1885, Professor Bertrand designed a small and simple refractometer in which the sudden beginning of total reflection at the critical angle could be seen as a shadow-edge on a transparent scale. Several of these little Bertrand refractometers were amongst the equipment in the British Museum (Natural History) where Herbert Smith was working as an Assistant in the Mineral Department. He was often faced with the task of identifying specimens of gems submitted by members of the public, and there were moreover many unidentified or wrongly identified specimens of faceted stones in the Museum's own collection. It was thus that Herbert Smith felt acutely the need for a robust and simple refractometer of reasonable accuracy. He found that the Bertrand



Refractometer No. 119

50	1·402	40	1·548	30	1·648	20	1,727
49	1·418	39	1·559	29	1·657	19	1·733
48	1·434	38	1·570	28	1·666	18	1·739
47	1·449	37	1·580	27	1·675	17	1·745
46	1·464	36	1·590	26	1·683	16	1·751
45	1·479	35	1·600	25	1·691	15	1·756
44	1·494	34	1·610	24	1·699	14	1·760
43	1·509	33	1·620	23	1·706		
42	1·523	32	1·630	22	1·713		
41	1·536	31	1·639	21	1·720		
40	1·548	30	1·648	20	1·727		

MIN. DEP. No. 7.

Herbert Smith's own calibrations for his first model (1905) refractometer.

instruments were incapable of giving reliable readings owing to a faulty optical system, in which the focal surface was not a plane. By introducing a correcting lens between the dense glass hemisphere and the scale and by other modifications he was able to rectify matters, and in 1905 the first Herbert Smith refractometer was born—being manufactured by J. H. Steward, the well known opticians in the Strand, London.

Though a great improvement over the Bertrand, the 1905 Herbert Smith refractometer had several faults. Large stones could not be accommodated, the scale was an arbitrary one, and had to be translated into terms of refractive index with the aid of a calibration card supplied with the instrument, and the highest index which could be read was 1·76, so that the instrument would not give refractive index readings for the important corundum gems, ruby and sapphire, nor for many of the garnets. The second model of the " Herbert Smith " was a great improvement, with a table capable of taking gems of any dimensions, and a scale calibrated directly in refractive indices and reading up to 1·775. This was in 1907 ; and in the same year Steward had the good sense to publish a slim booklet " The Herbert Smith Refractometer and its Use," in the last few pages of which is given a masterly summary of the optical and other properties of thirty-four gemstones. In his preface, Herbert Smith remarks " I have paid particular attention to the usefulness of the instrument for the discrimination of faceted gemstones, because in not one of the many treatises on precious stones is enough prominence given to the extreme importance of the refractive indices as a discriminative test, and because no orderly arrangement of the requisite data is at present available." The refractive index figures given in this booklet were largely the results of his own observations, and have hardly been bettered since that time.

Herbert Smith must have enjoyed himself in those early years, in which he was prodigiously active in research and in the design of instruments. One version of a schoolboy's dream of heaven was to have the whole of the Crystal Palace to throw stones at, with Brighton beach handy for ammunition. In more adult terms, Herbert Smith had at his disposal the whole of the Museum's collection of gemstones to verify, and his own newly-designed instrument with which to undertake the job.

LATER REFRACTOMETERS

For nearly twenty years the Herbert Smith refractometer held the field unchallenged. Then, in 1926, the gemmologist and Bond Street Jeweller, B. J. Tully, whose name is commemorated in the " Tully Medal ", co-operated with the firm of Rayner and Keeler to produce an altogether larger instrument which in many ways was easier to use than the little Herbert Smith. The " Tully " is no longer being made, but for a time was very popular, with its large and easily-read erect scale, extending to 1·86 ; its rotating hemisphere, white reflector, and covering shield for the stone.

The range of this refractometer was potentially much greater than that of the earlier instrument, because a glass of index over 1·90 was employed—but the *effective* range was limited by refractive index of the contact liquid, which consisted of a saturated solution of sulphur in methylene iodide, having an index of approximately 1·78.

In an effort to raise this limit, C. J. Payne and I, working in the Precious Stone Laboratory of the London Chamber of Commerce, sought out, and where necessary prepared, a number of organic fluids of high refractive index, some of which enabled us to take readings to the 1·86 limit of the Tully scale, though at the expense of tarnishing the chemically sensitive surface of the lead glass hemisphere. Our most successful non-harmful liquid was prepared by adding 18% of yellow crystalline tetraiodoethylene to sulphur-saturated methylene iodide, which gives a stable liquid of index 1·81, and is now issued as a standard refractometer liquid.

We then co-operated with Messrs. Rayner in attempting to increase the range of the refractometer by using minerals of high index in place of the usual lead glass. Two minerals with high single refraction suggested themselves : zinc blende (2·37) and diamond (2·42). It was when experimenting with blende that Rayners had the bright idea of employing a truncated prism of the material in place of the usual hemisphere, and the first " Rayner refractometer " was actually a blende model with a scale extending up to 2·20. With this little instrument, using a spontaneously inflammable mixture of phosphorus, sulphur and methylene iodide suggested by West, which has an index of 2·05, we were able to measure the refractive indices of a whole range of zircons in which we were at that time particularly interested. Soon afterwards, the generous gift of a diamond by the Diamond Trading Co. enabled Rayner to make for us the first diamond refractometer. Apart from the initial cost, diamond is of course the ideal material for a refractometer prism, with its optical purity, single refraction, and its superb surface which is virtually impervious to chemical or physical attack.

It is the lack of suitable contact fluids which now chiefly prevents the gemmologist from making high index readings. All those so far tested in the range 1·81 to 2·05 are in some way noxious. It has been suggested that firm contact of the stone being tested with a slightly curved refractometer surface may enable dry optical contact to be made, and obviate the use of any liquid.

In actual practice, it is far more important to have a refractometer that will give clear readings in the lower index ranges than to have one which is capable of very high readings. It is in the " one-fifties " and " one-sixties " that the stones most tricky to identify occur, and that range is admirably covered by a special Rayner refractometer employing a prism of synthetic white spinel, which gives very clear readings even in white light—a point I shall refer to later. Of the gemstones with indices above 1·81, only zircon, diamond, demantoid, sphene, and an occasional almandine, are used in jewellery, and these can all be identified by means of the spectroscope or other simple tests, if not at sight.

I have so far been speaking as though every substance had only *one* refractive index, whereas in reality, as you know, even singly refracting substances have an infinite number of indices, according to the wavelength of the light employed. Yellow sodium light of mean wave-length 5893A is the universally accepted standard for refractive index measurements, and refractometer scales are designed to give accurate readings for this light. Sodium light can be cheaply produced by means of a gas or spirit flame in which an asbestos wick saturated with a sodium salt is inserted, though for those who can afford it a sodium discharge lamp is brighter and more convenient. Only in monochromatic light can the knife-sharp shadow-edges be obtained which are needed for a detailed study of the movements of shadow-edges in birefringent stones which I am going to describe presently. For routine identification purposes white light readings are often sufficient, particularly if they are sharpened by use of an orange colour-filter.

The ratio between the refractive index of the refractometer glass and the stone which is being tested, upon which the critical angle between the two depends, varies considerably with wavelength since the glass has a dispersion far higher than that of the stones which come within the refractometer range. The higher the dispersion of the stone or liquid tested the less is this variation of the critical angle. Thus the contact liquid, which has high dispersion, gives a relatively sharp, uncoloured edge in white light —and so does a lead paste—whereas a low-dispersion stone like quartz shows a broad fringe of colour. Here lies the advantage of the spinel refractometer : the spinel used has a dispersion very similar to those of the stones tested, so that sharp edges are the rule even in white light. Pastes are at once noticeable for their colour-fringed shadow edges, and so are contact liquids such as bromonaphthalene—a reversal of the effects seen on the normal refractometer. Careful observation of the sharpness or otherwise of a shadow edge in white light will thus often reveal whether the substance tested has high or low dispersion—a piece of information which is occasionally of practical value.

MEASUREMENT OF BIREFRINGENCE

But it is with birefringent stones that the refractometer really comes into its own, as it gives information of the highest diagnostic value about the extent and nature of the double refraction, merely by rotating the facet which is in contact with the refractometer table. *The full amount of double refraction can be measured on any one facet,* a most important fact. All that is needed is to note the highest and lowest readings obtainable and subtract one from the other. A single invariable edge is sure evidence of an isotropic stone—either a cubic mineral or a non-crystalline material such as opal or glass. In uniaxial stones the shadow-edge due to the ordinary ray is invariable in position, while in general the edge due to the ordinary ray can be seen to move when the stone is turned. If the moving edge has the higher index, the stone is optically positive; if it has the lower index it is negative in sign. Where the optic axis lies in the plane of the facet used a single edge will be observed twice in a complete rotation, this being a sign that the axis is lying along the line running from the eyepiece to the observer. As the stone is turned from this position the extraordinary edge is seen to separate from the ordinary, and to reach a position of maximum birefringence before starting to close in again. This is often seen in specimens of green tourmaline and in aquamarine. When the table facet of a uniaxial stone is parallel to the basal plane of the original crystal (that is, at right angles to the optic axis) we see the strange effect of *two* invariable edges, since all the rays grazing along such a facet are travelling in a direction of maximum birefringence. Another case where two invariable edges are seen is in specimens of chalcedony, when two edges separated by about 0·007 units can be seen rather lower on the scale than for crystalline quartz. This is due to so-called " form birefringence " caused by fibres of quartz being set in an opaline matrix.

With biaxial stones the behaviour of shadow-edges is rather more complicated, though the simple rule that maximum index minus minimum index reading equals the full birefringence still

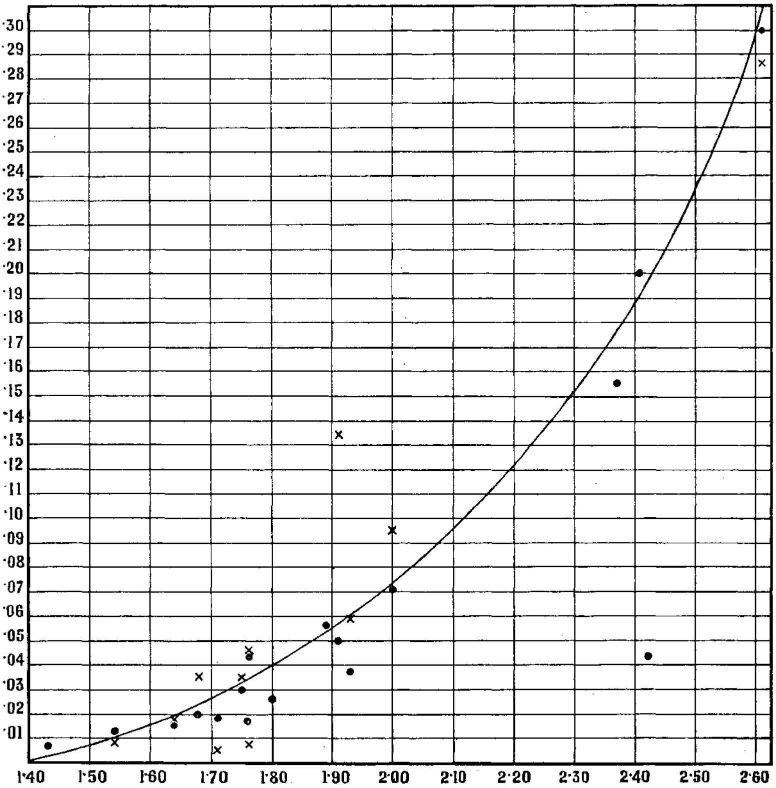


Diagram showing numerical relationship between dispersion (•) birefringence (X) and refractive index. The dispersion/refractive index relationship is fairly regular, with the exception of diamond, which has an unusually low dispersion for its index. The birefringence figures are numerically often similar to those for dispersion, but they bear no real relationship to the refractive index values

The values indicated are for :—Fluorspar, Quartz, Tourmaline, Peridot, Idocrase, Epidote, Corundum, Benitoite, Almandine, Demantoid, Slhene, Zircon, Cassiterite, Blende, Strontium Titanate, Diamond, Rutile.

happily holds good, and is the thing that matters most. In general *both* shadow-edges move, since both the rays are " extraordinary " in their behaviour. Rays vibrating parallel to one of three mutually perpendicular directions have critical values. The least and greatest of these, alpha and gamma, vibrate parallel to the lines bisecting the angles between the optic axes. Rays vibrating at right angles to the plane of the optic axes have an intermediate critical value, known as beta. When beta is closer to alpha than to gamma, the stone is called positive ; when it is nearer to gamma the stone is negative. When the angle between the optic axes is small, either the lower or the upper edge will move very little, and it is then easy to see whether the stone is positive or negative by analogy with uniaxial stones. In special cases, where the facet tested happens to be cut at right angles to the vibration direction of one of the critical rays, this ray will be seen as an invariable edge when the stone is rotated. If the ray happens to be beta we have the intriguing sight of the moving edge crossing over the invariable beta position, giving at four points in a complete rotation a *single* edge. This of course is a sign that the rays are all running along one of the two optic axes in one direction or the other.

Thus we see that readings carefully taken on a refractometer give us much more information about the material we are testing than just its refractive index. We are enabled to place the stone in one of five optical categories—isotropic, uniaxial positive, uniaxial negative, biaxial positive, biaxial negative. If it falls within the last four groups we can obtain a figure for the birefringence, which is an enormously important piece of information. We also gain a fair idea of the degree of dispersion of the stone, and of the optical direction in which the stone was cut in relation to the original crystal.

Until recently, it was thought essential to have a flat facet available if a refractometer reading were to be expected. A valuable technique suggested some years ago by the American gemmologist Lester Benson now enables us to obtain refractive index readings on polished cabochon surfaces also, though these are not so critical as the readings obtained on flat surfaces, and the birefringence cannot usually be measured. In this " spot contact " or " distant vision " method the smallest possible drop of contact fluid is applied to the table of the refractometer and the cabochon surface makes a tiny disc of contact at this point which can be seen when the eye of the observer is withdrawn by about twelve inches from the refractometer eyepiece, while keeping the head in the line of sight. When the eye is slowly moved in an up and down direction this little disc can be seen to change from being dark in the low refractive index regions of the scale to light in the upper portions—this being a sign that total reflection has set in. The trick is to manoeuvre the eye into the exact position where the disc is bisected by the line of shadow and then to refocus the eye by an effort of will in order to ascertain on what part of the scale this particular point falls. While performing this operation the gemmologist is apt to assume the attitude of a cobra about to strike. Auxiliary lenses may help to make the contact disc and the refractometer scale more easily focused at the same time, but with practice quite good results can be obtained without altering the standard refractometer eyepiece. The " distant vision " technique is also useful for obtaining readings on tiny faceted stones which give too faint an edge in the ordinary manner of observation.

There are other helpful tricks that can be used on occasion with the refractometer. Certain stones and many pastes seem reluctant to give a shadow edge. Sometimes this is due to a surface tarnish that can be removed by rubbing the surface on a cloth or leather, perhaps with addition of a little jeweller's rouge. But sometimes the trouble persists. My colleague C. J. Payne has found that one can often get " bright line " readings by grazing incidence in such awkward cases. All that one need do is to pull off the covering shield of the standard Rayner (which is designed to be removable), block the window through which light normally enters the instrument by means of a box of safety matches, which, on its side, is exactly the right height, and arrange one's desk or microscope lamp at a level slightly above that of the table of the refractometer. When the stone is turned, a bright line (or two bright lines in a birefringent stone) should be seen crossing the scale, which will otherwise be almost entirely dark. The effect is rather beautiful and the technique is worth trying out if only for this reason. It is as well to start with a step-cut stone since this style of cutting yields better results than others. In the case of a green tourmaline and an andalusite tested by this method recently it was amusing to notice the distinctly different colours of the two bright lines—an effect due to the strong dichroism of these minerals. One does not normally associate dichroic effects with the refractometer.

OTHER METHODS

There are of course many other methods that can be used to determine the refractive indices of gemstones, and some of these may have to be pressed into service where a refractometer cannot be applied or when no refractometer is available.

It has to be admitted that a microscope is an even greater essential to the gemmologist than a refractometer, since only with its aid can he distinguish with certainty between synthetic and natural stones. A young gemmologist who has spent his spare money on a microscope may not be able to afford the extra fifteen pounds or so needed for a refractometer, however much he would like to. It is worth his while, therefore, to gain some skill in using the microscope to measure the refractive index of stones. If the microscope has a fine adjustment which has marked on it a scale to show the number of rotations and parts of a rotation made when adjusting the focus, this can be used to take measurements by the " real and apparent depth " method, which was first suggested by the Duc de Chaulnes and brought to a high degree of accuracy by Sorby towards the end of the last century. In this, the stone can be supported by a small piece of wax or plasticine on a glass slide with its table facet uppermost and horizontal and its culet in contact with the slide. The microscope is focused accurately (using a fairly high-power objective, such as 8 or 16 mm.) on the surface of the table facet, and the reading A taken on the scale of the fine adjustment. The focus is then lowered until the culet appears sharply in focus : let this reading be called B. The slide is then moved a little way so that the stone is no longer under the objective, and the focus again lowered (using the fine adjustment, of course) until the surface of the slide is reached. Then the refractive index of the stone should be given by the formula $A - C/A - B$. This formula only holds true for isotropic stones and for the ordinary ray in uniaxial stones, and results are in any case not accurate to more than one or two units in the second place of decimals. There is no upper limit to the index that can be tested, however, and the method can form a useful check in the case of a dubious diamond. In this connection it is useful to remember that the extent of a flaw or the depth of an inclusion can be assessed by measuring the " apparent " depth under the microscope and then multiplying this by the refractive index of the stone. This may be useful information where re-cutting is contemplated.

The use of liquids of varying refractivity is a more generally useful and flexible method of refractive index determination. It is well-known that when a transparent solid is immersed in a liquid of the same refractive index it becomes virtually invisible due to the lack of reflection and refraction at its surface. Ice in water is a homely example of this, and quartz in ethylene dibromide is one instance of it that can be easily demonstrated by the gemmologist. A trial of the degree of " relief " shown by an unknown stone when immersed in turn in liquids of different refractive index will often by itself give helpful information. A yellow topaz, for instance, in the ethylene dibromide mentioned above, which has an index of 1·54, will stand out quite clearly compared with the yellow quartz or citrine with which it is often confused. Where the stone is mounted and a density test precluded, simple immersion tests of this kind can be very useful.

Still without calling in any apparatus, we can do better than this rather vague observation of relief or lack of relief. If the stone or stones being tested be immersed in a glass dish of liquid and a sheet of white paper placed underneath, and closely observed under a single overhead light, each stone will show one of two effects: either it will be surrounded by a pale border and the junctions of its facets appear dark, in which case the stone has an index lower than that of the liquid; or the stone will be surrounded by a dark border and the facet edges appear white—in which case the stone has a higher index than that of the liquid. The breadth of the border and the thickness of the facet-edge line effect will give a very good idea how closely the liquid index and that of the stone are matching. If the stone has an identical index with the liquid for light of one wave-length it will still not be quite the same for other wave-lengths, as the dispersion of the liquid will be higher. Thus a very near match between stone and liquid is heralded by a coloured fringe to the stone. Using this simple immersion contrast technique with overhead light and white paper under the dish one can pick out with certainty and rapidity white synthetic sapphires which have become mixed in a parcel of synthetic white spinels by immersing them all in methylene iodide, or amethyst-coloured pastes which have been mixed with a parcel of genuine amethysts, by immersing them in ethylene dibromide—to mention two actual instances where I have used this technique with success quite recently. Records of such differences in contrast can be obtained by very simple photographic means, as I explained not long ago in the JOURNAL OF GEMMOLOGY.

As with all other tests, immersion methods are more easily carried out when the stones are unmounted, but they can none the less prove useful with mounted goods. A diamond eternity ring, for instance, is an awkward thing to test for " strangers " in the form of synthetic white sapphires or other substitutes, but by immersing the whole ring in methylene iodide and examining it under the microscope, diamonds stand out in bold relief and any substitutes are at once detectable.

Only a few well-chosen liquids need be kept in stock, and these will last for years if properly stoppered. In addition to the usual " stock " liquids of the gemmologist which would normally include ethylene dibromide (so useful for hydrostatic weighing) with its index of 1·54, bromoform (1·598), monobromonaphthalene (1·658) and methylene iodide (1·745) one can recommend chloro- bromo- and iodo-benzene, supplying liquids with indices respectively 1·525, 1·560 and 1·620, which fill in gaps between the others and are not unpleasant in use.

There is no time to deal with other refractive index methods such as the minimum deviation method, which was greatly favoured by Dr. Herbert Smith, as the full description of it in his book indicates. His chart relating prism angles, angles of minimum deviation, and refractive indices is a most ingenious piece of work. The method is a beautiful one and very accurate under ideal circumstances : it further enables an accurate measurement to be made of the dispersion of the stone tested. But the fact that a rather elaborate instrument, the table spectrometer, has to be used, that much skill and time must be spent over each determination, that only occasionally can a full measure of the birefringence be obtained, and that it is almost essential that the stone should be unmounted, puts the method out of court except for the laboratory worker or the dyed-in-the-wool enthusiast.

Mr. R. Webster's talk given on the 6th May to the Midlands Branch is here recorded:

AFTER being introduced by Mr. T. P. Solomon, the Chairman of the Midlands branch, Mr. Webster opened his talk with the explanation that, although the title of the talk was " Some newer gem problems," his remarks would deal with what is new in materials and techniques since the war, and he craved the patience of his audience if much of the things he would refer to was material which had already been published, but it was necessary to do so to complete the picture adequately.

Much had been made of the new gem minerals, and indeed, as no new gem minerals had been discovered since the finding of benitoite in 1907, the finding of three new gem minerals in the past decade was an achievement. The speaker referred to taaffeite, brazilianite and sinhalite and mentioned the latter as being unique in that it was known for 60 odd years under another name—brown peridot. These new minerals have little commercial importance.

It was in the realm of synthesis that the greater advances had been made since the war, and in the corundum gems the production of the synthetic star rubies and sapphires was an important advance. The star effect is formed by oriented rutile needles developed after secondary heating of the boule, which contained a small proportion of titanium dioxide as well as the alumina and the colouring oxide. The earlier specimens of these synthetics were comparatively clear, showing a good star which did not reach all the way down to the girdle of the stone, and they were easily detected by the curved lines and many gas bubbles. Later syntheses are much more opaque, making it difficult to see the curved lines, but they contain gas bubbles which can be seen with a microscope if a strong light be used, and moreover the base does not show the zonal structure so common in natural star stones, and the " star " and the colour are much too " good." Specimens of synthetic star corundums were exhibited, but to illustrate star stones further, Mr. Webster showed on the screen a coloured slide of an attractive young lady holding in her hand the three famous star corundums of natural origin which are the show pieces of the American Museum of Natural History, New York. These are the 100 carat De Long ruby and the 563 carat " Star of India," and with them the 117 carat

" Midnight Star." Among ordinary clear varieties of synthetic corundum, the speaker referred to some newshades of colour, including the pale pink sold as " Rose de France ", a much richer pink sold as " Rosaline," and two brown colours, " Palmyra topaz " and a darker shade known as " Madeira topaz."

The synthetic rutile resulted from experiments on the production of strategic minerals. Originally made in a yellowish white, yellow, orange, and blue, only the near-white shades are seen at all in jewellery. The blue colours were quickly taken off as they tended to chip badly. The strong double refraction and the exceptional " fire " allowed easy distinction. What is really new, said the speaker, is the strontium titanate. This stone has less " fire " than the rutile, is much whiter—so more the appearance of diamond—and is singly refracting. It has a similar refractive index to diamond but the density is high, being just over 5, and it is somewhat soft, about 6. Only two of these new stones have been seen in this country so far and these two stones have now left these shores and so cannot be exhibited.

The new synthetic spinel of lapis colour is made by sintering powdered synthetic spinel coloured with cobalt oxide. It was devised by a German dentist using sintering techniques common to his profession and some specimens are equipped with included specks of " pyrites " which are in fact particles of gold. Synthetic emerald, although rather a pre-war advance than a post-war, was mentioned, with a report that about 50,000 carats of rough crystals were grown per year, of which only ten per cent. were of gem quality and the best fetched some 120 dollars per carat (say about £40). The synthetic can be distinguished by several methods, all of which may need to be called into play to pin the stone down completely. One of the more important of these was the nature of the internal inclusions and to illustrate this coloured slides of inclusions in natural and synthetic emeralds were shown. Mr. Webster emphasized to his listeners that proficiency must be obtained in the use of the microscope and to drive this home mentioned that one should start young.

It was recalled that for many years the fact that certain gemstones could be turned to a different colour by heating them was well-known. This was particularly so with topaz, zircon and some quartz, mainly amethyst to a yellow colour. The only new departure in this direction is that some amethyst from Montezuma, a place about 37 miles from Rio Pardo, in Minas Gerais, Brazil, will turn green on heating. The effect was found by a prospector who used some of the rough amethyst to build a fireplace and found after drawing the fire that the amethyst had turned green. These " greened amethysts " are now marketed under the name " prasiolita."

The speaker said that what was the most interesting development in coloration of gemstones was that by radiation and by bombardment with particles of subatomic size. Coloration by X-rays has produced spectacular effects, especially in the wishy-washy yellow sapphires from Ceylon, which develop a rich topaz colour in a few minutes in a strong X-ray beam, and kunzite which turns green. Except for the possibility of fraud in the case of yellow sapphires offered at a good price to a customer soon after radiation, the radiation coloration has little practical importance, for the stones fade quickly in about 3½ hours' exposure to sunlight or by heating to 230 degrees Centigrade. (In reply to a questioner it was suggested that if the stone be placed in boiling medicinal paraffin the necessary temperature would be obtained.)

With respect to bombardment with atomic particles, Mr. Webster said that this had the greatest importance in the case of gem diamonds. Coloration of diamond to green by emanations from radium compounds had been known since the experiments of Sir William Crookes in 1905, but as such " greened " diamonds themselves became radioactive they could easily be detected by the aid of an electroscope, a geiger counter, or the scintillations seen on a suitable fluorescent screen ; the best all round method, however, was to place the stone on a bare photographic film for a night, or even a few hours, when the radioactivity of the stone would cause it to take its own photograph, termed an autophotograph, and such a picture was thrown on the screen. (Fig. 1.)

Since the war much work has been done experimentally, and in some cases commercially, in the colouring of diamonds by bombarding them with particles of subatomic size, such as deuterons (the nuclei of heavy hydrogen), alpha particles (which are the nuclei of helium atoms), protons (the nuclear particle with unit

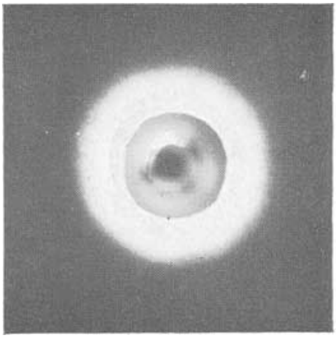


Fig. 1

An autoradiograph of a radium-treated diamond

positive charge), neutrons (the uncharged nuclear particles), and electrons (which are the unit of negative charge and are planetary around the nucleus of the atom). The apparatus used for this type of coloration is a cyclotron, and a picture of such a formidable piece of apparatus was shown on the screen. The stones thus treated are intensely radioactive when they come from the cyclotron, but this quickly dies although the induced colour remains, so radioactivity cannot be used to detect such stones as in the case of the radium-treated diamonds. The colour induced is, like the radium-treated stones, a green, but by heating, either on the apparatus by the heat generated during the process or subsequently, a brown colour is induced. Thus by keeping cool whilst being bombarded—and this is done by using water-cooled probes or by a jet of liquid helium impinging on to the stones—green colours are produced. By varying the heat and beam intensity a number of shades of green and brown can be produced. Coloured slides of bombarded diamonds were shown. Like the radium-treated stones the colour is usually only skin-deep, but more recent techniques have produced coloration throughout. Detection is not always possible, but many cyclotroned stones show a typical pattern around the culet, said to be due to the method of fastening the stones on to the holder of the apparatus. This pattern, called by the laboratory workers "The Umbrella," was shown by a slide (Fig. 2). "The

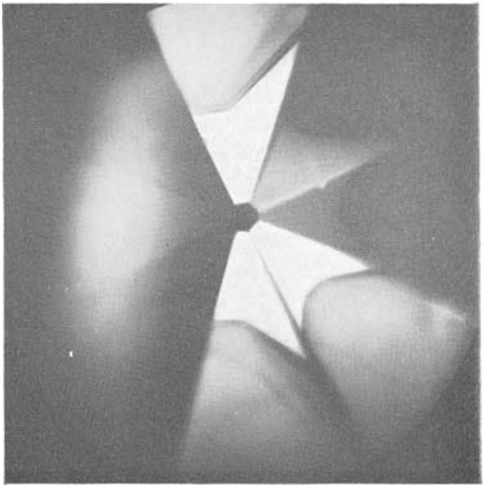


Fig. 2

The "umbrella" seen in some cyclotron-treated diamonds

Umbrella " is a sure sign of cyclotron coloration, but its absence does not imply that the stone is not artificially coloured. Indeed it is not always possible to be sure, although other signs may assist, including the response to ultra-violet light. As more of these stones become available for examination, they will give the laboratory staffs more and more data to build up the picture and eventually an answer to the problem may be provided.

Bombardment by neutrons from an atomic pile has been carried out experimentally. On removal from the pile the stones are practically black and need to be heat-treated in order to obtain a green or brown colour. Three specimens which had received treatment and subsequent heating in the pile BEPO at Harwell were on show.

Recent reports have stated that an aquamarine-blue colour can be induced in diamonds by bombardment with high-speed electrons from a Van de Graaff generator, a picture of one being shown on the screen. No " blued " diamonds have been available for examination, but, according to Dr. Custers, as the natural blue diamonds are electroconducting and the "blued" stones are not, a method of distinction lies in that direction.

Mention was made of the new techniques worked out during the past decade. Methods of immersion contrast by direct observation, which Mr. B. W. Anderson had described to the Midlands branch at an earlier talk, were briefly mentioned and illustrated with slides. The use of the short-wave ultra-violet lamp as a useful tool for the discrimination of synthetic spinel was mentioned, slides being shown of a number of synthetic spinels in ordinary light and glowing under the short-wave lamp. The " crossed-filter " method for observing the fluorescence of chromium-coloured minerals and the use of the copper sulphate filter in absorption spectroscopy were discussed and beautifully illustrated by a couple of slides taken by Mr. Anderson, showing a powerful light with a round glass flask of copper sulphate solution before it and bathing a group of stones in the blue light. The second slide was taken through a red filter and showed the stones glowing red.

Mention was made of a number of cases of cultured pearls going a dirty black colour and the experiments to find out the cause. It was suggested that it was caused by a trace of metal impurity in the pearls becoming a dark sulphide by chemical change from noxious sulphide gases in the air coupled with the heat of some shop windows, a possible cause being sulphide vapours given off from the leather of jewellery cases in a hot shop window.

Some interesting inclusions in glass and natural stones, particularly " bubbles " in apatite, and crystal inclusions in glass, were shown by coloured slides.

The meeting closed with a word of thanks to the lecturer from Mr. Norman Harper, Vice-Chairman of the Gemmological Association, after which the audience spent some time examining the many specimens on show.