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and

PROCEEDINGS OF THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

THE GEMMOLOGICAL ASSOCIATION
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REFRACTOMETER ADVANCES in the U.S.A.

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

UNTIL quite recently, the refractometers used by gemmologists in the U.S.A. were all of British manufacture. While these well-made and satisfactory instruments were available in plenty there was not sufficient incentive for any of the American optical firms to enter this specialized field.

The War altered all this. The manufacture of refractometers, even in normal times, is of course only a small side-line for firms engaged primarily in ophthalmic or other important work. In Britain, the vast demands of Government war-work, which claimed all the time of the most skilled workers, together with the lack of special materials such as the dense lead glass used for hemispheres and prisms, brought the production of refractometers completely to a standstill for several years. We in Britain had no alternative but to wait for better days, and " queues " of orders hundreds deep gathered on the files of the principal makers. The standard " Rayner," considerably improved, has mercifully been with us again for some time, also the perennial " Herbert Smith," but we still await the new model of the " Tully " and that useful accessory type, the Spinel refractometer.

Americans also had to wait ; but before the post-war supplies of the new " Rayner " had reached them they had evolved at least one model of their own, the " Erb and Gray." This incorporates a very simple optical system of hemisphere, totally reflecting prism, scale, and eyepiece, the latter mounted on a swivel to traverse the scale. This has been followed by a still simpler instrument designed by Robert Shipley, Junior, and issued by the Gemological Institute of America. This sells for only 29 dollars in the U.S.A., and is by far the lowest priced refractometer on the market to-day. This makes use of a narrow hemicylinder in place of the usual hemisphere or prism, and the scale itself is curved. The latest American refractometer of which we have knowledge is the handsome-looking instrument with built-in lighting made by the Polarizing Instrument Co. to the design of the well-known mineralogist and gemmologist, Dr. F. H. Pough.

Unfortunately, a critical assessment of the performance of these American refractometers cannot yet be given, as the dollar position virtually bars their entry into this country. Whatever their merits or faults, their development seems to have made American gemmologists refractometer-conscious, and several notable papers on refractometer technique have been published which deserve our attention.

THE " DISTANT VISION " METHOD

The most important of these are two articles by Lester Benson and by G. R. Crowningshield, published in " Gems and Gemology," the attractive quarterly journal of the Gemological Institute of America.(1) These describe what can appropriately be called the " distant vision " method of using the refractometer, whereby readings can be obtained with cabochon stones and with faceted stones too small to give any visible shadow-edge in the ordinary way.

Essentially the method is quite simple, though practice and concentration are needed before reliable results can be obtained. The first essential is to apply only the smallest possible droplet of contact liquid to the refractometer table, and then to allow the stone to rest with its point of contact as near as possible to the centre of the glass. With a cabochon stone, the liquid droplet slightly enlarges the apparent area of contact, and this can be seen as a little disc as viewed by reflection from below if the eye be withdrawn some twelve inches from the eye-piece of the instrument while retaining the correct line of vision.

When this contact disc is viewed in the lower refractive index region of the scale it appears dark, since light is here striking the stone at less than the critical angle and is not totally reflected. As the eye travels in a vertical sense towards the higher readings a position will be reached where total reflection at the contact point will begin, and part, and finally the whole, disc appear bright and merge into the bright background of the scale. With care, the critical position can be found where the contact disc is exactly bisected by the shadow. By a slight readjustment of the eye's focus one can read almost simultaneously the position where the line of demarcation lies on the refractometer scale, thus obtaining a close approximation at least to the refractive index of the stone.

A certain amount of distortion seems to occur near the lower and upper limits of the scale, the middle readings being more clearly defined. It has not so far been possible to measure birefringence by this means.

Even if an exact index is not obtainable it is quite simple to separate minerals of similar appearance but widely differing refractivity since the change-over of the disc from dark to light takes place in quite obviously different parts of the scale. A good example of this is given by quartz and chrysoberyl cat's eyes. Fine specimens of quartz cat's eyes are very difficult to distinguish with certainty from not very good examples of cymophane ; and though absorption spectra, dichroism, inclusions, lustre and hardness may all provide information, where the stone is mounted and one cannot take the density one feels the need for a more conclusive test. The distant vision method on the refractometer provides this, quite definitely.

Another advantage of the method is that it enables readings to be obtained with poorly polished surfaces and with almost opaque substances like turquoise, which give no visible shadow-edge, or a very indistinct one, in the normal way.

Exact readings of the scale and disc are more easily harmonized by using a reading lens of lower power and larger diameter than the usual eye-piece lens, and it is quite possible that the makers will later be able to provide special facilities for using the new method.

The workers in the G.I.A. to whom we owe the idea are to be congratulated on widening the scope of the refractometer to such an important extent.

(1) Lester Benson, " Gems and Gemology," Summer, 1948. G. R. Crowningshield, ibid., Summer, 1949.

THE 1949 GEMMOLOGICAL EXHIBITION

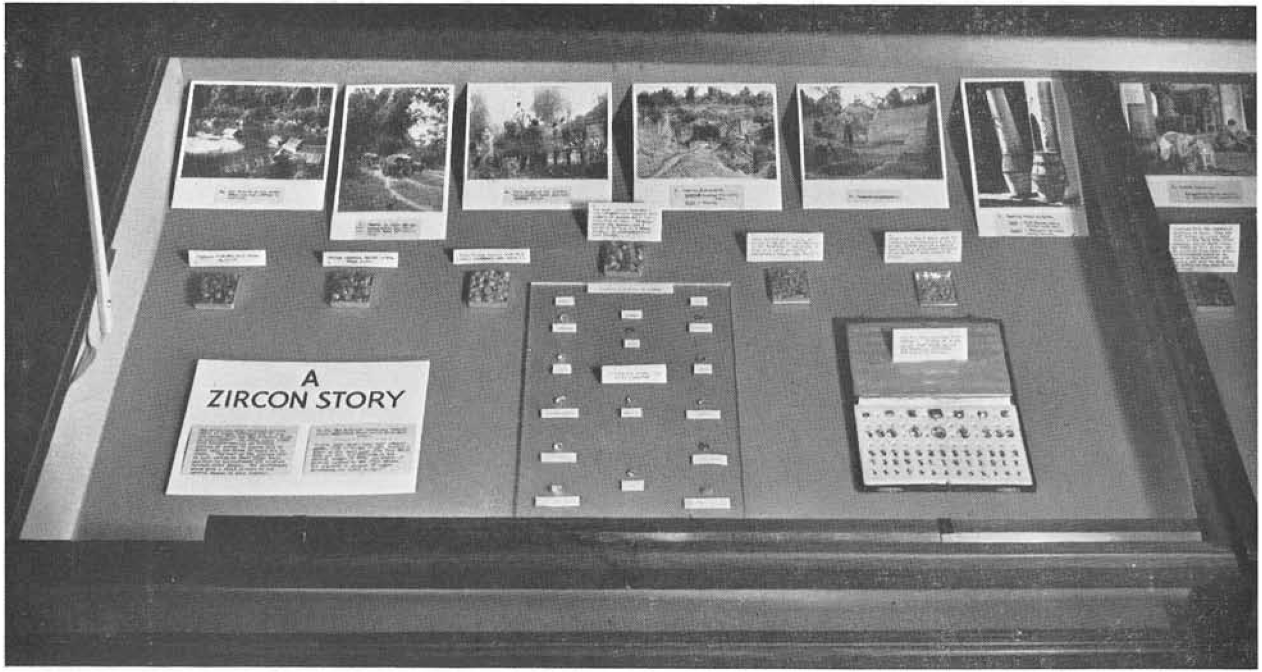
Reviewed by
Gerald Carr

"GEMMOLOGY Made Easy," might have been the title of the third exhibition held by the Gemmological Association at the Goldsmiths' Hall in the first week of October. For it was the kind of exhibition which, while it contained plenty to interest the knowledgeable, also had much to attract the ignorant and to make them converts to gemmology by easy stages. A typical example of the way the displays fascinated those to whom the very word " gemmology " was new was shown by one of the men engaged to guard the gems. He returned to the Hall on his afternoon off, bringing his wife as well.

Members of the Association acted as stewards, ready to explain to the novice what it was all about and to tackle the technical questions fired at them by experts. They were not kept too busy, because most of the exhibits were displayed in a form that was self-explanatory. They told a story that gave a deeper insight into the gems they showed. There was beauty, too, of course. A beauty of fine and common crystals immediately apparent to all, though its significance and wonder may have been better understood by the experts. And for those who delved really deep into the subject there was an array of instruments.

Dominating in size, at least, the centre stand of gems, was the famous Devonshire uncut emerald of 1,383.95 cts. An aquamarine, cut and also large, had a fine clear colouring and the beauty of quartz and fluorspar made them quite worthy to mingle in this stand with spinels, topaz and stones of the tourmaline family. Fine specimens of the more unusual gems were those of danburite, a fine green olivine, apatite and sphalerite in yellow and brown-red.

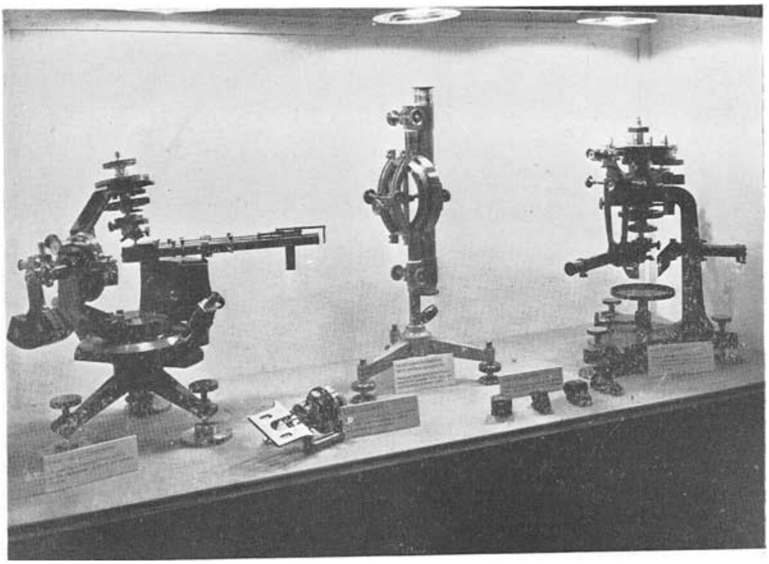
The export drive was—very happily—put into reverse to allow visitors to see on another stand a widely gathered and representative collection of gems found in Canada. Crocidolite in its rough and polished state showed how its popular name of " tiger's eye "


A
ZIRCON STORY

had been adopted, and apart from many gemstones found in most parts of the world, there was Thomsonite and the more felicitously named Patricianite, called after the daughter of the finder. Pyrites had that golden look which has trapped many a " get-rich-quick " amateur, and there was a lovely collection of spherical and polished stones, including several of the star varieties. The beauty of malachite in rough was seen in one specimen where a forest seemed to be depicted.

Finely made models of diamonds that are world-famous attracted many visitors, who thus had their first and probably only chance to see what names such as Cullinan, Jonker, Blue Tavernier, and Dresden Green really meant. Incidentally, nearby was another interesting and imaginative exhibit in which a student had reconstructed what may have been the original form of the Cullinan and shown the line of cleavage parallel to the octahedral plane.

The stand also gave a clear idea of the stages in the production of a brilliant from the rough and the many styles in which a diamond may be cut—an aspect which may have given some of the young and feminine non-gemmologists an idea or two regarding an engagement ring. On another stand were the rarities and freaks of the diamond world, a unique collection of diamonds in strange shapes, unusual colours and with queer inclusions. Their shapes seemed to defy their fundamental atomic and crystalline structure. As for their colours, ranging from port through to yellow green and back to pink, well, that was a surprise for the non-gemmologist, while the expert was happy to study these beautiful coloured

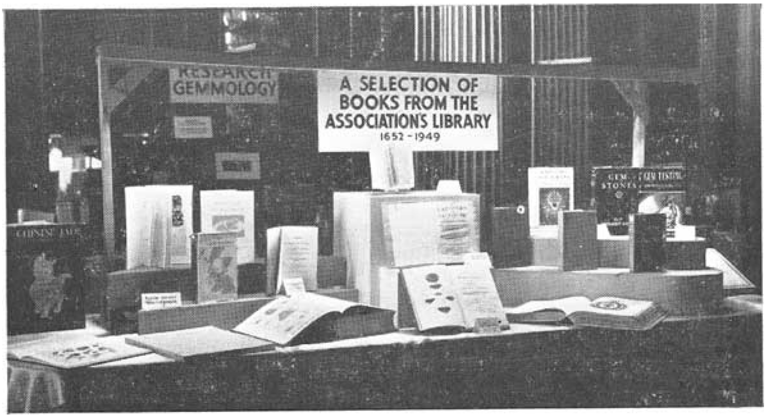


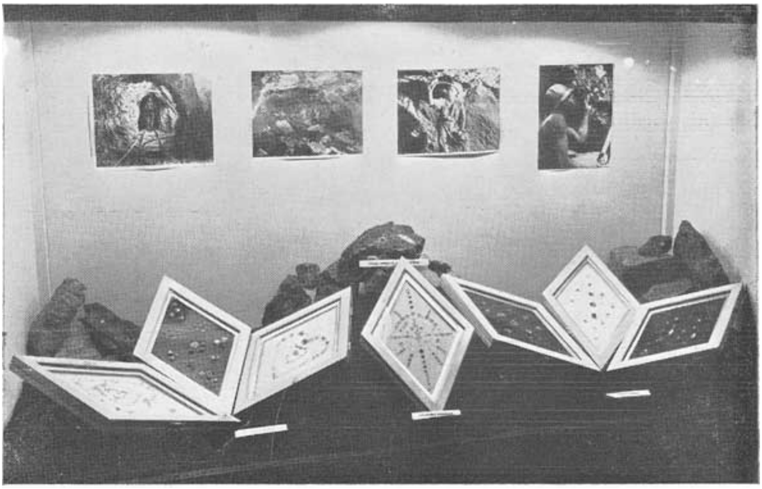
diamonds. And behind were samples of the blue ground with diamonds embedded in them so that it made it appear an easy task to find these gems in the richness of Mother Earth.

From the sublime to the " poor relation " that tries so hard to imitate his natural born superior. The United States specimens of synthetic rutile and of emerald crystals were on view, but nearby was a reminder that " there is little new " with a synthetic ruby made by Fremy in 1890. British attainments in this field were not forgotten, a complete range of synthetic stones made in the North of England from home-produced aluminium and chemicals underlining the fact that industry has not far to look for these goods. Another series of cases contained a wide range of synthetic sapphires, rubies and spinels, while dominating these exhibits was the queer rod-like erection, the Verneuil furnace, which started and still continues much of the work of synthetic making. The " tricks " that can be played by using X-rays to change the colour of some of the synthetics were also shown in the " before and after " manner.

Jewellers—and the public—may well have appreciated two display cases which showed combinations of well-known and lesser-known gems in jewellery and the contents of a jeweller's " junk box." There was a water opal and sapphire bracelet, the stones arranged on wax to give the public an interesting glimpse into how a jeweller tries out his ideas. A pair of drop earrings using sphenes were attractive and so was a carved tourmaline and fluorite necklace. Moonstones were used for another wax mounted bracelet and a pink diamond was an interesting mounted piece. A rare euclase necklet was another novelty and so was another piece using a huge aquamarine and morganite. This exhibit was well displayed and many retail jewellers who saw it were extremely impressed. The " junk box " represented a collection of gems gathered in the " gold rush " of the nineteen-thirties. They had lain almost forgotten down the years, but they were certainly not without considerable value to-day. I wonder if many other jewellers have such a forgotten Aladdin's cave? Here also were specimens, and fine ones, too, of black diamonds, fine cut rubies and emeralds from various parts, and garnets, spinels and zircons.

May I say that I was glad to see a case was devoted to specimens of opals, those rich stones which demand isolation. Here were black opals, fire opals and water opals forming a striking contrast with their particular displays of colour, some still in the rough, others polished, and some made up into jewellery. Then there was the fascinating story of the zircon, told in detail with photographs and examples of the stones from various mining districts in various stages of treatment, from the rough to the various colours and their final cutting and polishing. Another of the many stands which told a story and also gave examples of more

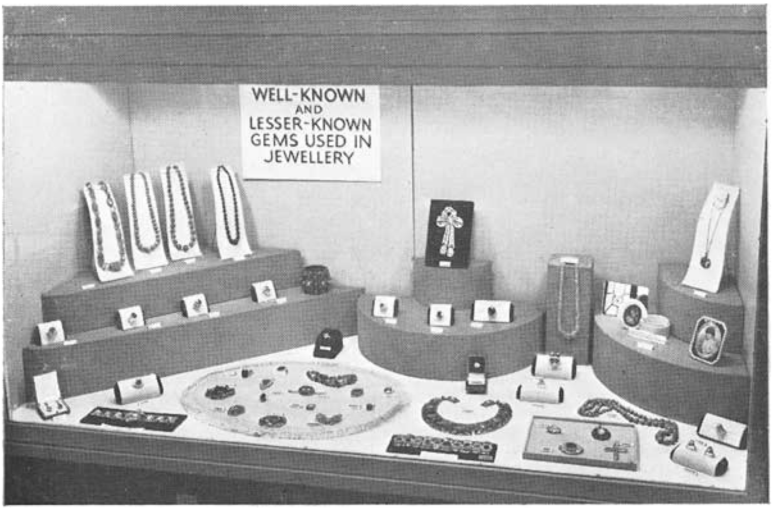




fine gems was that which illustrated the Mohs' scale of hardness of minerals, the different stones being shown in their rough and polished state, their hardness numbers indicated from one to ten and intermediately.

The beauties of crystalline structure were not exhausted by these precious gems. There was a lovely range of quartz, agate and fluorspar. One specimen of quartz must have had a wonderful group of more than fifty crystals and there was an egg-shaped piece of fluorspar. Different beauty was evoked on a " rockery garden " of crystals seen under ultra-violet rays so that they fluoresced, and a rock crystal made a delightful ornament lit from below with changing colours.

Many gemmologists must have had memories of the past evoked by the exhibition of Diploma No. 1 of April, 1913, gained by Mr. Samuel Barnett, who, it will be remembered, died only a few months ago, and commemorated his long association with the Association by mentioning it in his will. Then there was the impressive list of countries, twenty-three in number, in which the examinations have been held. Another indication of the leading part played in gemmology by the Association was in the display of some of the books from their library, undoubtedly unique in its range and selection and dating from 1671 to the latest book of Dr. Herbert Smith.



Then there were the technical exhibits, reminders of the important work done by the Association and its students over the whole field of gemmology. The interesting models of crystal formation used in the various gemmological classes, the G.A. papers themselves and the vast range of instruments devoted to the work. Of these, it was pleasant to see that the ever-useful tool, the Chelsea colour filter, has been produced in a handier and less austerity finish. There was a range of refractometers, not forgetting the early Herbert Smith model, and a new and ingenious specific gravity balance.

The working of the endoscope in pearl testing was demonstrated and the range of microscopes had interesting specimens below them that could be observed. Near at hand was the " sea-shore " with its specimens of pearls and coral and mother-of-pearl. For the advanced specialists there was a spectrometer and the development of plastic imitations has, it could be seen, easily been met by the scientist aided by micro-chemical testing, the various chemicals used being displayed. Various refractometers were also, of course, displayed, one with a diamond prism to give the widest possible readings.

The 1949 Exhibition attracted a record attendance and among the many distinguished visitors were Queen Mary, Princess Alice and the Lord Mayor of London.

Formation and Properties of Single Crystals of SYNTHETIC RUTILE

by Charles M. Moore, Jr., member A.I.M.E.

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INTRODUCTION

IN the study of the properties of rutile pigments it became apparent several years ago that certain physical and optical properties could not be determined on particles of pigmentary size. Since reflected light is the dominant type which reaches the eye from small particles, the true colour of pure rutile was not known. Most rutile pigments are acicular in habit, elongated parallel to the " *c* " axis. It was considered important to know the nature and tone of light transmitted, for example, by a basal plate. Further, as shown by spectrophotometric curves, there is a very strong absorption of light of 4000 Å as measured on particles with random orientation. It would be interesting to see whether this absorption position varied with predetermined and selected orientations. Also, since the behaviour of titanium pigments in a vehicle is important, a knowledge of the surface wettability of single crystals by various media should prove very fruitful. Finally, the optical properties of rutile are such that it should show, in a single pure crystal, greater fire and brilliance than the diamond. Mineralogists had long speculated that this would be the case and curiosity was strong to produce a single crystal large enough to cut.

In light of the above, a project was initiated for the formation of single crystals of rutile.

METHOD OF FORMATION OF RUTILE SINGLE CRYSTALS

Fortunately, purification of TiO_2 produced from both titanium tetrachloride and titanyl sulphate solutions had reached the stage where spectrographically pure starting material could be made. Spectographic analysis of the feed material used in the initial experiments is compared with the present feed material in Table 1. It is apparent that the present large scale purification is approximately as good as the original experimental, small scale purification.

Verneuil(1) produced synthetic ruby and corundum in 1904 by the well-known flame fusion process, which to-day bears his name. Except for mechanical improvements the present commercial production of synthetics by flame fusion is essentially unchanged from his initial method. His burner consisted of an inner orifice through which was fed the feed material and oxygen. Surrounding this was a larger outer orifice through which was fed hydrogen at lower pressure. This arrangement consists then of a lance of oxygen burning in an atmosphere of hydrogen. The proportions of hydrogen to oxygen usually used in corundum production is about 3:1, providing there is sufficient temperature to reach the 2050° C. required for the fusion of alumina.

From work done in the Titanium Division Laboratories(2) and from the published work of Erlich(3) it was known that rutile appears to lose oxygen near its melting point and that it would not be possible to grow single crystals in a strongly reducing environment. Consequently, in order to determine whether single crystals could be grown at all, an Airco oxygen-acetylene torch with twin nozzles was set up. A hopper, consisting of a 6 in. length of mullite furnace muffle 1½ in. in diameter was mounted vertically, with the bottom covered by a 100 mesh wire screen. A glass funnel leading to a copper tube was mounted below the hopper, with the end of the feed tube terminated an inch above the junction of the flames from the two tips. The feed material was vibrated through the screen by means of a small magnetic vibrator attached to the side of the hopper.

The tips of the torch were bent 45°, so that they faced each other. They were wound with 1/16 in. copper cooling coils and inserted through holes cut into a porous refractory brick. A hole was cut in the centre to admit the feed material and the brick cemented to the torch with sodium silicate cement.

A preliminary furnace shell with an inside diameter of 2 in. was cast from the standard clay mix and the brick top with the torch inserted was rested upon it. In order to lower the fused material away from the flame, the furnace assembly was placed upon a scissors automobile mechanical jack, and the furnace lowered by hand. Small crystals, approximately 1 to 2 mm. in diameter and 4 to 5 mm. in length were grown with this apparatus. This showed that in spite of its tendency for very rapid crystallization rutile single crystals could be grown by the flame fusion method. It was obvious, however, that with a point fusion zone, no crystals of appreciable size could be grown and that any crystals produced would be so badly strained as to be useless. In consequence we designed a burner which would provide the minimum reducing environment and which would enlarge the area of constant temperature, to yield a broader fusion zone without a horizontal thermal gradient.

Where hydrogen and oxygen burn, an intense heat is created at the zone of mixing of the two gases. Turbulence of the gases broadens the zone but it is still a single reaction area. However, if an envelope of oxygen is made to surround the hydrogen to yield a three component, or three envelope, nozzle burning flame, there are two reaction zones with sufficient turbulence so that a constant temperature is maintained over the effective diameter of the nozzle. In addition, the outer oxygen envelope prevents excessive reduction of the TiO_2. A 0.5 in. nozzle diameter burner was built according to this design and single unfractured crystals of pure rutile, 1 in. long and 0.45 in. in diameter, were grown. The burner is virtually fool-proof, and the only critical factors are the relative space velocities of the three gas streams.

In order to prevent periodic cooling of the flame by the showers of feed material produced by the customary tapping of the hopper, a very sensitive hopper was designed and a vibrator employed in place of the tapper commonly used on commercial burners. The constant flow of feed not only prevented the strain in the crystal which had formerly resulted from periodic cooling of the flame, but also eliminated the layer structure characteristic of Verneuil Process synthetic crystals. This layer fusion had been deemed by Verneuil as an essential part of the flame fusion technique.

It was also felt that the hand lowering of the growing boule must contribute to strain in the crystal, since any operator must of necessity lower the boule a minimum of several millimeters if he is to keep up with the rate of boule growth and hold the fusion zone at a constant position in the flame. Therefore, a variable speed motor was attached to a worm gear and the pedestal lowered automatically. A provision was made also for a variable speed rotation of the pedestal in the event this was found to facilitate crystal growth.

The control of flow of oxygen and hydrogen to the burner is of the greatest importance. This was accomplished, in the 0.5 in. burner, by reduction valves on the tanks followed by low pressure diaphragm valves in the line ; and which were followed in turn by needle valves in front of the rotometers. A simultaneous shut-off valve also was used. A filter of Spanish moss placed in the line removed excess moisture from the gases, but is not considered essential when gases of normal purity are used. Pigtails connecting two tanks each of hydrogen and oxygen gave sufficient capacity of gas so that a 6-hour run could be made without shutting off, and without marked gas fluctuation.

The final burner design is essentially the same, except for engineering improvements, as the 0.5 in. nozzle burner. The present burners are 0.75 in. nozzle diameter and on which the hopper and lowering mechanism have been materially improved. These burners are connected to fixed lines which are fed from a series of 5 hydrogen and 5 oxygen tanks.

Table 1. – Comparison of Original and Present Feed Material

	Original Feed Material	Present Feed Material
SiO_2	< 0.02	0.04
Fe_2O_3	< 0.001	< 0.001
Al_2O_3	< 0.001	0.001
Sb_2O_3	< 0.002	< 0.002
SnO_2	< 0.001	< 0.001
Mg	0.0005	0.0005
Cb	< 0.005	< 0.005
Cu	< 0.0001	0.0001
Pb	< 0.002	< 0.002
Mn	< 0.00005	< 0.00005
W	< 0.005	< 0.01
V	< 0.0005	< 0.002
Ca	< 0.01	
Cr	< 0.0001	
Ba	0.001	

Mechanism of Growth.

A congruently melting compound which has a melting point within the range of the temperature of combustion of hydrogen and oxygen is quite simple to grow as a single crystal. The only absolutely essential features are accurate control of gases, a burner which will yield a fusion zone with a low horizontal thermal gradient, and a perfectly straight spindle under the pedestal. The control of particle size and shape is essential for a commercial operation, since the particles must be absorbed into the molten surface and melted completely as rapidly as possible.

Single crystals of rutile are grown in the following manner. The burner is cut on, the sintered alumina furnace (2½ in. id) is closed and the chamber allowed to heat for several minutes. The pedestal, consisting of any sufficiently refractory ceramic material, usually alumina or stabilized zirconia, is raised until it is just below the hot zone of the flame, which has a very steep vertical gradient. The vibrator is then turned on and the feed material drops on the pedestal. The temperature of the flame is held below the melting point of the compound by holding the hydrogen content of the flame low. A steep sintered cone is built up until the tip is approximately 1 mm. across. The hydrogen flow rate is then increased and the tip melted. If frozen at this point the tip is found to consist of 3 to 5 crystals with various orientations. If not frozen, it is allowed to grow up into the hottest zone of the flame. It is essential at this stage that the flow of feed be very concentrated, since the " foot " must be kept narrow. This is necessary in order for one crystal to assume dominance and " freeze out " the others. After the foot has grown to a height of 4 to 6 mm., which takes about five minutes, the gas velocity is increased, the automatic lowering turned on and the width of the growing crystal is increased. This increase in velocity is continued until the desired width is obtained. The lowering rate is then synchronized with the rate of crystal growth and the mechanism is allowed to run until a boule of requisite size is attained, when all gases are cut off simultaneously. After cooling in the furnace for 30 minutes the boule is removed. Although boules of large size can be grown, because of the increase in strain with size, the boules are restricted to approximately 100 carats.

Growth from a seed crystal is much simpler since the very critical " foot " stage is eliminated. However, this is not considered a desirable technique for commercial production because of the manpower-time requirements. Seed are usually cemented to the pedestal by an alumina-clay cement. The crystallographic orientation obtainable by growth from a seed does not appear necessary with rutile. Crystals grown from cones have the "*c*" axis less than 20° off the vertical axis of the boule.

Table 2.—Hardness of TiO_2 Crystals by Knoop Microindentation Method

Sample	Orientation				Pyramid Face Cut 45° to "c" Axis	Standard		
	Basal Plane Perpendicular "c" Axis		Prism Face Parallel "c" Axis			Mineral	Mohs Hardness	Indentation No.
	Parallel One Prism	Parallel Other Prism	In Direction of "c" Axis	Perpendicular to "c" Axis				
Perfectly orientated colourless cube	898	898	805^a	840		corundum	9	± 1,800
Yellowish over-oxidized crystal					940	topaz	8	± 1,200
Light blue partially reduced cube	750	850	831^a	835	890	quartz	7	790 710
Dark blue cube	766	840	859^a	885		orthoclase	6	600—690
Black	940	950	$1,000^a$	767				

^{a} Indicates erroneous readings caused by excessive brittleness.

CHARACTERISTICS OF SINGLE RUTILE CRYSTALS

Rutile single crystals grown by the above process are opaque black when removed from the furnace. However, because of the outer oxygen envelope, the rutile structure holds and there is no increment of Ti_2O_3 in the entire structure. A measurement of the unit cell of this black material is nearly identical with that of the fully oxidized rutile structure, both having a tetragonal unit cell. The colourless crystals show 4.5815 and 2.9509 Å, and the black shows 4.5820 and 2.9510 for the *a* and *c* directions respectively.* This black material is a strong semiconductor, and has a specific gravity of 4.268. It is possible to convert this material to colourless rutile by heating in a stream of oxygen. The oxygen addition to the crystal is directly proportional to the size of the crystal being reoxidized and the temperature used. The degree of reoxidation is readily checked by colour changes, as the material goes from black through deep blue to light blue to green to colourless with a yellow tone. The specific gravity of the clear material has been found to vary between 4.29 and 4.30.† As will be shown, this variation in optically identical material was also noted in the dielectric measurements.

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* Measurement made by W. F. Sullivan, of Titanium Division, Research Laboratory.

† Measurements were made by the volume displacement method.

Table 2 shows hardnesses of the oxidation states of TiO_2 single crystals, measured by the diamond indentor, commonly known as the Knoop microindentor.

The synthetic material as measured by the Knoop microindentation method is universally harder than natural rutile, in that the latter is reported having a hardness of 6 to 6½ Mohs scale, while the synthetic is as hard or harder than quartz in all directions. However, hardness measured in the direction of the " *c* " axis on the prism face exhibited a " butterfly " fracture effect around the indentation. This indicates a relief of stress in a sharp angle cone, with the length of the indentation correspondingly shortened. This is brought about by an excessive brittleness in this direction, making the indentation measurements in the direction of the " *c* " axis unreliable. Such a phenomenon would be expected to occur if there exists an atom deficiency in the planes parallel to " *c* " leaving many broken bonds, or if the atoms are slightly displaced along these planes, creating a state of strain.

Table 3 shows the dielectric measurements of single rutile crystals. These data show a marked change in dielectric properties, corresponding to the degree of " reduction " of the crystals. The measurements were made by the Crystal Section of the Naval Research Laboratory,(4) using a General Radio 716 capacity bridge in conjunction with a simple sample holder. All samples were colourless material reduced by H_2 at 600° C. for the various time intervals. The samples were held at five-minute intervals for the first five steps, 10-minute intervals for the next two steps and 30-minute intervals for the last three steps (with the latter held at 700 to 800° C.). It was observed on making the reduction tests on the oriented cube, that the cube was coloured a faint blue in the region of the basal faces after 10 minutes while still colourless in the central portions. As reduction time increased the blue zone moved into the crystal from both basal planes. This supplements the evidence shown by the hardness tests that the greatest loss of the oxygen upon reduction is in the direction of the " *c* " axis. Since TiO_2 is teragonal, one would expect, if the change from colourless to black is caused by loss of planes of oxygen atoms, that this loss would be in a preferred direction. This is indicated by the evidence.

In light of the physical data, certain facts are noted concerning the single crystal rutile structure:

1. It is possible to vary these crystals from clear to opaque black without apparently affecting the volume or dimensions of the tetragonal unit cell.
2. There is a distinct difference in bonding between the planes of atoms parallel to the " *c* " axis and those in other directions.
3. Differences in hardness, brittleness, specific gravity and dielectric constant occur in crystals which are identical in colour.
4. A given crystal can be taken through a complete cycle from colourless to a black semiconductor, apparently identical with the original furnace product, and back again to colourless, at least four times without materially affecting its properties. After six to eight cycles, the crystal becomes embrittled. The ability of the crystals to reduce and oxidize without structural change indicate an elasticity of structure not generally recognized.

The concept that removal of oxygen atoms brings about a darkening of the colour upon reduction, to yield an increasing increment of Ti^{+3} may be correct, but it is difficult to apply to oxidation. A structure for the clear rutile analogous to FeO and FeS_2 should be considered as a possibility. These compounds exist as stable lattices with nonstoichiometric proportions of constituents. The strong covalent bonds necessary for such a cation deficient structure to exist have been shown, by dielectric studies, to occur in rutile.(5)

Rutile pigments show a strong absorption of light at 4000Å to yield a higher increment of longer wavelengths in the transmitted light which results in a yellow tone. Single crystals of rutile are opaque to all wavelengths of light between 2100 and 3200Å and transparent from 4100 to 6800Å at 77°K.(6)

SYNTHETIC RUTILE AS GEMSTONES

The indices of refraction of synthetic rutile, measured by a three circle goniometer on a 20° prism cut parallel to the "*c*" axis showed 2.605 ± 0.004 for the ordinary ray and 2.901 ± 0.004 for the extraordinary ray. Sodium light was used. Measurements made by B. W. Anderson and C. J. Payne(7) on a cut rutile gem show very similar results. These values are within the range of the refractive indices of natural rutile. The refractive index, the marked dispersion, and the extremely high birefringence yields a

Table 3.—Change of Properties Upon Reduction

No. of Reduction Exposure	Crystallographic Direction	Oriented Cube		Rectangular with Long Direction Parallel to "*c*" Axis		Rectangular with Long Direction Parallel to "*c*" Axis	
		Dielectric Constant	Resistivity (ohm cm)	Dielectric Constant	Resistivity (ohm cm)	Dielectric Constant	Resistivity (ohm cm)
0	a	655	3.14×10^{2}	149	15.0×10^{12}	187	3.79×10^{12}
	a	275	4.5×10^{10}				
	c	83.5	1.55×10^{10}				
1	a	4.9×10^{4}	1.7×10^{5}	4.68×10^{4}	1.13×10^{5}	2.34×10^{4}	4.73×10^{5}
	a	3.88×10^{4}	4.82×10^{5}				
	c	3.16×10^{4}	6.33×10^{3}				
2	a	5.7×10^{4}	3.82×10^{4}	5.35×10^{4}	2.35×15^{6}	3.01×10^{4}	7.12×10^{5}
	a		1.92×10^{4}				
			3.0×10^{4}				
3	a	4.58×10^{4}	4.2×10^{4}	4.15×10^{4}	3.39×10^{5}	2.22×10^{4}	9.5×10^{5}
	a	4.58×10^{4}					
	c		1.55×10^{4}				
4	a	4.42×10^{4}	1.275×10^{5}	2.95×10^{4}	2.82×10^{6}	1.59×10^{4}	2.37×10^{7}
	a	4.24×10^{4}	2.24×10^{5}				
	c	3.64×10^{4}	1.55×10^{5}				
5	a	4.31×10^{4}	2.55×10^{4}	3.17×10^{4}	2.62×10^{6}	1.62×10^{4}	1.66×10^{6}
	a	4.37×10^{4}	4.82×10^{4}				
	c	4.8×10^{4}	2.64×10^{4}				
6	a	4.2×10^{4}	2.12×10^{4}	3.22×10^{4}	2.82×10^{5}	1.79×10^{4}	9.47×10^{5}
	a	3.53×10^{4}	7.06×10^{4}				
	c	4.7×10^{4}	2.18×10^{4}				
7	a	4.25×10^{4}		3.27×10^{4}	9.42×10^{5}	1.81×10^{4}	
	a	3.88×10^{4}	8.02×10^{4}				9.47×10^{5}
	c	5.67×10^{4}	4.97×10^{4}				
8	All samples indicate strong decay of dielectric constant during measurement.						
9	Cannot measure dielectric constant—resistivity too low.						

brilliance and fire unrivalled by any other gem. The birefringence gives rise to a marked phenomena in the cut stones. The well-known illustration of the double refraction for different optical orientations is clearly shown by the single, overlapping double and apparently separate culets at the base of the stones.

Even though the stone measured by Anderson and Payne was not cut to yield maximum values, the dispersion of the lowest index of refraction (0.2851) is six times that of a diamond. This dispersion of the extraordinary ray is even higher. This, of course, accounts for the tremendous " fire " of the material.

The standard brilliant or diamond cut is satisfactory for rutile. Since this type of cutting is designed to give total reflection of light by the facets of material with a critical angle of 24° (diamond) it will, of course, also serve for material with a critical angle of a maximum of 18° (rutile). However, if desired, the 6° advantage rutile has over diamond could be utilized to allow a wider bottom internal angle (100° is critical for diamond) yielding a larger diameter stone for its weight.

Since the colourless rutile is not a duplication or imitation of a natural stone as are the other synthetics, it is probably the first truly new gem since the advent of modern jewellery. It is the first material whose optical properties are such that it is superior to diamond in both brilliance and fire. Its future in this industry at least seems assured.

ACKNOWLEDGMENT

The writer wishes to express his appreciation to Dr. R. Dahlstrom, Technical Director, Titanium Division, National Lead Company, who made this investigation possible ; to Drs. Paul Egli and S. Zerfoss and the staff of the Crystal Section of the Naval Research Laboratory for the electrical measurements ; and to H. F. McMurdie, of the National Bureau of Standards, for refractive indices determinations. He also wishes to thank Dr. B. Levin, Chief of the Microoptical Section, Squier Signal Corps Laboratory, Fort Monmouth, N.J., for use of their equipment for the hardness testing.

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By M. D. S. Lewis, A.R.C.S., B.Sc., F.G.A., C.G.

PASTE

SOME gemmologists and jewellers dismiss " paste " as unworthy for consideration in the same class as gemstones because it is " imitation," " glassy," or amorphous. As a matter of fact, the " glassy " or vitreous condition is of far greater rarity and more difficult of achievement than the crystalline state, which is the one normally assumed by most ordinary inorganic solids from table salt to rubies. Whilst the gemmologist enthuses over the high crystallinity of diamond the glass technologist considers this property most objectionable and one to be avoided at all costs. The crystalline state is now believed fairly well understood, but the glassy state still remains to a certain extent mysterious and difficult to define. As will be seen later, it is almost a fourth state of aggregation—something between solid and liquid—analagous to the twilight through which day passes into night.

Older than the jewellery trade itself, paste in historical importance far transcends all other gemstones. In the same way that modern chemistry had its roots in mediaeval alchemy, so glass technology owes much to the early lapidaries for their work on paste gemstones, which were actually the first articles to be made of glass. Representing a technical achievement of the highest order, they were more treasured than gems, which they surpassed in rarity and the acquisition of which merely required diligence in searching.

The earliest known glass—a moulded amulet of deep lapis colour—probably dates back to 7,000 B.C. Many of the so-called " gemstones " of historical significance are undoubtedly paste, including the " Sacro-Catino " emerald bowl, from which Christ is said to have partaken at the Last Supper and the " emerald " slab through which Nero watched the gladiators in the glare of strong sunlight. Many of the " garnets " used in Byzantine jewellery of the 5th and 6th centuries were also probably paste.

Until fairly recent times paste and, in fact, all glass was invariably coloured and often opaque, colourless glass being a comparatively modern invention. At the courts of Louis XIV and Louis XV, when France led the rest of the world in culture, pastes were freely mixed with real stones, emphasis being placed on artistic effect rather than on intrinsic value. Flemish crosses of this period were sometimes set with large pastes in front, whilst the backs were ornamented with small diamonds, which thus played quite a subordinate role.

The manufacture of paste as a separate industry may be said to have begun in 1758, when the Viennese jeweller, Joseph Strass, opened his workshop in Paris. Even now, in some countries paste is still called " Strass." Rapid success seems to have rewarded his efforts, for in 1762 Pouget, a French jeweller, wrote: " Women wear nothing else but Strass," and five years later a Corporation of " Joailliers-faussetiers " was established in Paris. Paste is, of course, a glass rich in lead and it is somewhat surprising that its manufacture was never established on a large scale in England, for in the 18th century English lead glass was supreme in quality and favour throughout the world.

In order that a liquid may form into a glass, two main requirements must be met. Firstly, the electrically charged ions which are present in the liquid must have a tendency to join up with each other to form endless chains in three dimensions, and secondly, the liquid must become highly viscous near the point of solidification. In a liquid, the ions are in violent motion and constantly changing their position relative to each other, and their kinetic energy is so high that their electric charges—through which they are attracted to or repelled from each other—are insufficient to impose a stable arrangement. As the temperature falls their energy of motion becomes less and at a certain point these electric charges gain the upper hand and the ions usually form together in more or less fixed positions in orderly symmetrical fashion. In other words, the melting (or freezing) point has been reached, and the substance has solidified in the crystalline state. Now, if when the ions are joining up near this critical temperature the liquid becomes very viscous, they cannot—through lack of movement—arrange themselves in an orderly crystalline pattern. In other words, the molten or high temperature configuration will be " frozen " in the structure, even in the solid (low temperature) state, and the result is a glass. Water turns into crystalline ice because near the freezing point the liquid remains highly mobile ; molten silica often turns into silica glass because at this point the " melt " is highly viscous. Thus glass, although a " solid," still retains some of the random arrangement which is characteristic of liquids and is often described as a " super-cooled " liquid. The properties of a crystal are always the same however it is formed, but obviously those of a glass will depend on the temperature at which the viscosity has overcome the natural tendency to crystallize and are therefore governed by the thermal treatment. If two glasses are made from precisely similar materials, mixed in identical proportions, but submitted to different heat treatments, the results may differ widely.

Like most gemstones—with the important exceptions of diamond and fluorspar—the structure of any normal glass would appear to be dominated by its oxygen atoms. In nearly every transparent glass—no matter what, or how many constituents there may be—the total weight is practically equal to the sum of the weights of the " oxides " of all the elements it contains and it may be significant that liquid oxygen near its freezing point becomes a highly viscous fluid.

As in all silicate gemstones, the fundamental building brick of any normal glass is the SiO_4 tetrahedron. Imagine four oxygen ions compactly arranged in tetrahedral fashion—three at the base all in contact with each other forming an equilateral triangle—and one placed on top in contact with the three below. The central hole which is thus left is very small, compared in size to an oxygen ion, and can only be occupied by another element if the ionic size is very much less than that of oxygen. Furthermore, this central ion must possess a high positive electric charge to confer stability and prevent the negatively charged oxygen ions from flying apart through mutual repulsion. Silicon is therefore the ideal glass former because its ion is both small and highly charged and there are only a very few other elements, e.g. boron, arsenic, phosphorus, etc., which possess these two essential properties and can thus form glasses. SiO_4 tetrahedra cannot exist separately but may join up with each other to share all four oxygen corners and thus endless chains of Si—O—Si—O atoms are obtained. Since each oxygen is shared by two silicons the overall formula reduces to SiO_2, which, of course, is that of silica. Now there is more than one way of joining these SiO_4 tetrahedra corner to corner. Imagine two such tetrahedra " hinged " together through a common oxygen ion so that the Si—O—Si angle can vary, at the same time bearing in mind that each oxygen ion throughout the structure must be a " hinge " connecting two adjacent tetrahedra. When this angle is 145° the quartz structure results (Fig. 1), and when 180° the cubic crystalline form of silica—cristobalite—is obtained (Fig. 2).

In each case two SiO_4 tetrahedra are joined through sharing an oxygen corner. The silicon atom lies vertically below the topmost oxygen of each tetrahedron. The same linkage is repeated at each oxygen corner throughout the system.

Now it has been established by X-ray diffraction that the structure of vitreous silica—which is the simplest and most perfect glass—is somewhat similar to that of cristobalite ; in fact a blurred or distorted modification of it. Thus, if molten silica cools under

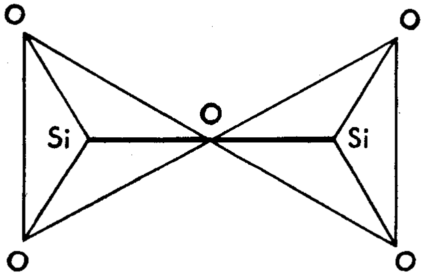


FIG. 1
Linking of SiO_4 tetrahedra in Quartz Structure.
Si—O—Si angle = 145°

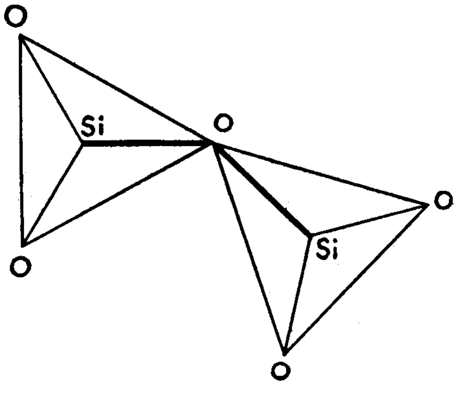


FIG. 2
Linking of SiO_4 tetrahedra in Cristobalite Structure.
Si—O—Si angle = 180°

In each case the fourth oxygen must be imagined iimmedately above or below the silicon. A similar link occurs at each oxygen atom throughout the structure.

suitable conditions, the ions begin to form crystalline cristobalite, but before they can reach this state they are frozen solid and remain in disorder.

Fortunately, the glass maker has no need to juggle with silicon and oxygen ions, as they exist in enormous quantities on the earth's surface, combined in just the required proportions in the form of sand (quartz), which is, therefore, the starting point of all normal glasses. If, then, by the simple process of melting sand and allowing it to cool, perfect silica glass can be obtained, why look further and seek other types? Firstly, because quartz only melts at a very high temperature and the attainment of the enormous heat required for fusion is expensive. Secondly, because molten silica, through its high viscosity—the very property which confers its glass forming qualities—is awkward to mould and work. Thirdly, because it is difficult to colour. By fusing sand with alkali (soda or potash) two of these problems are solved, as fusion occurs quite easily and the viscosity is greatly reduced, but a fatal complication intervenes—the glass is soluble in water. To counteract this, a third component, usually lime, magnesia or alumina, is added, giving a three component glass of the type SiO_2—Al_2O_3—Na_2O, although all three metals may be replaced to a varying extent by others. This, then, is the usual pattern of glasses, although the proportions may be altered and yet more elements introduced to obtain special properties.

It has just been stated that the fusion of quartz with soda reduces the viscosity and this happens through the rupture and sealing off of Si—O—Si—O chains ; the more chains which are broken the less viscous is the " melt " (Fig. 3).

The closeness of silica glass structure to that of crystalline cristobalite has also been commented on and this illustrates the peril which always confronts the glass maker, because if conditions permit, every glass tends to " devitrify " and become crystalline. This is a disastrous fate for glass as it does not, of course, crystallize in one piece, but in innumerable crystallites which scatter the light and destroy transparency and strength. Aluminium is a particularly good stabilizer, resisting devitrification for the following reason. Its ion is somewhat larger than that of silicon, which it can replace at the centre of an SiO_4 tetrahedron, but the substitution distorts the structure and introduces further randomness of

Fig. 3

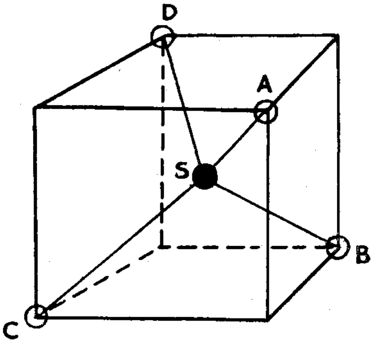
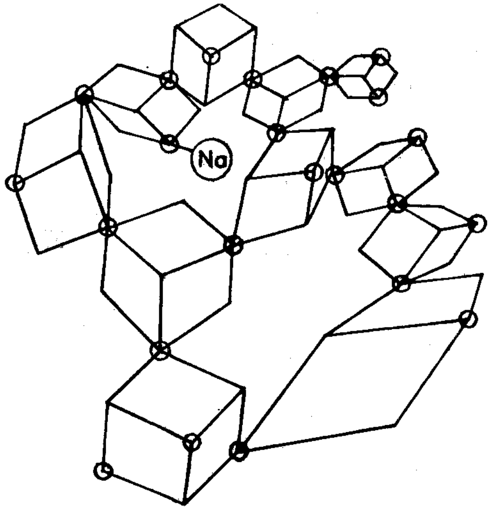


Diagram of Silicon-oxygen Tetrahedron. Silicon atom at centre of cube and oxygen atoms at corners ABCD.



Sketch of Random arrangement of atoms in glass. The silicon atoms are at the centre of each distorted cube.

Representation of glass structure by R. W. Douglas
Reproduced from Journal of Society of Glass Technology by kind permission.

arrangement. By itself, aluminium cannot possibly replace silicon as it has not such a high positive charge, but the deficiency can be made good by the simultaneous introduction of a sodium ion, thus preserving electric neutrality. (Silicon has 4 positive charges, aluminium 3 and sodium 1 ; thus Si^{++++} is balanced by Al^{+++} plus Na^{+}.)

Further reference to Fig. 3 shows that the glass structure is a fairly open one dominated by groups of large oxygen ions and two types of " holes " will be seen to exist. There is the very small hole within each oxygen tetrahedron, usually occupied by silicon, which can be replaced by a few other elements. An element within this tetrahedral hole is called a network former as it plays an essential part in the structure. Between each tetrahedral group of oxygens there are also much larger holes of approximately octahedral shape and of varying sizes, and these may, or may not, be filled by other atoms, each of which will then be surrounded by at least six or eight oxygens. Elements within these larger holes play only a secondary part in the structure and are therefore called network modifiers. Some elements, notably aluminium, titanium and iron can occupy either type of hole, acting as network formers or modifiers. Titanium, often added to raise refractive index, is interesting because if in a tetrahedral hole it is surrounded by four oxygens and absorbs in the visible blue part of the spectrum, conferring an objectionable yellow colour on the glass. If, however, the titanium ions can be shifted to the octahedral holes they will each be surrounded by six or more oxygens, when the absorption band moves to the ultra-violet, outside the visible spectrum, and no colour results. To achieve this, the glass maker adds zinc or cadmium also, as these ions have a marked preference for the tetrahedral holes which they occupy and so force the titanium ions into the vacant octahedral holes.

In the course of its 9,000 years' existence the glass making industry has solved most of its problems by patient and laborious methods of trial and error, with little knowledge of the scientific principles involved. One of its greatest difficulties was the preparation of colourless glass because sand, the all-important primary material, is nearly always coloured by iron impurities, which impart a green or red tinge. The principle decolourizers used were manganese dioxide and arsenious oxide, both of which tend to oxidise the highly coloured green ferrous iron to the paler ferric yellow. At one time it was thought that manganese dioxide assisted the decolourizing process through its violet colour, which is complementary to the yellow of iron. It is also possible that arsenic combines with some of the iron to form colourless ferrous arsenate. Arsenic has always been a favourite ingredient for glass making, and Mr. W. B. Honey, the eminent authority on antique glass, attributes the " mellowness " of old paste to the presence of this element. It is difficult to find any scientific basis for this view ; it may perhaps be due more likely to a " patina " of lead sulphate which has probably formed on the surface.

Of all the elements which may be added to improve the appearance of glass, lead is unique and really good paste nearly always contains large amounts. Although the hardness of such a glass—as measured by scratch tests—may be low, it possesses other " wearing " qualities which more than compensate. The enhancement of optical properties resulting from the addition of lead has long been known, but the reason has only been ascertained in the last few years. The refractive index of glass or silicate gemstones is usually determined by the oxygen atoms. They are large and the outer electrons relatively far from the stabilizing influence of the nucleus. The incoming light waves, which may be regarded as electrical in character, interact with these loose electrons and are thus slowed down. Most metallic ions used in glass or found in gemstones are small and contribute little to refractivity, but the lead ion is so large and unsymmetrical that it is easily distorted or polarized and its interaction with the light waves is correspondingly drastic. W. A. Weyl, the American authority on glass, has also found that lead confers a chemical inertness to the surface which reduces friction and solubility in water, thus improving wearing properties. The outer layer of the lead ion in glass has only two electrons, which being relatively far from the nucleus and weakly held will therefore be repelled from negatively charged bodies. Consider a lead ion at a glass surface, below which lie the negatively charged oxygen ions. Strong polarization will result, the two outer electrons being repelled, producing a very inert top side which may be crudely expressed thus:—

$$\underset{\text{lead ion}}{\mathrm{Pb}^{++}} \longrightarrow \underset{\substack{\text{highly charged}\\\text{underneath}}}{\tfrac{1}{2}\mathrm{Pb}^{++++}} + \underset{\substack{\text{neutral}\\\text{at surface}}}{\tfrac{1}{2}\mathrm{Pb}^{\circ}}$$

The inertness arises from the zero electric charge—there is no force of attraction extending to other ions—hence the diminution of friction. Glass which does not contain lead readily attracts water, which gradually dissolves the alkali constituent, and then this alkaline solution attacks the remaining silica, thus breaking down the entire structure. Some time ago the writer conducted experiments on the spreading of drops of water on pastes and other gemstones. Contrary to expectation, complete spreading (zero contact angle) was not obtained and the writer attributed this to inability to remove the last traces of dirt from the surface, but it now appears that lead glass surfaces are inherently hydrophobic (the reverse of water attracting) and a zero contact angle is theoretically unobtainable. It is hardly correct to describe this as water-repellent, as no special repulsive forces reside in the surface —it is merely inert or neutral and the particles of water are more attracted to themselves than to the surface. The high polarizability of the lead ion is also responsible for the stability of lead glasses, as the effect of polarization is to reduce the symmetry of the structure, thereby increasing resistance to crystallization. By reducing friction, solubility, and tendency to devitrification, lead thus confers improved wearing qualities which may counterbalance lack of hardness and the magnificent appearance of fine old paste after two or three centuries' use is probably due to a reasonably high lead content.

It is not proposed in this article to discuss the normal physical properties of paste, which are fully dealt within the usual textbooks, but the following points may be of interest, although of little gemmological significance.

Paste, being amorphous, is fundamentally isotropic, but a glass can be made which is so anisotropic that it is used as a polarizer. E. H. Land, of " polaroid " fame, has patented a process whereby glass containing lead oxide is exposed before solidification to the reducing action of hydrogen. Droplets of metallic lead are formed and the semi-solid glass is stretched to give elongation in one direction, and marked anisotropy results.

The refractive index of paste is usually between 1.5 and 1.7, but by incorporating rare earth oxides and titanium oxide, glasses have been made having a refractive index of well over 2.0. By carefully treating a glass surface with hydrofluoric acid some of the oxygen ions can be replaced by fluorine, but still leaving a sufficiency of Si—O bridges to retain the glass structure. The decomposition products are very soluble in water, and if leached away a skeletonized glass surface remains which gives the phenomenally low refractometer reading of 1.28 (less than that of water).

Only glasses containing soda are appreciable conductors of electricity—due to the small size of the sodium ions which can therefore move through the holes and channels to produce an electric current. (The only other ion small enough to do this is lithium.) As most pastes contain some soda, a suitably devised conductivity test would probably differentiate them from many other gemstones.

Except in the case of those containing rare earths, the absorption spectra of pastes will be usually " woolly " and diffuse, in contradistinction to the sharp lines and bands shown by many gemstones. In a crystal the environment of atoms is constant and consequently absorption of certain frequencies intense and sharp, but in glasses the environment varies and absorption takes place with less intensity on a broader front. Rare-earth glasses still show sharply defined spectra as absorption in this case is due to electron transitions taking place in inner " protected " orbits which are insensitive to chemical environment.

It would probably be easy to produce a " dichromatic " effect in paste by the inclusion of rare earth oxides, and the famous Moser factory at Karlsbad rather specialized in the production of so-called "Alexandrite " glass. This glass contains neodymium and other oxides, which by absorption in the yellow green sharply divide the light into two components—red and blue—the latter predominating to give a blue colour in thin layers. As, however, blue light is more easily absorbed or scattered, the red component eventually predominates and imparts this colour to thick layers.

The writer would have liked to conclude this article by a definition of " glass " and more particularly " paste," but glass technologists cannot agree among themselves on this point. Indeed, one of them once abandoned the attempt in despair, saying: " Glass is that which, if there were none, we should have to make bottles out of something else, such as goat-skins." The same authority (Dr. F. W. Preston), in a less pessimistic mood, has, however, offered the following:

> " A glass is obtained from a liquid by cooling it (without crystallizing it) until its viscosity has become so high that the configuration remains fixed at a state not corresponding to the equilibrium configuration, but one determined by the heat treatment and the time elapsed."

If the gemmologist wishes to substitute " paste " for " glass " he must also specify the presence of positive ions of large size and polarizable nature.

A SOURCE OF LIGHT FOR SPECTROSCOPY

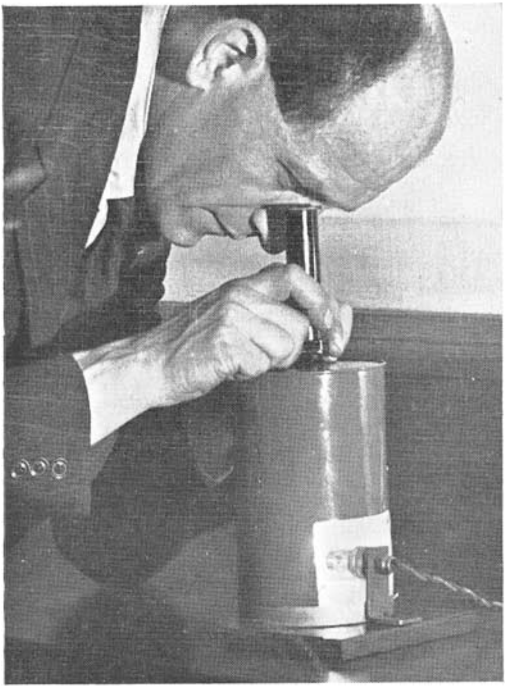
by D. J. Ewing, F.G.A.

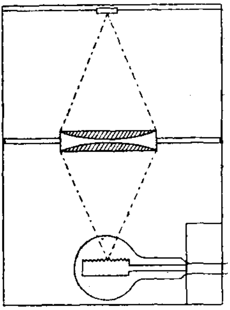
WHEN dealing with the use of the spectroscope, text-book writers invariably describe and recommend the microscope technique as the most convenient.

Although methods based on the use of transmitted light are, in the writer's opinion, preferable to those using scattered light, nevertheless there are disadvantages attached to the use of the microscope. Firstly, microscope objectives are comparatively inefficient as transmitters of light, especially those of low power. Secondly, the magnification obtained results in still more loss of light. Another disadvantage is the discomfort of heat and glare through the necessity of using a 250 or 500 watt projection lamp, apart from the fact that only a fraction of the length of the filaments of such lamps can be used with ordinary optical systems.

A diagram of apparatus is given which has been successfully tried by the writer and, in his earnest opinion, is much more convenient to use. The construction is a circular metal container, such as a double-sized cocoa tin 7 inches in height and 4½ inches in diameter. A condensing lens is fitted midway between top and base and the source of light is a 12-volt 24-watt car headlamp bulb. The top of the container should have a small aperture similar in size to those seen in hand dichroscopes. A more efficient result is given if the metal top is covered with thin glass. This enables the specimen to be slipped into place more easily.

When the stone is placed over the aperture light is directed through the specimen from the source of light below and a choice of positions with regard to holding the spectroscope may be made. It may be held directly over the stone with ½ inch to 1 inch working distance. Alternatively, in some crystals it might be more advantageous to examine stones in several directions, since the absorption may be more apparent in certain directions than in others.





Numerous modifications may suggest themselves to the enthusiastic spectroscopist. For instance, since many gemstones are dichroic, it is advisable to place a polaroid between stone and spectroscope which helps immensely to bring out the finer points of the absorption. Similarly, by placing a transparent dish containing a little toluene or similar liquid over the aperture a stone may, in certain instances, be immersed in such liquid and examined in the manner described above.

For workers who wish to examine the stone for a lengthy period in the one position a retort stand will serve the purpose.

Gemmological Abstracts

"Artificial Colouring of Agate." By K. H. Biegel and G. O. Wild. "Achat," 1949, Vol. 2 (3), pp. 116-118.

To the colouring of agate apply the general hints applicable to the colouring of carneol given in "Achat," 1949, Vol. 2, p. 3. (1) Test samples must be taken. Generally speaking the larger the molecules of the dye the more porous should be the agate. (2) The grain should run vertical to the surface to allow the dye to enter easily into the pores. (3) The stones must be clean and should be boiled in nitric acid to remove iron (except when the stone is to be dyed red) and in soda to remove paraffin used as cooling agent. Only dyes which are practically light, heat-proof and insoluble are used, therefore they must be formed in the stone by heat or the reaction of two solutions. Aniline colours are not used as they fade when exposed to air and light. The only good dye not using a metal salt is the black sugar dye. The agate for black stones must be "soft," i.e. very porous. Honey is better often to use than sugar. The colour is to be preferred to that of cobalt sulphide. The usual colouring processes are as follows:

I. BLACK.

a. 1. Solution: lukewarm concentrated sugar or honey solution.

2. Solution: sulphuric acid ; boil 20 minutes to two hours.

b. 1. Solution: cobalt nitrate ($Co(NO_3)_2$.

2. Solution: ammonium rhodanide NH_4SCN.

The stones are treated, either first with solution 1 then solution 2, or the two solutions are mixed. The black cobalt sulphide only is formed in the stone through subsequent firing.

II. RED.

The dye is iron nitrate. It can be made at home by dissolving rusty nails in concentrated nitric acid.

III. GREEN.

1. Solution of potassium bichromate $K_2Cr_2O_7$ or (better) chromic acid.
2. The saturated stones are next put into solid sal-ammoniac (ammonium chloride), heated for two weeks, then fired. This method has been modified, but no details can be given.

IV BLUE.

1. Solution: yellow prussiate of potash $K_4(Fe(CN)_6)$.
2. Solution: iron sulphate $FeSO_4$ with a few drops of sulphuric and nitric acid, so that a dark blue hue results.

The dyeing sometimes takes several weeks, then the stones are dried, washed and fired. Careful drying at 120° C. is important as traces of water in the pores tend to crack or burst the stone through steam pressure during firing. The old method of firing makes use of covered earthenware jugs on a stove, but more suitable are electric furnaces giving a temperature of about 350° C. With the above methods it is possible to obtain quite useable colours in agate and jasper, but for commercial purposes one needs long experience and thorough knowledge of the material.

E. S.

" Tourmaline Tester according to F. Vandrey." By S. von Gliszczynski. " Achat," 1949, Vol. 2 (3), p. 109-111.

The simplest determination of a tourmaline makes use of a polariscope. The most popular instrument used to be the dichroscope, but this is too expensive as it requires Iceland spar, which becomes quite rare. At the moment " herapatite " and " bernotare," which are used as polarizing foils, are not available and are replaced by a set of glass plates. These are inclined by 57° towards the incident light beam. Vandrey's newly developed tourmaline tester consists essentially of an aluminium cylinder, height 3.2 cm. (1.3 in.), diameter 3.9 cm. (1.6 in.), containing the glass set. Two openings 0.8 cm. (0.3 in.) wide in the cylinder base and top allow viewing along the cylinder axis. If the instrument is held between eye and stone and rotated quickly through 90° around the cylinder axis, dichroism is observed in tourmalines. Green tourmalines display green and olive green colours, reds show darker and lighter shades, brown and blue stones behave likewise. The application of the instrument is not restricted, of course, to tourmalines, but may be usefully extended to any pleochroic material.

E. S.

" Determination of Silver in Pearls which have been dyed Black." By G. O. Wild, R. Papke and K, H. Biegel. " Achat," 1949, Vol. 2 (3), pp. 111-112.

Natural and cultured pearls can be coloured dark brown to black by dipping them into a solution of silver nitrate. The artificial colouring is very difficult to determine by chemical means, but spectographically the determination is possible. Silver shows three marked lines in the spectrum if only small quantities are present as contained in matter scraped from the drill hole of the pearl. Two lines are in the ultra-violet part of the spectrum, the third, which is the least intense, lies between the ultra-violet and the visible part. The following wavelength (in Angstrom units) are given:

Iron	3441 Å
Silver	3383 Å
Silver	3281 Å
Copper	3274 Å

The third silver line at 4055 Å is not visible with small quantities, so that the use of a quartz spectograph is required. Spectra of matter from an artificially coloured natural pearl illustrate the short article.

E. S.

" Handbook of Fluorescent Gems and Minerals." By Jack DeMent. Mineralogical Publishing Company, Portland, Oregon, U.S.A. First Edition 1949. 68 pp. Price $1.50.

A useful paper-covered handbook dealing with fluorescence production and its effects. Contains an excellent survey of radiation sources, including X-rays, cathode rays, grenz rays and ultraviolet light. The book contains valuable information on the various filters which can be used to isolate different wave-lengths of ultra-violet light. Some thirty gem species, including pearl, are remarked upon with reference to their reactions and fluorescent colours, and likewise some 230 minerals are discussed. The appendices contain a not very helpful set of tables based on the fluorescent colours and a useful bibliography. A number of the author's remarks on fluorescence effects are open to criticism and there are many typographical errors and mis-spellings. Garnierite is not a green garnet as stated.

R. W.

" A Report on a Radio-active Diamond." By John A. Hardy. " Gems and Gemology," Vol VI, No. 6, pp. 167-170.

Relates the experiments carried out on a green diamond and on other diamonds. The stone, .71 carats in weight, was, in 1938, of a lively green colour. After some alteration of the shank (in 1940) the stone was found to have turned a rich golden-yellow—possibly due to heat. The stone, which showed neither fluorescence nor phosphorescence, was found to be strongly radio-active by autophotography (three illustrations). Tentative theories as to how the radio-activity may have been induced are given. Experiments in 1940 and in 1941 at the University of Michigan by the use of an electrometer and Wilson Cloud Chamber produced the suggestion that the radio-activity is due to one of the daughter products of one of the radio-active series, and that there were indications that the radio-activity comes from atoms inside the diamond lattice. No decision was arrived at as to whether this was a natural phenomenon or had been artificially produced. In 1942 the radio-activity was about the same and the stone was then subjected to deuteron bombardment by cyclotron, when the stone regained its original green colour which it has since retained. Cyclotronic bombardment by deuterons showed that nearly all diamonds colour green if the bombardment be not too intense, but brown if too intense ; the latter is considered to be a heating effect rather than due to the deuterons. After such treatment the diamonds were found to be highly radio-active, but the effect drops almost to zero after an hour or two. The colouring of cyclotronic treated stones are, so far, apparently permanent, but is thought to be a purely surface effect. A note of warning is given on the wearing of radio-active radium treated diamonds, for in the case of the stone examined, radio-activity was detected in the wearer's finger after the ring had been removed.

R. W.

" A Handbook of Precious Stones." By L. A. N. Iyer (Foreword by W. D. West). Calcutta (Baptist Mission Press), 1949.

A conventional book on gemstones, with particular reference to gems and gem workings of India, Burma and Ceylon. The references are not altogether reliable.

G. A.

" Mineral Collectors' Handbook." By Richard M. Pearl. Colorado Springs (Mineral Book Co.), 1948-1949. First edition, 297 pp.

Written by a Fellow of the Association, this is an excellent book for the amateur mineral collector. Chapters are devoted to care, cleaning, preservation and labelling of minerals, and the chemistry, chemical tests and physical properties are comprehensive enough for the scope of the book. There are competent lists of museums and books dealing with mineralogy and a vocabulary.

G. A.

" Symposium on Reconstructed Rubies." By A. E. Alexander, E. J. Gubelin and B. W. Anderson. " Gems and Gemology," Vol. VI, No. 6, pp. 184-190.

Reports on the examination of a reconstructed ruby and on a specimen artificially produced. The symposium contains notes on the history, the physical and optical properties and the internal structure of these and other reconstructed stones. The density, refractive indices, absorption spectra and fluorescence (under ultraviolet light and X-rays) were found to be similar to natural ruby. The structure showed remarkably curved " swirl marks " of short radii which are markedly irregular when compared to the striations seen in synthetic ruby. Confusing " genuine-like " gaseous inclusions are also seen in association with isolated round bubbles. The colour is similar to Burma rubies but show the greater transparency in the ultra-violet (to 2700 Å) that has been observed in synthetic, but not in natural, ruby.

R. W.

" Oriented Zoning in Synthetic Corundum." By W. Plato. " Edelsteine u. Schmuck," 1949, 1 (9), pp. 193-194.

Apart from the straight colour bands in genuine corundum and the curved lines in synthetic stones, the author points to another phenomenon in synthetic corundum. When a synthetic corundum is viewed between crossed nicols along the optical axis zoning, intersecting at 60° or 120°, due to anomalous double refraction can be seen in nearly every case. This zoning is quite distinct from the straight colour bands in genuine stones and is particularly useful when colourless or very pale stones are examined.

E. S.

" Progress in the Synthesis of Diamonds." By K. F. Chudoba. " Edelsteine u. Schmuck," 1949, 1 (8), pp. 163-165.

Attempts to synthesize diamonds are enumerated and discussed, especially those of Moissan, Hannay, Günther and coll., Bridgman. The author arrives at the conclusion that the problem will not be solved in the near future as the technical and scientific basis has not yet been ascertained.

E. S.

" Emeralds and Rubies—Why so Scarce? " By Prof. Dr. K. Schlossmacher. " Edelsteine u. Schmuck," 1949, 1 (8), pp. 166-168.

Rubies and emeralds are formations of the pneumatolyic phase of the solidification of sial magma, emeralds being nearer to the pegmatic and hydrothermal phase. The colouring matter—chromium—does not belong to this formation. It only enters as colouring matter into corundum and beryl when carried from chromium deposits in sima stones by rising melts and solutions.

E. S.

" From Synthetic Ruby to Synthetic Rutile." " Achat," 1949 2 (5/6), pp. 205-209.

A historical review mentioning the work of A. Gaudin (1837), E. Frémy (1891), A. Verneuil (1902), G. A. Duabrée (1849), E. Ebelmann (1851), H. de Senarmont (1851), and others.

E. S.

" Fluoroscope for the Classification of Genuine Rubies." By S. von Glisczynski and F. Vandrey. " Achat," 1949, 2 (7/8), pp. 270-272.

Instead of employing a comparatively expensive ultra-violet light outfit, the authors used with good success an ordinary 15 watt lamp or preferably a 40 or 60 watt lamp in combination with two complementary colour filters. The light passes through a blue-green on to a red filter. The specimen is placed between the filters. No visible light from the lamp passes through the red filter. The blue-green light, however, which has passed the first filter, excites red fluorescence in a suitable specimen, which can be observed through the second filter. Examples of identification are given.

E. S.

OBSIDIAN OR MOLDAVITE?

By Robert Webster, F.G.A.

EVEN in quite well-informed circles some difficulty is often found in distinguishing between the so-called "natural glasses," *obsidian* and *moldavite*, despite the fact that examination of the internal structure clearly differentiates between the two materials. The difficulty probably results from misconception in early days, when the green glassy lumps found along the Moldau river in Bohemia were thought to be a type of obsidian and were sold as such.

Indeed, looking back through the literature, one can see that the misconception must have started early, and with the mineralogist, who, in fairness, quickly corrected the error. Moldavites, which had been known before 1787,(1) were not referred to in the second edition of Phillip's "Mineralogy" of 1819,(2) but in the fourth edition of that work(3) are referred to as a variety of obsidian ; a similar version being given in Mohs's "Mineralogy" of 1825.(4) In the 1852 edition of Phillip's "Mineralogy" (revised by Brooke and Miller),(5) moldavite is not included—the mineralogist had apparently decided against the pieces being volcanic glass, although as late as 1894 F. Rutley(6) still terms moldavite a variety of obsidian.

The gemstone literature seems to have been much later in clearing up the discrepancy, for we find that as late as 1909 Wodiska(7) classed moldavite as obsidian. Many of the earlier works (Claremont, Cattelle, Emanuel and Church in his first edition) ignore the material altogether. Church(8) in the 1905 edition clearly states that moldavites are not a volcanic glass, and in the last edition he writes: "The material differs in intimate structure, in fusing point, and in chemical composition from any kind of glass. It is not identical with obsidian."

Further, many text-books describe obsidian as having a leaf-green colour, a shade rarely, if ever, found in the natural volcanic glass. Therefore it can be little wondered at that the gemmologist, with all this initial misunderstanding, finds himself at a loss over these materials. Maybe these few notes will clear away some of the ambiguity.

For convenience it may be as well to give initially some notes on the moldavites themselves. These glassy pieces are found in lumps having peculiar surface markings and are of a deep leaf-green in colour—they are faceted in the usual styles for marketing. The origin of the pieces is wrapt in mystery ; they have been variously described as being the remains of a prehistoric glass works, or to have a celestial origin, and as such have been grouped with the *tectites*.

Moldavites have a range of density, according to Herbert Smith, of 2.30 to 2.50 ; eight determinations reported by the writer(9) on cut and rough specimens gave values between 2.32 and 2.38. The refractive index, the material being a glass and therefore isotropic has only one index of refraction, is given as 1.48 to 1.52. Here again the writer found from the specimens available, the more restricted range of 1.49 to 1.50. There is no absorption spectrum pronounced enough to be of use in identification. However, it is by examination of the internal structure that the most conclusive evidence can be obtained, for the large and profuse round gas bubbles combined with peculiar swirl markings are typical of the material and totally unlike the swirl striae and gas bubbles seen in glass imitation gems.

Obsidian, a volcanic glass, results from the rapid solidification of volcanic lavas, which, if slowly cooled, would assume a crystalline structure ; e.g. granite. Most obsidian does show incipient crystallization, generally known as *devitrification*, which is evident by the texture or microstructure showing crystallites. These are spherical, rod-shaped or hair-like bodies, the different forms being given specific names ; thus the droplike bodies are termed *globulites*, the rod-shaped ones *belonites* and the coiled and twisted hairs *trichites*(10), and globulites in chains are termed *margarites*, probably in fanciful analogy to a string of pearls. It is by this texture that obsidian may be clearly differentiated from moldavite, and further, a sort of preferential parallelization of the crystallites —probably due to flow structure—produces a silver or golden sheen.

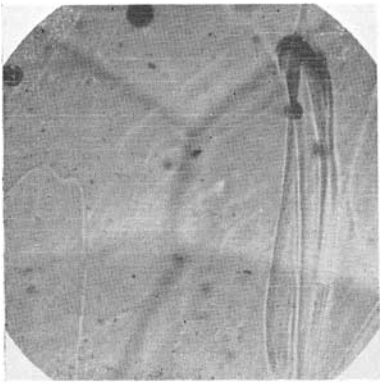


FIG. 1

Gas bubbles and swirl marks in moldavite. X25.

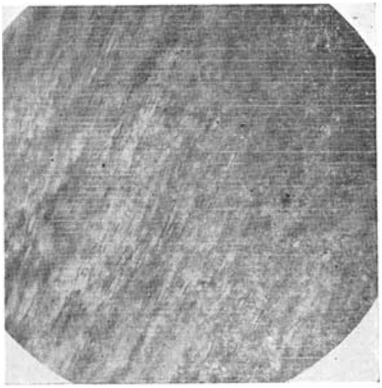


FIG. 2

Microscopic crystallites in parallel orientation in an obsidian. X25

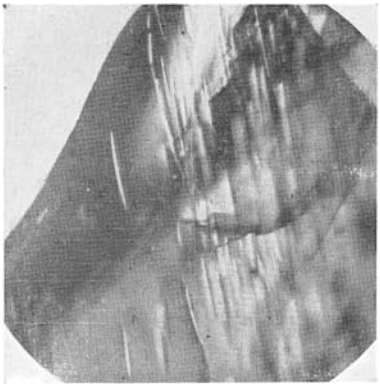


FIG. 3

Torpedo-shaped vesicles in obsidian. X25.

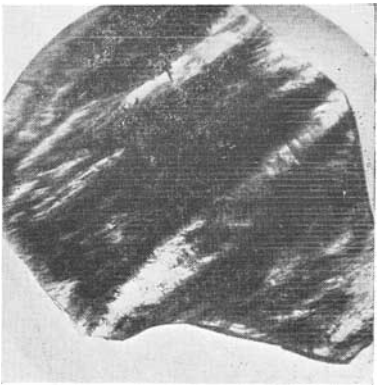


FIG. 4

Colour bending appears to be composed of microscopic crystallites in "Mountain mahogany obsidian." X25.

Obsidian is generally dark grey or black in colour, or may be brown and black, the two colours being banded and showing a very definite flow structure. The obsidian used as a gem material is usually the iridescent variety showing a golden or silver sheen ; and perhaps for some occasions the black and brown striped material is fashioned. The name " mountain mahogany " has been applied to this black and brown material.(11) The hardness of obsidian is about 5 on Mohs's scale, and the material has a pronounced conchoïdal fracture producing sharp knife-like edges—a character which has endeared obsidian to Stone Age Man.

The density of obsidian, according to Herbert Smith,(12) is 2.33 to 2.47, a value range which the writer's personal determinations fully confirm and which for completeness are appended:—

" Mountain mahogany "	2.338
" Mountain mahogany "	2.341
" Mountain mahogany "	2.343
" Mountain mahogany "	2.345
" Mountain mahogany "	2.347
Black	2.356
Golden iridescent	2.358
Golden iridescent	2.361
Black	2.361
" Mountain mahogany "	2.381
Silver iridescent	2.393
Black	2.399
Silver iridescent	2.41
" Mountain mahogany "	2.414

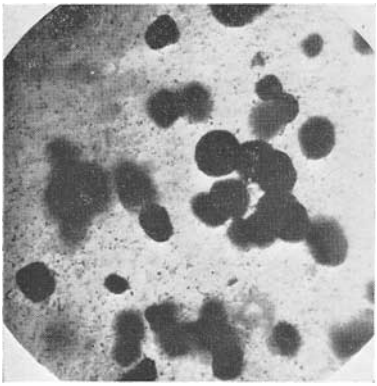


FIG. 5

Spherulites and small globulites in obsidian. X25.

The refractive index is given as 1.48 to 1.51, and thin fragments viewed between crossed nicols are generally completely isotropic, unless fairly large crystallites, or rather *microlites*(13) are included, which show up as bright points of light and which are also seen to show sharp extinction.

Observation of thin slivers under the microscope, even with low magnification (x25), will clearly distinguish obsidian from moldavite. In obsidian the texture observed may vary considerably from the crystallites already mentioned to torpedo-shaped, or cigar-shaped, vesicles ; the latter often in association with belonites or other types of crystallites—which may require a much greater magnification to resolve. It is hoped that the accompanying photomicrographs will illustrate the structures more clearly.

The obsidian used in jewellery is mostly obtained from the United States, important localities being the Glass Butte, Oregon ; Obsidian Cliff, Yellowstone National Park, and in a number of localities in California. A variety, miscalled " Iceland agate," is found, as the name implies, in Iceland. Many other localities throughout the world are known, mainly, though, through the interest they hold as being the sources of material used for ancient artifacts.

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(1) Spencer (L. J.). " A Key to Precious Stones," 2nd Edn., p. 207. Blackie, London, 1946.

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(3) Phillip's " Mineralogy," 4th Edn. (by Robert Allan), p. 141. London, 1837.

(4) Mohs's " Treatise of Mineralogy " (by W. Haidinger), Vol. 2, p. 341. Edinburgh, 1825.

(5) Phillip's " Mineralogy " (by H. J. Brooke and W. H. Miller).

(6) Rutley (F.). " The Study of Rocks," 6th Edn., p. 187. London, 1894.

(7) Wodiska (J.). " A Book of Precious Stones," p. 191. London, 1909.

(8) Church (A. H.). " Precious Stones," London, 1905, p. 110. London, 1924.

(9) " The Gemmologist," Vol. 16, No. 186, p. 18. London, January, 1947.

(10) Hatch (F. H.). " Petrology of the Igneous Rocks," 7th Edn., p. 32. London, 1914.

(11) Bauer (M) (trans. by L. J. Spencer), " Precious Stones," p. 446. London, 1904.

(12) Herbert Smith (G. H.). " Gemstones," p. 398. London, 1949.

(13) Hatch, ibid., p. 33.

TWO USEFUL HOME-MADE POLARISCOPES

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

IN response to one or two inquiries from Chelsea students early last session, I had some one-inch squares of polaroid mounted between glass for supply to such students as wanted them. Two of these squares, held in a crossed position with a space between them, in the left thumb and forefinger, formed, with a little practice, a crude but none the less effective polariscope. The stone under test being placed between them and moved as required by means of corn-tongs held in the right hand, light being reflected from a strongly illuminated sheet of white paper and side light excluded by the position of the thumb and forefinger.

It was at first intended that these sets of polaroids should be used in this way and be available for refractometer work and any other uses to which polaroid may ordinarily be put. But two students have independently elaborated on the simple idea to build permanent and useful polariscopes at remarkably small cost.

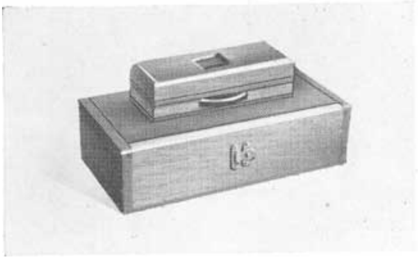

FIG. 1

The first of these, made by W. Frake and illustrated in Figure 1, is a very simple little instrument. The main body, which houses a pocket torch lamp and battery, is made from one end of a cigar box with a sliding lid to allow easy access to these items. The polarizer (glass-mounted polaroid) is recessed into a 1¼ in. square hole in the sliding lid. Above this is a metal rimmed glass disc, sandwiched between three rectangles of plywood, with its edges projecting fore and aft, so that it may be rotated at will. The plywood is screwed and glued into place on the box lid. A further sandwich of three layers of glued ply holds the polaroid analyzer, and is pivoted on the first by means of a screw at one corner.

In use, the top section swings out to allow a stone to be placed on the glass disc. It is then swung back into place, when the polarizer and analyzer are in crossed position. The stone is illuminated from below by means of the lamp and viewed through the square hole at the top of the instrument, the glass disc being rotated as desired. An ordinary brass jewel box catch has been cleverly utilized as a switch for the lamp.

FIG. 2

The second instrument, illustrated in Figure 2, was made by F. Kench, and is a considerably more elaborate job. It consists of a rectangular wooden box housing batteries and switch, surmounted by a square wooden tube containing bulb, diffusion screen, polarizer, rotating glass, analyzer and lens. Again the construction is mainly from cigar-box wood. The tube is hinged to allow a stone to be placed on the rotating disc. Further hinges give access to the bulb and batteries respectively. The top wooden plate can be unscrewed for cleaning the back of the lens and the analyzer. A rather complicated inner lining (not shown in the diagram) gives similar access to the glass disc and polarizer. By hinging the instrument immediately above the glass disc this complication could be avoided.

In use, this instrument gives similar results to those obtained with the first one, with the additional advantage of a small degree of magnification. Three two-volt batteries are used, giving somewhat stronger illumination. The lamp housing is painted white inside, while all above the polarizer is painted black.

Both instruments are intended for use with loose stones, but the larger one would accommodate a mounted ring of reasonable size if necessary. The student originally thought of devising some means of immersing the stones in a suitable fluid, but this would seem impractical in view of the damage that might result from spilled liquid.

These, no doubt, are far from being the first home-made polariscopes to be constructed by gemmologists, but they are of interest as illustrating some degree of enterprise and also of the fact that no more than about ten shillings was expended on each.

COMMENT ON "THE FINE CUT OF SYNTHETIC RUTILE"

By W. F. Eppler, Ph.D.

There are two approaches open to the student in analyzing the design of gem cuts. Dr. Eppler has followed the usual path. The less common method is to set the stone up on a special optical bench and physically examine the light lost out the back, the pattern thrown on the screen and by pin-hole or mask trace the ray paths. No simplifying assumptions such as render the results of a drawing-board analysis doubtful are necessary.

I would like particularly to point out in Dr. Eppler's paper that the only facets considered (except for 0° incident light) are those cut by the plane of the paper. For these facets his argument is on sound ground. It is inadmissible to use the results for these facets for the remainder of the area of the gem presented to the light at other than 0° and compute thereby percentage of light lost for the whole gem.

If memory serves me right, Dr. Eppler in his 1938 article develops his whole series of "Ideal" cuts on the basis of 0° incident light. Unfortunately, this angle of presentation to a light source is rather impractical unless one wants to use a surgeon's forehead lamp when examining gems. Dr. Eppler apparently recognizes the greater rationality of Tolkowsky's oblique illumination in his current article.

I have cut and examined, on the optical bench, a number of Synthetic Rutile Gems. As a result, I have abandoned the standard round Brilliant-cut for these stones where the finished weight exceeds 8 or 9 ct. The largest cut to date weighs 27 ct. The cut I have found to be superior to the standard round brilliant is the Jubilee-Cut. The crown is shallow, there is no table. The angles to the plane of the girdle are:—

Main Pavilion Facets	$-40°$
Point Pavilion Facets	$-35°$
Main Crown Facets	$-30°$
Star Crown Facets	$-10°$

For what my judgment is worth, I would say that Dr. Eppler's Fine Cut points to improvement in gem design. I can only hope that he will come to analyze gem designs on the optical bench and report his findings.

GRIFFIN GRANT WAITE, Toronto 12.

ASSOCIATION NOTICES

FIRST GEMMOLOGICAL CHAIRMAN DIES

The Council regrets to announce the death in London on June 21st of Mr. S. Barnett, the first Chairman of the Gemmological Association. Mr. Barnett was born in Swineshead, Lincs, in 1874, and served an apprenticeship with his father, a watch and clock maker.

After experience with a number of firms, in 1902 he went as manager to Butt & Co., Ltd., of Chester, and on the death of Mr. A. W. Butt became managing director, a position he held until 1920, when he bought a business at Brighton. Two years later he purchased a business in Peterborough and carried on there until his retirement in 1943.

Throughout his career Mr. Barnett was keenly interested in trade education. In 1901 he became a Fellow of the Spectacle Makers' Company, and was that year granted the Freedom of the City of London. In 1912 he qualified as an F.B.H.I. At the Annual National Association of Goldsmiths' Conference in Manchester in 1908, he proposed on his own initiative that the teaching of gemmology should be one of the objects of the N.A.G. and that the Association should hold examinations in the subject. After four years of work in furthering the scheme, the first examination was held in 1913. Mr. Barnett sat for the examination and was awarded Diploma No. 1.

Prior to the formation of the Gemmological Association in 1931, of which he was the first Chairman, Mr. Barnett acted as chairman of the N.A.G. Education Committee for three years. In his will (subject to probate) he bequeathed £100 free of duty to the Gemmological Association.

GIFTS TO ASSOCIATION

The Council wishes to express its appreciation of the following gifts that have been made to the Association: A text-book on Gemmology, in Finnish, presented by the author, H. Tillander, Esq., F.G.A. ; the "Armytage Collection of Maori Jade," by K. Athol Webster, Esq. ; a collection of synthetic sapphire and spinel boules by Wiedes Carbidwerk.

MEMBERS' MEETING

A meeting of Fellows and members will be held in the Medical Society of London's Hall on Tuesday, November 15th, 1949, at 7 p.m. The speaker will be R. K. Mitchell, F.G.A., whose subject will be "Cleavage and the structure of gem minerals."

BIRMINGHAM POST-DIPLOMA CLASS

A post-Diploma class in gemmology has been instituted at the Jewellers' and Silversmiths' School, Vittoria Street, Birmingham, and Fellows of the Association who may be interested should address inquiries to the lecturer, Norman Harper, F.G.A., at the school.

MEMBERSHIP

The following were elected to membership of the Association at a meeting of the Council held on August 10th, 1949:—

Fellow:
- Thody, J. T., Bedford.

Probationary:
- Katz, Arnold, S. Africa.
- Katz, Basil, S. Africa.
- MacKillip, A. J., Ardrossan.

Ordinary:
- Helzberg, Barnett C., Kansas City, U.S.A.
- Law, Leslie, London.

DR. A. E. ALEXANDER

Messrs. Tiffany & Co. announce that Dr. A. E. Alexander, authority on gemstones and pearls, will join their organization in an executive capacity on October 1st. Dr. Alexander recently resigned the directorship of the Gem Trade Laboratory, Inc., New York.

RESULTS OF THE 1949 EXAMINATIONS

For the 1949 Diploma (Fellowship) Examinations of the Gemmological Association of Great Britain a record number of candidates, 111 in all, presented themselves, of whom 96 sat in Great Britain and 15 overseas ; of these seven did not take the practical part of the examinations and could qualify for Associateship only. Upon the recommendation of the examiners the award of the Tully Medal has been made to Mr. P. J. Thomson, of The Jade Dragon, Ltd., for the competent knowledge of the subject displayed in his papers. It has also been recommended that two Anderson Prizes be awarded, one to Mr. E. T. Hartland, of A. E. Poston & Co., Ltd., and the other to Mr. F. C. L. Salisbury, of W. C. Mansell, for papers of equal merit in the practical examination.

A large number of entries was received for the Preliminary Examinations also, 14 from overseas and 112 in Great Britain, making a total of 126. The Rayner Prize has been awarded to Miss S. G. Warnes, of Messrs. Speed & Son.

The following is a list of successful candidates, arranged alphabetically:

DIPLOMA

Qualified with Distinction

Batty, J. (Keighley)
Blanshard, D. (London)
Butler, Miss J. M. (Greenford)
Butterfield, M. L. (Leeds)
Davis, K. C. (London)
Day, N. H. (Salisbury)
Dresme, D. (Amsterdam, Holland)
Feitelson, P. ((London)
Franklin, L. (London)
Gudridge, E. H. (Perranporth)
Harkins, T. (Johnstone)
Hartland, E. T. (London)
Heetman, J. G. (Rotterdam, Holland)
MacDonald, E. W. (Bearsden)
McDonald, Miss T. (Edinburgh)
Newman, J. A. (London)
Rosas, M. M. R. P. (Oporto, Portugal)
Sanitt, L. (Ilford)
Stephanides, S. G. (Birmingham)
Thomson, P. J. (Thundersley)
Whitehead, G. W. (Surbiton)
Winnert, G. M. (Edinburgh)
Wright, G. T. (London)

Qualified

Allan, Miss W. M. M. (Prestwick)
Backers, F. C. M. (The Hague, Holland)
Barker, R. J. (London)
Benson-Cooper, P. (London)
Blatchford, D. C. (Plymouth)
Boston, T. L. (Colchester)
Bowden, A. (Plymouth)
Brocklehurst, M. J. C. (Chorley Wood)
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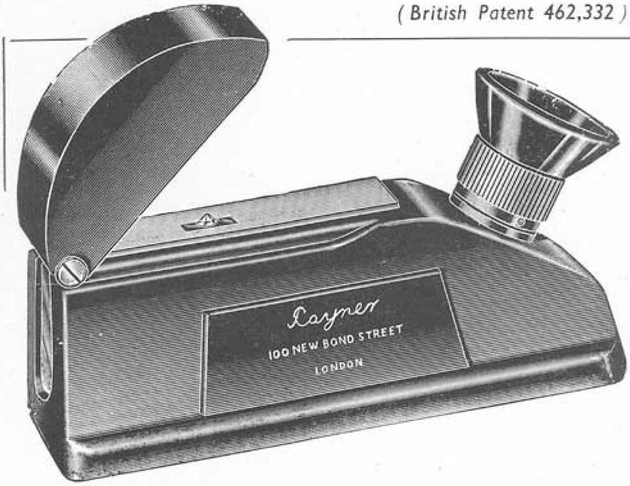
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