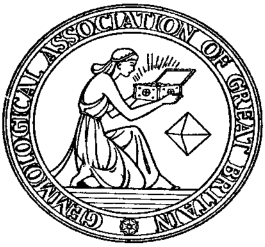
Vol. IX No. 3 July, 1963

THE JOURNAL OF GEMMOLOGY

and

PROCEEDINGS OF THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN



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TESTING A RUBY

By A. E. FARN

THE three essential properties necessary to a gemstone are beauty, durability and rarity. Seldom does one find all three together and if one does, then size very often acts as a neutralizer in commerce.

The three main instruments a gemmologist requires are microscope, refractometer and spectroscope. Seldom will all three be necessary together to test a gemstone, and, if the occasion does arise, then rest assured that the stone which calls for these three tests has beauty, durability and rarity. One of the most frequently tested stones, and one about which a good deal has already been written, is ruby.

Ruby fulfils all the requirements of a gemstone; it has beauty, durability and rarity (if of any size). It certainly needs all three tests since the refractometer does not yet tell synthetic from genuine, neither can the spectroscope, but certainly the microscope will. I know that many eminent gemmologists require only a microscope or lens plus experience to test their rubies and they are usually correct. Maybe when a person of eminence in the trade states positively a stone is genuine, no further challenge is forthcoming, and, to all intents and purposes, the stone lives happily ever after in its " proper " setting, giving pleasure to its owner, and every one is happy.

Fortunately a laboratory test states a fact backed by specific tests which double check and allow for no speculation or doubt. Because of this rigid adherence to correct scientific principles, it behoves us (although years of practice make it seem wasted labour) to carry through strict routine to prove a stone we know by practice to be genuine or synthetic as the case may be. That is why earlier I have stated the case where ruby needs all three tests—microscope, refractometer and spectroscope. There are instances where one uses extra techniques, such as X-ray fluorescence and phosphorescence and transparency to X-rays and immersion contact photography. These latter cases are usually last resort extremes in the case of the clean synthetic ruby or clean genuine ruby.

To proceed in an orderly manner therefore to test a ruby—let us dispense with the usual routine of a parcel of red stones (beloved of examiners) and stick to a red stone.

First checks are usually made by looking and deciding by colour and appearance that the stone is a ruby. Then examination by lens, looking through the stone. Very often to a laboratory gemmologist this is sufficient an indication; being an expert in lens testing, he will have seen perhaps " silk ", feathers, " treacle ", or crystal twin planes, which he will then confirm by using his microscope for a more intimate examination. Every now and again one comes across a case which pulls one up short and delivers a chastening blow to one's know how. This can be very useful because, being human, we all tend to relax somewhat and this surprise gives us personal food for thought which can be far more effective than advice or caution from an outside source. In similar manner, a successful dealer who has a run of good buying and selling sometimes gets a little careless.

Usually a glance is sufficient to the expert for him to decide a stone's provenance and authenticity. Sometimes, however, one comes across the small, fine, exquisite stone which is so strong in colour that it *looks* synthetic, or the ruby which looks like a fine garnet and one cannot say for sure which it is. As is well known, the better selling rubies are those from Burma, although in my opinion Siam stones are lovelier to look into. However, since it is money which lubricates the wheels of commercial jewellery, it is the Burma stones which count. Some chrome-rich Burma stones literally suffer from an overdose of this colouring matter and look quite dark and from the outward appearance *look* like Siam stones.

Inevitably they are labelled Siam, thus emphasizing one of the aspects of beauty, i.e. colour. The trade sells its goods on appearance. Fine colour rubies are Burma and poor, darker ones Siam. By and large this rule is roughly correct in provenance too. To the uninitiated, some very fine deep red spinels can slip by as rubies and I have seen a superfine red tourmaline with a small liquid feather accepted as a ruby.

When tackling the problem of testing a ruby (as gemmologists) we mostly rely on the microscope. Perhaps it is here then that we betray this 100% confidence which earlier I have stated has the occasional jolt which is beneficial in deflating our ego. The testing of a ruby requires the absorption spectrum and internal structure to be checked.

A ruby has to be proved firstly to be corundum. To do this is elementary by use of either refractometer or spectroscope. I would advise the spectroscope as opposed to the refractometer since there is no wear on the spectroscope and standard refractometers' prisms soon wear and are costly to re-polish.

The absorption spectrum of ruby is a nice easy one to recognize. Although the following measurements are given it is not necessary to measure them each time since it is such a distinctive pattern seen through a spectroscope that it *cannot* be confused with any other red gemstone. In the red end of the spectrum will be seen two bright lines at 6928Å and 6942Å close together appearing as one line or doublet. Covering most of the yellow and green portions of the spectrum is a broad band centred at 5500Å. In the blue portion of the spectrum are three dark thin absorption lines at 4765Å and 4750Å (these two very close together) and another at 4685Å. This spectrum pattern of bright red line and two dark thin lines in the blue is distinctive and diagnostic for ruby (synthetic and genuine).

If no spectroscope is available, then a refractometer will suffice to establish corundum with readings at 1·76 to 1·77 and a double refraction of ·009, the pure reading being 1·759 to 1·766. Having established the material as corundum, it is now necessary to prove genuine or synthetic. Perhaps here I should step back a little to point out that in the case of a very small stone or a very rubbed stone, the spectroscope scores heavily over the refractometer. If the stone is rubbed or too small, then it is the soft glass prism of the refractometer which scores.

If a ruby is in a ring, then no tongs will be required since the shank will facilitate handling and rotating. A straightforward examination by simple microscope of not much more than 30 × magnification should be sufficient. If nothing much can be seen the stone should be cleaned in a weak detergent solution to remove grease and collected dust from the back facets. Being an aqueous solution, care should be taken to dry the stone since, it if has to be later immersed in methylene iodide or monobromonapthalene the detergent will cause a general soupiness or immiscibility of liquids. Having now immersed the stone, the examination will now reveal diagnostic features. The main inclusions to be seen in a typical Burma ruby are silk, crystals, treacle and feathers. Silk is an effect created by criss-crossing at 120° of fine rutile needles, generally finer and shorter in Burma than in Siam stones. When stones are cut " en cabochon " this causes a three ray (six legs) star effect, thus making a star-ruby. (This effect is also seen in sapphires for the same reason.) Crystals are generally rounded and/or angular inclusions of other materials, or same materials. Very often zircons are included as crystals and these stand out in high relief against a background of ruby. These crystalline inclusions are transparent or opaque. When transparent they have a much more open centre to them than do the included gas bubbles of synthetic stones. The gas bubbles of synthetics are highly refractive and have a jet black polished look with only a pin point of light transparency in their centres. " Treacle " is the effect of the colouring matter of ruby, i.e. chromic oxide occurring in denser proportions in certain parts of the stone. This has an effect similar to that of a thick sugar solution of syrup or treacly consistency being poured into water of lesser density. It is visible by its viscosity and higher refractive index as a pouring effect. In rubies it is a fine rich carmine on a red background. This can give an appearance similar to swirl striae seen in some pastes. I can remember an occasion when a dealer friend brought a ruby for testing which he thought was a gemmological curiosity, being a ruby with swirl striae and silk. It was his first introduction to treacle. I think that treacle as a rule is seen in Burma stones and not in Siam stones.

Feathers are a structure in themselves, less typical for Burma than Siam stones. The feathers so typical of Siam are delightful in their structures and appearance and are virtually a form of hallmarking. Sometimes in the Laboratory on a carbon copy, not the customer's portion, among the hieroglyphics will be seen succinct statements such as " Siam feather hallmark ", which gives a vital shorthand description of a feature seen in a microscope test.

Feathers generally are a form of network or lacework two-phase liquid droplets forming something like a veil in a stone and are a beautiful feature when studied for themselves alone. They are not solely to be relied upon as a diagnostic feature since synthetics have been known to exhibit a series of queer shaped gaseous bubbles joined together in something like an aspect of frogs spawn, which does have a natural look about it.

Some feathers in Siam rubies are rounded, halo-like, tight-knit feathers with rounded opaque hexagons in their centres. Care must be taken in looking at these dark Siam stones since the rounded opaque hexagons tend to look like gas bubbles in synthetics.

From the description of some of the internal structures in rubies it sounds very much as if some features are easily mistaken for synthetic inclusions or paste inclusions. Theoretically yes, but practice will soon dispel any doubts. If one keeps a typical synthetic ruby as a comparison stone, its included bubbles—whether rounded or profilated—have such a typical gaseous look to them that they will present no real difficulty in detection.

Fortunately it is always easy to procure a good cheap Siam ruby, full of inclusions. Some of them are delightful studies of criss crossing of twin planes and lath-like inclusions, together with their " poached egg ", feather and crystal formations. Burma rubies, of course, are dearer but a poor one or a pink one, which has too many obvious signs in it to be of commercial value, is ideal for observation and comparison.

Having in general become " au fait " with inclusion spotting, one's eye also becomes attuned to colour and, very shortly, one can say without much hesitancy where a stone comes from by just looking at it by eye alone. Having reached this rather useful and happy stage, one is cut down to size by the advent of a clean, fine looking red corundum which one's instinct and knowledge insist upon being synthetic by its very outward appearance. Since practical proof has to be forthcoming and not sheer instinct, one must refer to routine testing. After routine check by microscope and no signs seen, it is then necessary to immerse the stone either in monobromonaphthalene or methylene iodide. The former is the cheaper liquid; the latter, closer to the refractive index of ruby, is preferable. These liquids, if left on a microscope stage to become slightly over luke-warm, will irritate the sensitive membranes of the nostril, causing a slightly allergic person very considerable suffering from all the characteristics of hay fever! Keeping the eye glued to the eyepiece of the microscope places one's nostrils in an ideal position to inhale the vapours of the warm oil in the dish below. The mere fact of a stone necessitating prolonged study inevitably means lengthy immersion and heating of oil.

If possible, a glass dish with a concave floor to it is ideal since this automatically centres the stone. There is nothing quite so frustrating as chasing with a pair of tongs an elusive small red stone around the perimeter of a dish under the magnifying effect of the microscope.

If no obvious signs are immediately apparent it is possible that glare is obviating accurate inspection. Lowering of the condenser will help enormously. If gas bubbles are not seen and the stone is obviously (suspect) synthetic, then curved structure lines must be searched for. These can also be somewhat fugitive and palely loitering. Here again a lowered condenser will help. After having rotated the stone slowly through 360°, the closing down of the iris diaphragm will help towards a " dark ground " effect as well as the tilting of the mirror to give a glancing effect of light through the structure lines. The combined effect of mirror-tilting and lowered and closed condenser will often suddenly reveal line structure in a fleeting glimpse, and one can track back until one achieves the ideal position for optimum effect. This effect of racking up and down slowly of the coarse adjustment by the left hand whilst the stone is turned slowly in the tongs by the right, or alternatively tilting the mirror backwards and forwards with the left hand as one again rotates the stone, gives many added variations of focus and field. One often sees banding either hexagonal in pattern or curved in structure under these conditions. It is necessary to guard against racking down too far into and through the stone so that bubbles or swirl striae can be seen through the ruby which may be in fact in the glass of the cell. Increased magnification will seldom be more revealing since the faintest curvature of a fine line seen in small sections of length will, by increased magnification, appear straight. When one has been peering for too long in liquid at one colour one's eyes become fatigued and it is a good thing to leave the stone and liquid to cool. If a small pin-point bubble is found, then it is permissible to leave the stone and bubble in focus and use a higher power objective in order to bear more intimately upon the suspect bubble. I can remember once finding small localized groups of dust-size bubbles which had the outward appearance of minute bubbles but they looked like dust and X-ray transparency tests later proved the stone genuine. Since then I have seen similar dust-like bubbles in a stone which, because of their similarity to the case just mentioned, helped me to diagnose a genuine clean ruby (with other tests, of course).

Considerable searches by microscope are usually conducted only for bubble and/or curved structure formation. Feathers, silk, crystals, twin planes, and similar features are always seen much more readily and easily with lower powers. When no amount of diaphragm manipulation, condenser-lowering or mirror-tilting will reveal possible fugitive bubbles or curved striae, then one must adopt other techniques. Such techniques are immersion, contact photography, X-ray transparency and X-ray fluorescence and phosphorescence. To a laboratory worker, after a short period of microscopy with nil result, the next move is to subject the stone to X-rays. The ruby will *fluoresce* with a red glow under X-ray excitation when observed in the dark through the protective lead glass observation screen. If it is a synthetic it will continue to glow (phosphorescence) after the X-rays are switched off. This effect is quickly and easily seen under ideal conditions, but caution is to be observed in not jumping to conclusions. I can remember a five carat ruby a few years ago which was clean to a frustrating degree and looked superbly synthetic, but the dealer who owned it did occasionally have very fine rubies. Placing this particular stone over the aperture of the X-ray window I saw it glow red under excitation (fluorescence) and as I switched off, so did the stone (no phosphoresence). This I repeated several times and felt that the stone must be natural. However, thanks to sounder experience, a suggestion to keep on looking for a few seconds after switching off showed a latent build up of phosphorescence after cut-off. This phosphorescence of synthetic ruby is a very, very strong diagnostic feature. Although

X-ray apparatus is not easily available to the average gemmologist, a short-wave ultra-violet light is. Short-wave ultra-violet light under dark room conditions will show synthetic rubies to glow brighter than genuine stones when a parcel of mixed rubies is examined. (This is not an X-ray set up but a short-wave lamp.) One stone on its own cannot be tested, whether genuine or synthetic ruby, under short-wave ultra-violet light, because some fine Burma stones glow beautifully and some chrome-rich stones do not, and Siam stones are not so active. The use of the mineralight has to be considered as an additional test and is *not* safely diagnostic on its own. (Neither is it for sapphires; most synthetic blues glow greenish, but so do some natural Ceylon stones.)

Immersion contact photography, a very pretty test in every sense of the word, developed by B. W. Anderson from tests and techniques appertaining to the measurement of refractive indices, can show the contrast of various refractive indices of stones in liquids of known refractive index *and* also show structure within the stone. A contact photo of a stone often reveals its refractive index and its curved structure which is not always visible under the microscope. Thus, sometimes very fine evanescent curved structure lines are revealed.

Another simple test which can be very revealing is to immerse the stone in methylene iodide. Place a sheet of matt white paper on a desk, tilt a desk lamp onto the paper at 45° and observe the stone, holding the cell in the left hand over the paper whilst a low power lens is held in the right hand. Sometimes this much lower power will help, particularly against a matt background. There probably are other refined techniques, but what I find impressive is the fact that with ruby, not only are the refractive index and the absorption spectra the same for natural and synthetic, but if one did a chemical analysis the results would be so close as to allow no clear-cut diagnosis to be obtained.

Rarity, durability and beauty—these three, but the greatest of these is beauty. Beauty is in the eye of the beholder, and beauty in a stone is an outward expression of internal structure and inclusions. Ruby combines the best of the requirements of gemstones and necessitates for certain identification refractive index, absorption spectrum and internal inclusions, and the greatest of these is inclusions. One may safely say that, in conclusion, it is inclusions that reveal the truth to the exclusion of all others.

FINE ZONING IN AUSTRALIAN SAPPHIRE

By E. H. RUTLAND

A parcel of some 30 blue Australian sapphires was recently sent to me by Mr. John Fleming, of New Zealand. They had attracted his attention by the extremely close spacing of their growth zones. The resulting fine striations were of the same order of size as those found in synthetic corundum and strongly resembled these except that they showed no sign of curvature. However, the stones were only from ½ to 1 carat in size and in small stones cut from a large boule the curvature is occasionally not marked, particularly at strong magnifications. A typical picture of the zoning found in the Australian stones is shown in Figure 1.

Further search produced some convincingly hexagonal zoning (Figure 2) and healing fractures. No other features of special interest were found. The density was a little greater than that of the 3·995 sapphire kept as a check in the Clerici solution in which the stones were tested. The refractive indices lay between 1·765 and 1·780 (Rayner refractometer in sodium light). Dichroism was marked, in green and purple shades of the blue body colour. No signs of strain appeared between crossed nicols, nor any signs of twinning (which I had rather hoped for). The stones were a rich blue, a little on the dark side.

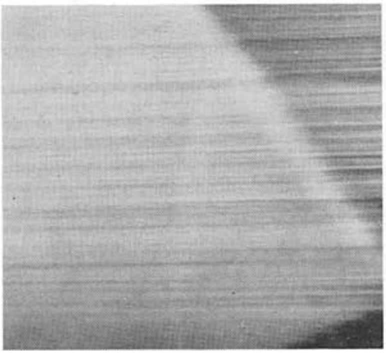


FIG. 1. *Straight zoning in a blue Australian sapphire.*

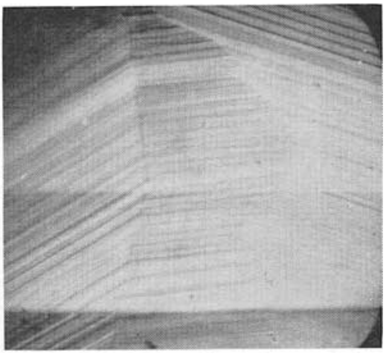


FIG. 2. *Hexagonal zoning in another sapphire from the same source.*

SOME NOTES ON THE MINERALOGY OF LAPIS-LAZULI

By J. OSTWALD

INTRODUCTION

Some time ago the author had the opportunity to examine in detail a collection of mineral specimens from the Sludyanka river area, at the west end of Lake Baikal, in Siberia.

For some hundreds of years this area has been one of the few sources of the rare and beautiful rock called lapis-lazuli. Little has been written on the area in English scientific journals, but Bauer, in his great work on gemstones, states that the rock is found in the beds of three streams—the Talaya, Malaya Bistraya and the Sludyanka—at the west end of the lake. The deposits are stated to be in white granular limestone near the contact with granite. The material is in many cases inferior to the Badakshan lapis-lazuli and contains less pyrite. The colour is said to be most variable, ranging from dark blue, violet to green and pink. The mines on the Sludyanka are situated eight miles from the town of Kultuk. The rock is found near the contact of white marble and granite and gneiss and pebbles of lapis-lazuli are also found in the bed of the stream. Fig. 1 is a geological map of the area.

As well as making a study of the Siberian minerals the author studied thin sections and carried out microchemical tests on similar material from Afghanistan and Chile. The purpose of this study was to determine the mineralogical nature of the rock, as the text books seem to have different views on just what is the composition of lapis-lazuli.

MINERALOGY

(*a*) *Lazurite:* $Na_4(NaS_3 \cdot Al)\,Al_2Si_3O_{12}$

Isometric. In cubes and rhomb-dodecahedra. Usually massive and compact. Cleavage: dodecahedral, imperfect. Fracture uneven. $H = 5\text{-}5{\cdot}5$. $G = 2{\cdot}38\text{-}2{\cdot}45$. Lustre vitreous. Colour rich Berlin-blue or azure-blue, violet, greenish blue. Translucent.

Analysis: Brögger and Bäckstrom, Zs. Kr., 16,236, 1890.

	SiO_2	Al_2O_3	CaO	Na_2O	K_2O
Central Asia:	32·52	27·61	6·47	19·45	0·28
	SO_3	S	Cl		
	10·46	2·71	0·47	= 99·57%	

Note 1. Before 1869 lapis-lazuli was thought to be a simple mineral. In an old copy of Dana's "Manual of Mineralogy", the 1852 edition, p. 196, under "Combinations of a Silicate and a Sulphate", lapis-lazuli is described as a monoclinic azure-blue mineral of composition: silica 45·5, alumina 31·8, soda 9·1, lime 3·5, iron 0·8, sulphuric acid 5·9, sulphur 0·9, chlorine 0·4, and water 0·1.

In the "Glossary of Mineralogy" by Bristow, 1861, the same material is described as a simple mineral, but of cubic symmetry. In 1869 Fischer discovered that it was heterogeneous and Vogelsang in 1873 proved it to consist of an isometric ultramarine blue mineral mixed in various proportions with crystalline calcite and scapolite. This blue mineral was named lasurit by Brögger in 1890, who in the same year, with Bäckstrom, had arrived at the analysis given above.

Note 2. The mineral was known to the ancient world under the name of sapphire. In the most ancient text on mineralogy, the *Περὶ λίθων* of Theophrastus the mineral is named *Σάπεφίρος*. Pliny, in his "Historia Naturalis" translated this as "*sapphiros*" by which name it was known in scientific circles until the sixteenth century, for Agricola in his "De Natura Fossilium" of 1546 calls it *Sapphirus*, though he may have used the word to describe two different minerals. Some of his descriptions of sapphirus are certainly not of our lapis-lazuli, but could easily be our sapphire, blue corundum.

The present day name originated in the Middle Ages, being an Anglicized version of an Arab word "al lazward", meaning "the blue sky". It appears in the "Gemmarum et Lapidum Historia" of de Boodt in 1609.

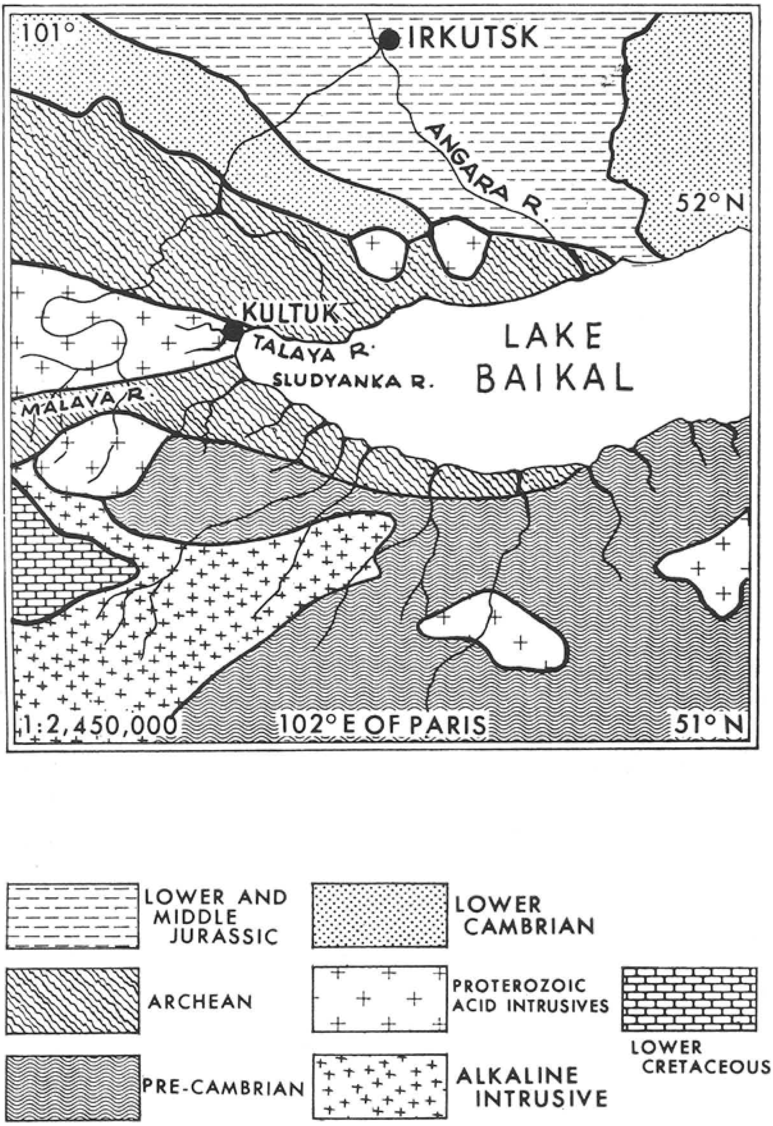

101°
IRKUTSK
ANGARA R.
52° N
KULTUK
TALAYA R.
SLUDYANKA R.
LAKE BAIKAL
MALAYA R.
1:2,450,000
102° E OF PARIS
51° N
LOWER AND MIDDLE JURASSIC
LOWER CAMBRIAN
ARCHEAN
PROTEROZOIC ACID INTRUSIVES
LOWER CRETACEOUS
PRE-CAMBRIAN
ALKALINE INTRUSIVE

Fig. 1.

Note 3. It is interesting to note that Brögger suggested that lazurite, sodalite, hauyne and noselite, along with the helvite group could be included in the garnet family. His reasons were:

(1) All are usually isometric;

the feldspathoids have chemical formulae which are closely similar to $\overset{II}{R}_3 \overset{III}{R}_2 (SiO_4)_3$ the garnet formula. Helvite, with formula $(Mn,Fe)(Mn_2S)Be_3(SiO_4)_3$ may also be considered a garnet if the bivalent group—S-Mn-S—take the place of a bivalent element R and 3Be correspond to 2Al.

Another point of geochemical interest is the apparent lack of garnets from feldspathoid deposits. Lime garnets are perhaps the most typical minerals from "skarns" (metasomatic limestones). Could it not be that the feldspathoids are the equivalent minerals in the metasomatism of other limestones?

(*b*) *Sodalite:* $Na_8Al_6Si_6O_{24}Cl_2$

Isometric. Rhombdodecahedron form common, often twinned. Generally massive, or in concentric nodules. Cleavage: dodecahedral, distinct. Fracture conchoidal to uneven. Brittle H = 5·5-6. G = 2·14-2·3. Lustre vitreous, sometimes greasy. Colour gray, greenish, yellow, white, sometimes blue or pinkish. Transparent to translucent. R.I. = 1·4827 (Na).

Analysis: Brögger and Bäckstrom, Zs. Kr., 18, 223, 1890.

	SiO_2	Al_2O_3	CaO	Na_2O	Cl
Lake Baikal (blue)	36·74	31·96	0·11	25·95	7·11
	K_2O	SO_3	IGN		
	trace	0·11	0·17	= 102·15%	

Note 1. Sodalite and lazurite are closely related minerals. In the latter, sulphide ions replace the chloride ions of typical sodalite. While the two minerals are so closely related chemically sodalite has a much wider distribution. It is a rare mineral in the volcanic and plutonic rocks of the nepheline-syenite family. The main differences are listed in the following table.

	SODALITE	LAZURITE
Fracture ...	Sometimes conchoidal	Uneven
Hardness ...	Greater than 5·5	Less than 5·5
Colour ...	Dark blue	Ultramarine blue
R.I. ...	Up to 1·487 Na	Around 1·50
S.G.... ...	2·14–2·40	2·38–2·45

The presence of free sulphide (iron pyrite) in the lazurite is often a help in identification.

(*c*) *Hauyne:* $Na_4(Na_2, Ca)\ Al_6\ Si_6\ O_{24}(SO_4)_2$

Isometric. Octohedra, rhombdodecahedra, often in rounded forms. Commonly twinned. Cleavage: dodecahedral, good. Fracture, flat conchoidal, uneven. H = 5·5–6. G = 2·4–2·5. Lustre vitreous or greasy. Colour shades of blue common, sometimes pinkish, yellowish, green. Translucent. R.I. = 1·49–1·51 Na.

Analysis: Brögger and Bäckstrom, Zs. Kr., 18, 230, 1890.

	SiO_2	Al_2O_3	CaO	Na_2O
Locality unknown	32·0	27·38	8·21	18·03
	K_2O	SO_3	Cl	
	0·35	12·62	0·31	
	MgO	S		
	0·11	0·44 = 99·75%		

Note 1. The following microchemical test may be carried out under the microscope to separate the three feldspathoids so far studied. A few scrapings are placed on a glass slide covered in nitric acid. A hot blast of air will accelerate evaporation. After a while small cubes of sodium chloride may form indicating sodalite, or monoclinic prisms of gypsum, indicating hauyne. If the gas hydrogen sulphide is evolved, recognized by its characteristic smell, then the mineral is lazurite.

Note 2. The standard English text-book on gemstones states that the blue component of lapis-lazuli is a variety of hauyne, and advocates that the term lazurite be dropped. However, the author has subjected a number of pieces of Siberian gem lapis-lazuli to the test in Note 1 and has only once detected hauyne in the material. Thin section studies of other rough material (from dealers in the stone) have likewise been tested and it was noted that the blue colour of the mineral was remarkably evenly developed in the crystals, not patchily as in most hauyne crystals from syenites. Bauer, however, states that in lapis-lazuli hauyne is always present in the largest amount.

(*d*) *Diopside*: Ca Mg $(SiO_3)_2$
Monoclinic. In prismatic crystals, often slender; also granular and massive. G = 3·2–3·38. Colour white yellowish to shades of green. Transparent to translucent.

Note 1. The pyroxene usually recorded from lapis-lazuli deposits is iron-free diopside. Van Hise gives an equation showing the possible alteration of dolomite to diopside

$$MgCaC_2O_6 + 2SiO_2 \rightarrow MgCaSi_2O_6 + 2CO_2$$

The specimen studied from the Lake Baikal deposit is a dark olivine green colour and most probably the variety of hedenbergite called baikalite. Its S.G. is approx. 3·5.

(*e*) *Tremolite:* $CaMg_3Si_4O_{12}$
Monoclinic. In prismatic crystals and fibrous. Commonly in compact bladed aggregates. G = 2·9–3·1. Sometimes transparent and colourless. Usually translucent to opaque, white to dark gray.

Note 1. An aluminous variety, Koksharovite, named after the Russian mineralogist, N. von Koksharov is found in the Lake Baikal district. Its analysis is given below.

	SiO_2	Al_2O_3	FeO	MgO	Na_2O
Lake Baikal:	45·99	18·20	2·40	16·45	12·78
	Na_2O	K_2O	IGN		
	1·53	1·06	0·60 = 99·01%		

(*f*) *Calcite:* $CaCO_3$

Hexagonal, rhombdodecahedral. Crystals variable, tabular or prismatic, often with sharp termination. Twins common, also massive, stalactitic, earthy. Cleavage rhombdodecahedral perfect. H = 3. G = 2·714. Lustre vitreous. Colour white or colourless and other pale colours. Streak white. Transparent to opaque.

Note 1. The calcite from the Lake Baikal area is often of a sky-blue colour. The author tested the stability of this colour by heating crystals in a laboratory oven at 300° for a few hours and the blue colour disappeared entirely. No thermo-luminescence was observed during heating but on being stood in direct sunlight for a few hours the blue colour returned, but now much paler. It seems likely that the colour arises from colour centres.

(*g*) *Pyrite:* FeS_2
Isometric, pyritohedral. Cube and pyritohedron or striated cubes. Twins common, also massive, granular, radiating, etc. Cleavage indistinct. Fracture conchoidal to rough. H = 6–6·5. G = 4·95–5·10. Lustre metallic. Colour a pale brass yellow. Streak greenish-black.

Note 1. Both in the Bible (book of Job) and in Pliny the small crystals of pyrite in lapis-lazuli were called gold, an idea which still exists among some of the general public to the present day.

(*h*) *Humite:* $H_2(Mg,Fe)_{19}Si_8O_{34}F_4$
Orthorhombic. Crystals and penetration, twins common. Cleavage distinct. Fracture subconchoidal to uneven. H = 6–6·5. G = 3.1–3·2. Lustre vitreous to resinous. Colour white, yellowish, brown.

Note 1. Humite is found in limestones ejected from Vesuvius and Monte Somma. It is also recorded in Dana's "System" from the Ladu mine near Filipstad, Sweden, from Andalusia and Brewster, N.Y. M. J. Barthoux in 1933 recorded humite from the Badakshan limestones, along with lazurite, phlogopite, forsterite and pyrite.

(*i*) *Forsterite:* Mg_2SiO_4
Orthorhombic. Prisms, pinacoids, pyramids common, also granular and massive. One distinct cleavage. Fracture uneven. H = 6–7. G = 3·21–3·33. Lustre vitreous. Colourless, yellowish, also greenish. Analysis: Rath, Pogg., Ann., 109, 568, 1860.

	SiO_2	MgO	FeO	
Mt. Somma:	42·41	53·30	2·33	= 98·04%

(*j*) *Phlogopite:* $\dot{R}_3Mg_3Al(SiO_4)_3$ where $\dot{R}$ = H, K, MgF
Monoclinic. Six sided pseudo-hexagonal prisms common. Cleav-

age: perfect basal. Thin laminae tough and elastic. H = 2·5–3·0. G = 2·78–2·85. Lustre pearly. Yellowish brown, often with a coppery reflection. Also colourless, greenish, brownish.

Note 1. Phlogopite is similar to common biotite but it contains little iron. It is usually recognized by its association with serpentine and crystalline limestone and dolomite. Large deposits of the mineral occur in the Sludyanka area according to Nalivkin, in association with pegmatites of upper Proterozoic age.

(*k*) *Scapolite:* An isomorphous series of variable composition between marialite $Na_4Al_3Si_9O_{24}Cl$ and meionite $Ca_4Al_6Si_6O_{25}$ as end members. Tschermak includes common scapolite and missonite (including dipyre) as intermediates. Tetragonal, commonly in prisms terminated by pyramids, also massive and granular. Cleavage good in two directions. H = 5–6. G = 2·66–2·73. Lustre vitreous to pearly. Colour white, blue, greenish, pink, purple. Usually transparent.

Note 1. The variety of common scapolite from the Sludyanka river is termed glaucolith and is massive and of a light bluish colour. Its composition is (Rath, Pogg., Ann., 90, 101, 1853.)

	SiO_2	Al_2O_3	FeO	CaO	
Lake Baikal:	47·49	27·57	1·54	17·16	
	MgO	Na_2O	K_2O	H_2O	
	0·47	4·71	0·58	0·48	= 100%

G (measured by the author) = 2·72

(*l*) *Epidote:* $HCa_2(Al,Fe)_3Si_3O_{13}$
Monoclinic. Crystals elongate prisms, striated along length. Perfect basal cleavage. H = 6–7. G = 3·37–3°50. Colour pistachio green to black.

Note 1. This mineral was detected by the author in small crystals just inside the granite - lapis-lazuli contact. Determination was based on:

(*a*) colour and pleochroism
(*b*) high birefringence measured by a Berek compensator of 0·036
(*c*) large 2V, OPT.(—)

(*d*) strong inclined dispersion
(*e*) parallel extinction in elongate sections.
Epidote is a fairly common contact mineral, but the author has not come across any reference to it in lapis-lazuli deposits.

(*m*) As well as the minerals previously listed lapis-lazuli often contains smaller amounts of feldspar, apatite, sphene and zircon. These are rarely seen in material from the gem-dealer and their presence is of interest to the mineralogist mainly because they may give some clue in the perplexing problem of the origin of lapis-lazuli.

THE MINERAL COMPOSITION OF THE DEPOSITS

Lapis-Lazuli is found in the following areas:

1. Badakshan:—Lazurite, hauyne, sodalite, pyrite, calcite, scapolite, forsterite, humite, diopside.
2. Lake Baikal:—Lazurite, sodalite, phlogopite, pyrite, epidote, calcite, tremolite, diopside.
3. Chile, the Andes of Ovalle:—Lazurite, calcite.
4. Monte Somma, Italy:—Sodalite, hauyne, lazurite (rare), calcite.
5. Latium:—Lazurite (exact composition not listed).
6. Dattaw Valley, Upper Burma:—Lapis-lazuli is recorded from the ruby-earths of Burma by Bauer, but Wadia, in his "Geology of India", does not record it, and this occurrence is not listed by Dana and Ford, Berry and Mason or Miers.

   A detailed review of the Mineral production of India for the years 1898–1903 by T. H. Holland, F.R.S., Director of the Geological Survey of India does not mention the mineral. However, J. Coggin-Brown notes the presence of a lazurite-diopside-epidote rock in the Myaungok district associated with augite gneiss, enstatite gneiss, granulites and pyroxenites. This is perhaps the material noted by Bauer.
7. Gunnison County, Colorado:—Mineralogical composition not known, but good lapis-lazuli is mined near the top of the North Italian mountain in this area.
8. San Bernardino County, California:—Lazurite (in patches and grains in a mica-diopside schist. A. F. Rogers considered it to be a sulphide-bearing hauyne).

Lapis-lazuli has also been recorded (rather doubtfully) from China, Tibet and the Ditro area of Transylvania.

FLUORESCENCE PHENOMENA

The Lake Baikal rocks exhibit in some instances striking fluorescence colours under longwave ultraviolet light (3650Å). The crystalline limestone near the contact with the lazurite rock glows like coals of fire—no better or nearer description can be given—when illuminated by ultra-violet light in a darkened room. Isolated patches of the fenite also glow with a pale blue colour and some of the metamorphic actinolite rocks are seen to be shot through with minute crystals fluorescing bright blue.

Owing to the fact that the fire—like fluorescence in the calcite—occurred mainly in a definite thin line along the contact, the writer at first imagined the presence of a thin band of previously undetected mineral, perhaps scapolite. A more detailed optical examination with the aid of a Berek compensator revealed no notable difference in birefringence between the fluorescing and non-fluorescing areas in the limestone and it was therefore presumed that the fluorescence was caused by some lattice disturbance or perhaps the manganese content of the calcite.

The pale blue fluorescing areas of the fenite proved to be small patches of a highly decomposed mineral. A similar fluorescence seen on weathered faces of rock from the area could be attributed to the same unknown mineral.

The small bright blue fluorescing needles proved an easier mineral to identify. Under high power oil immersion they showed the fairly high relief, second order colours and extinction angle of 16° to 18°, of tremolite.

ORIGIN

Lapis-lazuli must be looked upon as a rather unusual product of the contact metasomatism of dolomitic limestone. According to W. Lindgren (1933) metasomatism is defined as "the process of practically simultaneous capillary solution and deposition by which a new mineral of partly or wholly differing chemical composition may grow in the body of an old mineral or mineral aggregate". The term differs from metamorphism in that chemical material is migrating forward and back across the contact zone between the

FIG. 2. *Normal blue Siberian lapis-lazuli. The fine grained lazurite is set in course grained calcite and a few opaque cubes of pyrite are also visible. Diameter of field approx. 1.8 m.m.*

FIG. 3. *Contact of "granite" and lapis-lazuli. The lapis-lazuli is similar to that in Fig. 2. But the calcite is finer and tends to show "fan structure" at the edge. The "granite" consists of colourless and dotted alkali feldspars, dark aegirine, calcite crystals showing diamond-shaped cleavages and small crystals of sphene with very dark borders. Diameter of field 1.8 m.m.*

igneous rock and the country rock while the latter is subjected to greatly increased heat and pressure. We must think of chemical alteration of the intruding rock as well as the intruded.

A small distance off the contact zone crystals of calcite are easily visible (in thin section) inside the igneous rock. These may be crystals of the limestone not yet absorbed by the invading "granite" or they may be crystallizations of calcite injected in a magmatic state into the "granite". Actually the "granite" is a syenitic rock composed of alkali feldspars and aegirine. In fact it may itself represent a particular type of alkali metasomatism in which ordinary granite is altered to a syenitic rock by a process Brögger terms "fenitization". This writer, in his great memoir on the igneous rocks of southern Norway noted the association of "fenite" with pure carbonate rock (carbonatite). Numerous thin sections of the granite from the Lake Baikal area showed the presence of fenite containing crystalline calcite. (Fig. 3).

At the present time two slightly different hypotheses are mentioned in the literature to explain the feldspathoidal zone between granite and limestone. *These are summarized below:—*

(*a*) *Daly-Shand hypothesis:* This is the classical idea dating from 1910. In this year Daly postulated that a granite magma could be desilicated (desaturated in silica) by assimilation of carbon dioxide (from carbonate rocks), water (from sediments) and lime and/or magnesia (from dolomites). This syntectic magma then crystallizes and differentiates to give the feldspathoidal class of rock—the nepheline syenite family.

(*b*) *Adams-Barlow hypothesis:* Shortly after the publication of the original paper by Daly in 1910 Adams and Barlow published an account of their studies of the nepheline-bearing syenites of the Haliburton-Bancroft area in south east Ontario. Here high-grade rock of the Grenville Series (dolomitic marbles, amphibolites and paragneisses) have been intruded by pre-Cambrian granites. Granitization is widespread and the syenites are situated in the granitized belt. The authors considered that the syenite, far from being a simple contamination product of the granite magma, is a massive replacement body. It is often strongly banded and this they regard as a "ghost" structure of the foliation and banding of impurities in the original limestone. They therefore postulate a definite nepheline syenite magma resulting from the processes of metasomatism and granitization.

At the present time both hypothesis are repeatedly mentioned in the literature. Associated with the production of the nepheline syenite type of rock is the problem of the origin of "carbonatites" and "fenites". Carbonatites are carbonate rocks, mainly calcitic, which appear to be injected into their present position in at least a "plastic" condition, or more probably as an actual magma. They were first described by A. G. Hogböm from the Alnö island off Sweden in 1895, which area remains a classic location for their study.

For many years most petrologists opposed the idea of a carbonate magma on the grounds of the high melting range of anhydrous carbonates. This led Pecora in 1956 to state that the carbonatites had their source in highly concentrated hydrothermal solutions rather than pure magmas. Only as recently as 1958 was this difficulty resolved. Then Patterson reported the rapid complete melting of calcite at 1000°C and insipient melting at 900°C at a combined carbon dioxide and water pressure of only 50 bars. Thus the magma state seems a possibility.

Near the contact the author often noted a peculiar flow structure in the calcite and lazurite (lapis-lazuli) rock. The whole pattern on a much finer scale is reminiscent of the "flow" or "trachytic structure" so often seen in trachytes and other lavas in thin section. It thus seems as if this rock may have been in a "plastic" or sluggish magmatic state during its formation.

Fenitization of the granitic rocks is a common alteration associated with the production of carbonatite magmas. Fenite—an orthoclase, albite, aegirine, apatite rock—often contains calcite in well crystallized grains.

Another factor possibly of prime importance in the development of feldspathoidal zones is the association with rift valleys. According to Tilly the close relation between the alkali rocks of the carbonatite centres of Africa, from the Transvaal in the south to Uganda in the north, within and along the Great Rift Valley seems to suggest that the operating mechanism lies deep in the crust. The author noted in his studies of the Lake Baikal material the association of alkaline rocks (nepheline syenite and granite-porphyry probably related to those of the Aldan alkaline complex) with granites and limestones of Cretaceous age in the Lake Baikal rift valley. Possibly the same mechanism is operating here?

Even supposing a primitive nepheline mineralization of rocks, both granitic and calcic, in the contact zone, the process by which nepheline is subsequently converted into the other rarer feldspathoids is not clear. Clarke, in his "Data of Geochemistry" classes sodalite, hauyne, lazurite and nosean as derivatives of nepheline. To explain their rather rare development we must consider at least two types of metasomatism.

(*a*) *Sulphur metasomatism:* The lapis-lazuli rocks and the contact "skarns" in other areas are usually full of small crystals of pyrite, and in most cases this mineral has been attributed to the reaction between iron-bearing silicates (such as biotite, etc.) in the country rock and magmatic hydrogen sulphide. It seems possible that the same magmatic gas assists in the alteration of the primitive nepheline minerals to the sulphate-bearing hauyne and nosean.

(*b*) *Chlorine metasomatism:* The appearance of scapolite in a carbonate rock during metasomatism is usually caused by introduction of chlorine from magmatic gases. It is perhaps this process along with the introduction of sulphur which results in the development of lazurite.

So we can see that a number of conditions must be fulfilled before a lapis-lazuli assemblage of minerals can develop in a granite-limestone contact zone. These are listed below:

(1) Development of a feldspathoidal zone between dolomitic limestone and desilicated igneous rock. In the Lake Baikal area this zone is probably the result of metasomatism and migmatization (at least partial fusion of the country rock to give localized magmas of carbonatite and nepheline syenite type). A zone of mobility develops in which the lazurite later develops.

(2) Introduction of sulphur and chlorine from an adjacent igneous rock. These are usually believed to have been introduced during a pneumatolytic stage. It is also possible that sulphides of iron are introduced at a later stage in liquid solution.

Synthesis

It is difficult to say if the essential component of lapis-lazuli, i.e. lazurite, has ever been produced in the laboratory. Artificial "ultramarines" of variable composition have been in production since 1828 and as they are very variable in composition and never stoicheiometric, and have the same X-ray powder pattern irrespective of colour, it is quite possible that natural lazurite (not the more complicated mixture, natural lapis-lazuli) has been synthesized.

This lazurite (ultramarine) is produced in the solid state by allowing a mixture of oxides to react in a crucible under the action of heat. Complete reaction is slow, as it depends on the rate of diffusion of the elements. The result is a deep blue mass of often ultramicroscopic crystals.

Colour of lapis-lazuli

The colour of lazurite is an intense blue. It is not therefore surprising that many attempts have been made to determine the cause of this colour. And to anyone versed in modern solid state physics it is not in the least surprising that the beautiful blue mineral still retains its secret.

Before attempting to explain the blue colour of natural lazurite it is well to keep in mind three sets of facts.

(1) The light blue lazurite from Afghanistan is often converted into the normal dark blue material by the action of heat.

(2) In the following table the "ideal" compositions of various coloured artificial "ultramarines", produced by different chemical processes, are compared with the blue component of lapis-lazuli.

Sulphate Process	*Sulphate Soda Process*	*Soda Process*	*Natural*
White $Na_{10}Al_6Si_6O_{24}S_2$	White $Na_{12}Al_6Si_6O_{24}S_3$	White $Na_{14}Al_6Si_6O_{24}S_4$	
Green $Na_8Al_6Si_6O_{24}S_2$	Green $Na_9Al_6Si_6O_{24}S_3$	Green $Na_{10}Al_6Si_6O_{24}S_4$	
Blue $Na_6Al_6Si_6O_{24}S_2$	Blue $Na_7Al_6Si_6O_{24}S_3$	Blue $Na_8Al_6Si_6O_{24}S_4$	Blue $Na_{10}Al_6Si_6O_{24}S_6$

A glance at these formulae will show that there are two variable components, the alkali and the sulphur, and it is only reasonable to assume that colour changes are associated with changes in proportion of these.

(3) According to Jaeger, all ultramarines, regardless of colour, all lazurite, nosean and hauyne have the same powder diffraction patterns. Sodalite, on the other hand, gave an entirely different pattern.

Mineral colour is usually the result of the removal of certain wavelengths from white light by the mineral's structure. The eye reacts to the transmitted or reflected wavelengths as to a simple colour. Just what is the cause of the absorption is difficult to say. Both sodalite and lazurite have strong blue colour, a troublesome fact for the beginner in mineralogy, though the two colours are definitely different.

The lapis-lazuli minerals are usually classed as idiochromatic, i.e. the coloration is structural rather than produced by the presence of traces of impurities. Even in idiochromatic minerals there is variation in colour and this in most cases is yet unexplained.

There seem to be at least two theories which have been put forward to explain the blue colour:

(*a*) Theory of Hofmann and Ostwald. This classical theory relates the colour to the presence of colloidal sulphur in the crystal lattice. Coloured compounds containing colloidal sulphur can be obtained from ferric chloride and sodium thiosulphate, or by the addition of sulphur to fused halite. A number of other artificial compounds can be prepared, all containing sulphur, which give colours ranging from pink to green to blue (the lapis-lazuli colours) and all more or less related to the ultramarines. Ostwald and Auerback attempted to relate the variation in colour to the degree of dispersion of the colloidal sulphur. Later workers, however, including Podschus and Leschewski, basing their ideas on X-ray studies, consider that colloidal sulphur cannot exist in this structure, though the association of the blue colour with polysulphide sulphur is, however, not disputed.

(*b*) Theory of Weyl. According to Weyl the colour of lapis-lazuli is the result of absorption caused by the relatively large and easily polarized sulphur ions in the lattice.

In any crystal the particles which occupy the "points" of the structure are atoms or ions. We may furthermore assume that these particles are small spheres with fairly definite radii, the whole structure being a packing of small spheres touching one another.

These radii can be measured in the laboratory with accuracy and it is found that they depend on the nature of the element, its state of ionization and its mode of linkage with other adjacent atoms. As an example the radius of the sodium atom in the metal is 1·86Å while the radius of the ion in sodium salts is 0·97Å. Thus the radius is not equal to the radius of the outer electron shell.

However, this idea of an ion as a rigid sphere is only true as a first approximation. In structure of low or irregular co-ordination, in particular the AX compounds, where A is any of the cations Na^+, K^+, Rb^+, Mg^{++}, Ca^{++}, Sr^{++}, etc., and X any of the anions H^-, F^-, Cl^-, Br^-, I^-, etc., polarization, or the deformation of an ion in the presence of its neighbours, occurs. For in an electric field both the nucleus and the electron shells shift with respect to one another causing the particle to become a dipole. In fact, if the polarization is extreme a complete electron transfer may occur from anion to cation with the formation of a non-polar bond.

The extent to which we can expect polarization to occur in any special structure depends on the polarizability and polarizing power of the ions as well as the co-ordination. The polarizability depends on size and looseness of binding and for this reason marked polarization is confined to fairly large anions.

The polarizing power of ions is determined mainly by its electric field and this is greatest for small ions of large charge. In the following table, after Grimm 1927, the variation of polarizability and polarizing power among common ions is shown.

↑ As below

O^{2-}	F^-	Ne	Na^+	Mg^{2+}	Al^{3+}
S^{2-}	Cl^-	A	K^+	Ca^{2+}	Sc^{3+}
Se^{2-}	Br^-	Kr	Rb^+	Sr^{2+}	Y^{3+}
Te^{2-}	I^-	X	Cs^+	Ba^{2+}	La^{3+}

Decreasing Polarizability
Increasing Polarizing Power →
Decreasing Radius

Although some degree of polarization is to be expected in most ionic structures this is not likely to effect their physical properties. When extensive polarization occurs, however, changes in solubility, melting points, etc., occur, and characteristic optical properties develop. According to Weyl the large sulphur ions are very easily polarized and the resulting absorption causes the deep blue colour.

Conclusions

Lapis-lazuli—perhaps the earliest mineral product systematically mined by man, if we exclude flint—still presents difficulties to the scientist. Its mineralogical composition is complex and this complexity is increased by lack of agreement among writers as to just what distinguishes one feldspathoidal mineral from the other. This latter fact, one is certain, will be definitely cleared up when the volume (or volumes?) on the silicates of the seventh revised edition of the Dana's "System" is published. The mode of origin is still only known in outline, and the origin of the blue colour, so amazing to the chemists of the early 19th century, can hardly be said to be yet fully understood.

REFERENCES

1. Agricola, G. (1546). *De Natura Fossilium* (translated by M. C. and J. A. Bandy). Geol. Soc. Amer. special paper 63.
2. Barth, T. F. W. (1959). *Theoretical Petrology.* Wiley and Sons.
3. Barthoux, M. J. (1933). *Lapis-Lazuli and Spinel in Afghan Limestones.* Acad. Sci., Paris. C.R. 196 (15).
4. Bauer, M. (1904). *Precious Stones.* Chas. Griffin and Co.
5. Berry, L. G., and Mason, B. (1959). *Mineralogy.* W. H. Freeman and Co.
6. Bowen, N. L. (1924). *The Fen Area in Telemark, Norway.* Am. Jour. Sci. (5) **8**, 1-11.
7. Bristow (1861). *Glossary of Mineralogy.* Longmans, Green and Co.
8. Campbell Smith, W. (1956). *Some Problems of African Carbonatites.* Q.J.G.S. **122**, pp. 189-217.
9. Clarke, F. W. (1924). *The Data of Geochemistry.* U.S.G.S. Bulletin 770.
10. Coggin-Brown, J. (1924). *A Geographical Classification of the Mineral Deposits of Burma.* Records of the Geol. Survey of India, Vol. LVI, Part I.
11. Daly, R. A. (1933). *Igneous Rocks and the Depths of the Earth.* McGraw-Hill.
12. Dana, J. (1852). *Manual of Mineralogy.* London.
    Dana, J. D., and E. S. *System of Mineralogy*, 6th edit. John Wiley and Sons.
13. Dana, E. S., and Ford, W. E. (1922). *Text Book of Mineralogy.* John Wiley and Sons.
14. Emeleus, H. J., and Anderson, J. S. (1949). *Modern Aspects of Inorganic Chemistry.* Routledge and Kegan Paul.
15. Harker, A. (1950). *Metamorphism.* Methuen and Co.
16. Holland, T. H. (1905). *Review of the Mineral Products of India* 1898-1903. Records Geol. Survey of India, Vol. XXXII, Part I.
17. Jaeger, F. M., Westenbrink, H. K. G., Van Melle, F. A. (1927). *The Structure of Artificial Ultramarine,* A relation between this and the minerals, Hauynite, Noselite, Sodalite, Lazurite and Nepheline. Verslag. Akad. Wetensch. Amsterdam (1927) **37**, 29-47, 364-483, 743-762 **38**, 937-947.
18. Miers, H. A. (1902). *Mineralogy.* MacMillan and Co.
19. Morey, G. W., and Ingerson, E. (1937). *The Pneumatolytic and Hydrothermal Alteration and Synthesis of Silicates.* Economic Geol., Vol. **32**, pp. 607-671.
20. Murdoch, J., and Webb, R. W. (1956). *Minerals of California.* Dept. of Nat. Resources—Div. of Mines, Bulletin 173.
21. Nalivkiv, D. V. (1960). *The Geology of the U.S.S.R.—A Short Outline.* Pergamon Press.
22. Ostwald, W. (1926). Kolloid Z., **38**, 336.
23. Rankama, K., and Sahama, T. G. (1950). *Geochemistry.* Univ. of Chicago Press.
24. Surr, G. *Lapis-Lazuli in South California.* World Mining, Vol. 39, pp. 1153-1154.
25. Tilley, C. E. (1957). *Problems of Alkali Rock Genesis.* Q.J.G.S. **113**, pp. 323-359.
26. Turner, F. J., and Verhoogen, J. (1960). *Igneous and Metamorphic Petrology.* McGraw-Hill.
27. Turner, F. J. (1948). *Mineralogical and Structural Evolution of the Metamorphic Rocks.* Geol. Soc. Amer. Memoir 30.
28. Van Hise, F. (1904). *A Treatise on Metamorphism.* U.S.G.S. Monographs XLVII.
29. Wadia, D. N. (1961). *Geology of India.* MacMillan.

Gemmological Abstracts

POUGH (F. H.). *Cultured pearls.* Lapidary Journal, 1963, 16, 11, pp. 1014-1019; 16, 12, pp. 1090-1095; 17, 1, pp. 6.

A competent survey of present day cultured pearl production in Japan. Truly fine cultured pearls are comparatively rare in spite of large production. The 2 to 4 mm. nuclei can be grown on in about a year, with 80 to 85% of the oysters surviving the operation of mother-of-pearl bead insertion. 5 to 10% of the product can be classified as acceptable for necklaces. The 5 to 6 mm. nuclei take at least two years to become 6 to 7 mm. cultured pearls, and the yield for fine quality necklaces is between 3 and 5%. When 10 to 11 mm. cultured pearls are produced from 9 mm. nuclei the oyster mortality is about 80%, and the quality percentage is as low as 1%. An oyster may receive one or two bead nuclei.

The usual thickness of the " cultured " layer on a Japanese cultured pearl is half a millimetre thick. Larger cultured pearls (above 9 mm.) are grown in *Pinctada maxima,* in Pacific waters, and are marketed as " South Sea " pearls. The mother-of-pearl nuclei for Japanese cultured pearls comes from a freshwater clam obtained from river tributaries to the Mississippi River in the U.S.A. The reason for the use of the American mussel shell is that it has a weak lustre. There is concern about future supplies because of river pollution.

S.P.

SINKANKAS (J.). *Chromian sphene.* Lapidary Journal, 1963, 17, 1, pp. 4-5.

An emerald-green variety of sphene has been located in Baja California. Analysis by a commercial laboratory has shown that the mineral contains about 1% chromium, and examination of available mineralogical literature has not revealed any varieties of sphene in which chromium is more than a trace element. It is suggested that this sphene may be an important new variety of the species and may deserve the description *chromian sphene.* The find was made in a region about 30 miles east of San Quintin, on the west coast of Baja California. The size of the crystals so far discovered is small, but a gem of 2·25 carats has been cut, which is almost flawless.

S.P.

Butler (B. C. M.). *An occurrence of nephrite jade in West Pakistan.* Min. Mag., 1963, 33, pp. 385-393.

A description of two pebbles of good quality nephrite found in the river bed of the Teri Toi in the Kohat district of West Pakistan. The find appears to be the first authenticated record of either of the true jade minerals occurring in Pakistan or India and a full description of the pebbles and the locality is given. One pebble was greenish-white and the other a clear spinach green in colour. The former gave a specific gravity figure of 2·954 and the latter 3.021, determined by flotation method.

S.P.

Dalziel (A.). *New find of nephrite jade in situ made in New Zealand.* Lapidary Journal, 1963, 16, 11, pp. 1000-1008.

Nephrite *in situ* has been found in the southern Alps of New Zealand along the Arahura River below Olderog Creek. The occurrence is at the base of a large exposed outcrop of serpentine resting on schist. Large water-polished boulders of green and white material have been encountered weighing up to seven tons.

S.P.

Lunghi (A.). *Colour grading of diamonds.* Diamant, 1963, 49. p. 5.

There are several colour-grading systems for diamond in the jewellery trade. In the U.S.A. one system uses letters from D to X and another numerals from 0 to 10, subdivided into units of 100. In other countries a series of names, such as Rivers, Crystals, top Capes, or White, Commercial White, Yellows, is used. A series of names is useless unless every stone is based on and referred to a master sample. A commonly used denomination has different meanings in different colour-grading systems. There is a lack of uniformity, and, unless a rational method of classification is relied upon, much colour-grading of diamond is meaningless.

S.P.

SCHLOSSMACHER (K.). *Chrysoberyll-Katzenauge-Alexandrit.* Chrysoberyl cat's-eye alexandrite. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, 1962, 40, 9–12.

Article generally surveying gems of the chrysoberyl group. Various chemical and physical properties are discussed. Specific gravity, 3·71–3·72, is high enough for the gem to be found alluvially. Chrysoberyl, chrysoberyl cat's-eye and alexandrite are discussed in detail, and their occurrences mentioned.

W.S.

SCHLOSSMACHER. (K). *Neue Synthesen.* New synthetics. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, 1962, 40, 13.

Two new types of " synthetic " moonstones are on the market. Both are made of synthetic spinel. The first is backed with blue enamel and contains rutile needles. The second does not contain rutile needles, and is lacquered at the back.

SCHMIDT (P.). *Die Edelsteine in Israel, einst und heute.* Gems in Israel, then and now. Zeitschr. d. deutsch. Gesell. f. Edelsteinforschung, 1962, 40, 34–38.

Article surveying mentions of gems in the Bible, including the breast plate of the High Priest. Difficulties of old nomenclature are discussed, as the ancients tended to group all types of stones of the same colour together.

E.S.

WURMBACH (I.). *Die Diamantentstehung aus der Sicht seiner Synthesis.* The formation of the diamond as seen from its synthesis. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, 1962/63. 42, pp. 10-23,

Detailed article with bibliography of 43 items. The various syntheses are described, mainly those of G.E.C. of America, De Beers in South Africa, Carnegie Institute in Washington, one Swedish method, and two more American experiments. The behaviour of carbon at various temperatures and pressures is shown in a curve. The crystallographic and optic properties of diamond are discussed. The conclusion deals with the conditions of formation of the natural diamond, starting with the occurrence, paragenesis and origin of carbon.

E.S.

(ANON). *Neue Edelsteinvorkommen.* New gem occurrences. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, 1962, 41, pp. 21-24, and 1962/3, 42, pp. 25-26.

Diamond mining from the sea is shortly discussed. Ricolite is a combination of serpentine and talc used in various crafts and is found in New Mexico. Drayite, a brown tourmaline, has been found north of New York and new occurrence of chrysoprase is in the state of Goias in Brazil. Ruby from the Longido mine in Kenya is now cut into very pleasing stones. In the north of the state of Maine in the U.S.A. jasper is found, but the red colour is usually poor, though the stones take a very good polish. Spessartites from Madagascar have an orange-red colour, sometimes dark, sometimes light. Amethysts have been found in a new district of Minas Gerais in Brazil. Diamond is being looked for in Czechoslovakia.

E.S.

SALLER (X.). *Ueberraschungen in der Zuchtperlen-Herstellung.* Surprises in the production of cultured pearls. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, 1962/63, 42, pp. 4-9.

A survey of to-day's cultured pearl production. It is shown that the newer methods more and more approach the natural growth of pearls. Also components which made differentiation easier are not used any more. In future there will be great difficulty in differentiating between genuine and cultured pearls, necessitating a new terminology in the field of pearls. The article deals mostly with the new technique of S. uda, who uses the mantle of the pearl as a seed in the production of Biwa-lake fresh-water pearls. A large part of the produced pearls have a nucleus, but those produced by the described methods are without nucleus. An X-ray shows a drop pearl without nucleus, 18mm × 13mm, skin free of blemishes.

E.S.

BENECKEN (K.). *Studien zur Diamant-Spektroskopie.* Studies in diamond spectroscopy. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, autumn 1962, 41, pp. 14-18.

Various practical tests are recounted the results of which, together with other results, are summarized in a table listing 32 stones.

E.S.

RUFF (E.). *The Jade story.* Lapidary Journal, 1963, 16, 11, pp. 1046-1056.

The nineteenth and concluding part of a series of articles which have covered the occurrence and use of jade in Asia, New Zealand, America, Australia and the Pacific Islands. S.P.

Institut für Edelsteinforschung, Idar-Oberstein. *Neue Beobachtungen an echten und synthetischen Smaragden.* New observations on genuine and synthetic emeralds. Zeitschr. d. deutsch Gesell. f. Edelsteinkunde, winter 1962/3, no. 42, pp. 29-32.

Article dealing with Sandawana emeralds and synthetic Chatham emeralds, and their inclusions. There are 4 photomicrographs, one of a tremolite rosette in a Sandawana emerald, and three of various wisps in synthetic Chatham emeralds. The Institute makes a point of calling the latter "Chatham synthetic emeralds " instead of " Chatham emeralds " in order to make sure that people know their origin. E.S.

THURM (V.). *Das Karat gestern und heute.* The carat weight yesterday and to-day. Zeitschr. d. deutsch. Gesell. f. Edelsteinkunde, 1962, 41, pp. 27-29.

Survey of the historical development of the carat weight, which before 1906 was different in most countries. England started using the metric carat in 1914. E.S.

MILES (E. R.). *Diamond coating techniques and methods of detection.* Gems and Gemology, 1962/63, 12, 10, pp. 355-364 and 383.

The article discusses the methods used to coat diamonds in order to make yellowish-coloured diamonds appear whiter, and what methods may be used to detect such treatment. Colouring by the use of solutions made from an indelible pencil or similar inks is mentioned. More resistant coatings were produced in the 1940's, and in 1950 one firm offered a service for coating diamonds, and by 1962 traffic in coated diamonds had become big business. Some legal enactments are mentioned. Various methods of detection are suggested. These are by observation under different lighting conditions; by abrasive action; by use of solvents and by application of heat. The article is completed by a list of cautions.
16 illus. R.W.

CROWNINGSHIELD (R.). *Developments and highlights at the Gem Trade Lab in New York.* Gems and Gemology, 1962/63, 12, pp. 376-383.

Mentions abraded facet edges of diamonds, three-phase inclusions in fluorite, and unusual inclusions in peridot and sinhalite. Induced "moss-agate" effects in staines chalcedony and repeated twinning in natural and synthetic ruby are also discussed. Green plastic covers have been made to fit loosely over the pavilions of emeralds to heighten the colour. These plastic caps were found to enhance the red residual colour seen through the colour filter. Diamond doublets are discussed, as well as colour-zoning in Chatham synthetic emeralds. Black non-nacreous pearls and treated black opal are mentioned. Odd orientation of rutile needles in corundum, wax-treated rubies, and the naming of greened amethyst are other matters discussed.

19 illus. R.W.

LEE (H.); WEBSTER (R.). *Imitation and treated turquoise.* Australian Gemmologist, 1963, 19, pp. 7-13 and 20, pp. 7-10.

A reprint of an article published in the Journal of Gemmology, July 1960. R.W.

OSTWALD (J.). *Mineral colour.* Australian Gemmologist, January 1963, No. 19, pp. 5-6.

A general survey on the causes of colour in minerals. The transition elements as colouring agents are mentioned, and there is a discussion of "colour centres" and of the various types of lattice defects. It is suggested that the colour of yellow sapphire is due to radioactivity.

R.W.

First International Congress on Diamonds in Industry—Paris 1962. Industrial Diamond Information Bureau, 1963.

A valuable collection of papers, both technological anp scientific, read at the Paris meeting. Subjects included the semiconductivity, hardness, graphitization of diamonds and the optical properties of electron and neutron-irradiated stones.

S.P.

Gemmological Notes

NO DIAMONDS IN CANADA

The most thorough prospecting for diamonds ever undertaken in Canada has ended in disappointment. Although kimberlite, the parent rock in which diamonds are found, was traced no diamonds were found. The project, which was carried out at Coral Rapids, north of Cochrane, in Ontario, has now been abandoned.

MARBLE CUTTING IN THE U.S.S.R.

A cutting factory in Leningrad uses a new milling method for cutting marble and granite and thereby substantially reduces the cost of fashioning these ornamental materials. Wheels incorporating waste material from the cutting of brilliants are used.

SMITHSONIAN INSTITUTION

The Smithsonian Institution in Washington, D.C., has added a smoky quartz from Brazil (1,695 carats), an extremely fine sapphire of 423 carats and a Ceylon kornerupine of 21 carats, to its collection. An emerald crystal (176 carats) from Colombia was donated to the Institution.

GEM TRADING DIFFICULTIES

The political and economical problems of Brazil, Burma and Ceylon are making it difficult for gem traders to carry on their normal business. Governmental action and possibilities of some form of nationalization have caused prices to increase beyond what would usually be required. In Brazil mining is sometimes frustrated as miners do not know whether they will have to sell their goods to the Government at an uneconomic price or even be allowed to retain them for trade purposes.

Developments in Burma are somewhat similar. A correspondent writes:

" I was deeply disappointed about the development for the worst which I encountered in Burma. The political as well as the economic situation is catastrophic, tourists are unwanted, and people interested in buying precious stones are shadowed like spies.

" The Burmese used to give visitors the impression of being a happy-go-lucky people to whom laughter seemed second nature, and a charming smile was always hovering upon their faces. However, twelve months of General Ne Win's dictatorship and control by his army and police troops have changed this to a serious and gloomy expression on their features. Interference with unimportant details in the people's private affairs, complicated red-tapism, as well as the progressive nationalization of industries, import-export, banks etc., are creating great uncertainty and doubt. Export declarations of business men are not accepted but passed around among competitors to control the statements. Thus people are deeply scared, and trust as well as confidence, previously a natural feature of the true Burmese character, have become a rarity. Exporters who follow the official legal way in declaring their goods are 'punished' for their behaviour by endless red tape procedures and unbearable delays; buyers from abroad are delayed in granting the necessary visas—an endless list of similar vexations could be established, which render it most unpleasant for buyers and impossible for tourists to visit this fascinating land of sunshine.

" We had to report to the Immigration Officer, the township office, and the police at every village we visited, and we were followed and controlled by official informers. The local brokers were even afraid of forwarding the stones sold to persons in foreign countries. Buying precious stones was most difficult in various places in Rangoon because the sellers won't give you any bills, but if you wish to export your stones you have to produce the bills to the Ministry of Import and Export, as well as to the Foreign Exchange Controller. But with these officials new difficulties arise, because they detain you for days on end before giving their signature to a form which you have to fill in yourself. In one of these places when I implored the chap to give me his signature because I was leaving in two days and still had to take that form to two more offices, he retorted ' I don't care whether you leave to-day, to-morrow or next week '."

Doing business in Ceylon is likewise problematical, and in all three countries there has been a consequential resort by some traders to methods of business which cannot be regarded as normal.

ASSOCIATION NOTICES

ANNUAL MEETING

The 33rd annual general meeting of the Association was held at Saint Dunstan's House, Carey Lane, London, E.C.2, on 3rd May, 1963. In the absence of the Chairman, the Secretary, Mr. G. F. Andrews, was appointed to act as chairman of the meeting.

In commenting upon the work of the year the Secretary said that history was made in 1962 in as much that examination entries were the highest ever, being 213 in the preliminary and 135 in the diploma. He recalled that in 1913 the respective numbers were 12 and 8. It seemed that the record might be exceeded in 1963 for already 39 examination centres had been established.

The annual meeting was an opportunity for thanking those who had contributed to the work of the Association, continued Mr. Andrews. He expressed thanks to the active persons in the two Branches, the Midlands and West of Scotland. The Goldsmiths' Company had always been generous in placing various rooms at the disposal of the Association for meetings and examinations and the G.A. was very grateful to them.

The instructors and examiners, who did excellent work were also thanked, as well as those responsible for gemmology classes throughout the country, which did not come under the aegis of the Association. These people made a substantial contribution to gemmology.

The Secretary expressed his appreciation of the work of the Vice-Chairman, Mr. Norman Harper, who had been so enthusiastic in establishing a specialist diamond course in Birmingham, and thanked the United Kingdom Diamond Publicity Committee for so kindly arranging for rough and cut stones to be made available for teaching purposes. Mr. Andrews also thanked Professor S. Tolansky and Mr. Cyril Ginder for their assistance with the proposed examination. He also expressed the association's indebtedness to Mr. J. R. H. Chisholm for his kind assistance with the *Journal of Gemmology* and Messrs. H. and D. Wheeler who did so much work after office hours.

The Secretary then moved that the audited accounts and annual report be adopted. In calling upon Mr. P. Riley to second the motion Mr. Andrews recalled that Mr. Riley was a Rayner prizeman and had gained his diploma with distinction. Last year he had won the premier award in the retail jewellery examinations of the National Association of Goldsmiths and, as a result, had recently had the Freedom of the Goldsmiths' Company conferred upon him.

Mr. Riley formally seconded the adoption of the annual report and accounts, which were approved.

In the absence of other nominations the Secretary declared the following officers re-elected.

President, Sir Lawrence Bragg; Chairman, Mr. F. H. Knowles-Brown; Vice-Chairman, Mr. N. A. Harper and Treasurer, Mr. F. E. Lawson Clarke.

Mr. Andrews said that the Association was greatly honoured that Sir Lawrence kindly continued as President and he expressed the meeting's appreciation of the work of the other officers.

Messrs. T. H. Bevis-Smith, C. T. Mason and E. Levett, who were present, were re-elected to serve on the Council, and it was reported that Messrs. Watson Collin & Co., chartered accountants, would continue as auditors.

The meeting then terminated and members met informally in the Sir James Walton Library.

TALKS BY FELLOWS

GILLOUGLEY, JAMES: Film Lecture " Gems of the Sea ", Johnstone (Renfrewshire) Townswomen's Guild, 17th October, 1962; Paisley & District Ladies' Circle, 19th November, 1962; Irvine (Ayrshire) Inner Wheel Club, 27th November, 1962; Paisley & District Catenian Association, 6th March, 1963; Paisley Abbey Townswomen's Guild, 20th March, 1963; Paisley Soroptomist Club, 28th March, 1963. Talk on " Gemstones ", Paisley Soroptomist Luncheon Club, 14th March, 1963; Glasgow Central Soroptomist Luncheon Club, 22nd April, 1963.

CROYDON, J. F.: Mr. Croydon has just given his 75th talk on gemstones to organizations which have included Women's Institutes, Grammar Schools, Townswomen's Guilds, Rotary and Round Table Clubs.

FORSEY, P. (Mrs.): "Precious stones", Dunville Women's Association, Ontario, Canada, 13th March, 1963.

BAGLEE, G.: "Diamonds", Richmond (Yorks) Inner Wheel, 6th June, 1963.

WEST OF SCOTLAND BRANCH

The tenth annual meeting of the West of Scotland Branch of the Association was held in Glasgow on Thursday, 18th April, 1963. In the absence of the Chairman, Mr. I. Mackenzie, the chair was taken by Mr. J. McWilliam.

In a brief report Mr. McWilliam commented that the Branch had had an interesting year and he particularly mentioned the talk on synthetic gems given by Mr. W. H. Butler.

The following officers were elected: Chairman, Mr. C. D. Wade; Secretary, Mr. W. H. Butler. Messrs. I. Mackenzie, J. Hunter and A. Inglis were elected to the committee.

It was arranged that the Branch's summer outing should be to Balmarino, Fife, on 9th June, 1963.

MIDLANDS BRANCH

The annual meeting of the Midlands Branch was held at the Imperial Hotel, Birmingham, on 5th April, 1963. Mr. W. W. Bowen presided and reviewed the activities of the year. Mr. J. Shaw was elected as Chairman of the Branch in succession to Mr. Bowen. Mr. N. A. Harper was elected as Vice-Chairman, and Mrs. S. E. Hiscox re-elected as Secretary. Messrs. G. W. Davis, K. Hoskyns, D. King and J. Rossiter were elected to serve on the committee. The past Chairmen of the Branch, Messrs. T. P. Solomon, A. E. Shipton and W. W. Bowen, became *ex-officio* members of the committee.

Mr. J. Shaw expressed the Branch's indebtedness to Mr. W. Bowen for his work as Chairman.

After the meeting members enjoyed the film " The eternal gem ".

HERBERT SMITH MEMORIAL LECTURE

The 1963 Herbert Smith Memorial Lecture was given by Mr. E. D. Lacy, B.Sc., A.R.C.S., F.G.S., of the Dept. of Geology, Birmingham University, on Friday, 26th April, 1963, at the Birmingham and Midland Institute. Mr. J. Shaw, the newly-elected Chairman of the Branch, presided, and before introducing Mr. Lacy gave brief biographical details of the late Dr. G. F. Herbert Smith, who was born in Birmingham in 1872.

In his lecture Mr. Lacy said that in gemstones we recognize crystalline material outstanding in perfection and beauty; in common parlance we speak of crystal clarity. We may ask, " How perfect are crystals?".

Long ago it was noticed that while the external form of crystals showed departures from perfection of proportion the interfacial angles were not affected by the accidents of growth. Many mineral species show much variety in the faces developed, but in any species the different forms are related geometrically in conformity with the fundamental symmetry. Surface features such as striations and etch marks are blemishes due to accidents of growth or subsequent history. The internal symmetry of a crystal structure is elegantly revealed by X-ray photography.

A twinned crystal contains two or more regions distinguished by differing orientation of the internal structure. The surface separating two regions may be planar and the aggregate may resemble two crystals " glued " together. Other twins show repetition of lamellar units. Others again may show an extremely irregular and complex disposition of the separate orientations which may greatly reduce the value of the material for technical usage, e.g., quartz for the telecommunications industry.

The surface topography of natural crystals, as seen highly magnified, is complex. Features originating during growth include trigons on diamond, growth layers and growth spirals, e.g., on beryl. The latter are surface manifestations of screw-dislocations, which constitute one type of fault in the atomic packing. Another type of dislocation is the edge variety. A good natural crystal may contain 10^{12} dislocations per cubic centimetre.

Mosaic structure, consisting of blocks of about 5000 Å side tilted with respect to each other at an angle of a fraction of a degree, has been demonstrated in many crystals. Dislocations may be situated about 300 atoms apart in the boundary regions between blocks. Real crystals are always much weaker than would be expected of perfect material.

Many crystal species show zoning, a compositional variation from the core outwards, that is either progressive or repetitive. Such variation is governed by the rules of crystal chemistry. Solid solution in some types of crystal is extremely extensive and complex, e.g., the garnet family. Such structures are not fully ordered.

Natural silicate crystals are normally formed at elevated temperatures. On cooling, ordering processes may come into operation or ex-solution may take place. Moonstone is alkali feldspar material in which sub-microscopic ex-solution segregation of the constituents is present.

The solid-state physicist recognizes a whole series of defect structures in crystals. These include point defects (vacancies, interstitials, foreign species), and line defects (screw or edge dislocations), electrostatic defects (free electrons). Such defects are often intimately concerned with optical absorption effects (coloration). Their incidence is related to the temperature of formation and to other factors.

Radiation damage has been recognized in many natural mineral species and has been produced artificially by X-ray and by neutron bombardment. In extreme cases the crystalline structure is totally destroyed and the material is said to be metamict.

The lecture was illustrated by slides, models and specimens.

At the end of the lecture Mr. Norman Harper thanked Mr. Lacy for his interesting lecture, and said that the great preparation that had gone into it had provided an interesting and stimulating evening. He presented Mr. Lacy with a copy of Herbert Smith's " Gemstones ".

NEW MEMBERS

The following have been elected:—

Fellowship

Blanshard, Philip J. A., Croydon
McKay, Robin I., Thames Ditton
McKeen, Joseph D., Belfast

Ordinary Membership

Akuamoa, Martin A., Zurich, Switzerland
Brown, Philip H., Greenford
Chow, Cheng C., Hong Kong
Clogg, John D., Wimbledon, S.W.19
de Couto, Albert B., Kobe, Japan
Delbarre, Armand A. D., Colombo, Ceylon
Gow, William F., London, N.W.11
Khan, Jamil A., Birmingham

Kaufmann, E. Pius, Montreal, Canada
Levon, H. (Dr.), Welkom, O.F.S.
Patching, Stanley W. F., Letchworth
Primavesi, Thomas, Montreal, Canada
Rice, Robert, London, S.W.1.
Roberts, Alan M., Colombo, Ceylon
Rolls, William D., Ontario, Canada
Sidebottom, Eric C., Cliftonville
Tenbroeck, Sophia, Bangalore, India
Whistance, Mary M. N. T., Bangalore, India
Davies, David L., Teignmouth
Imai, Taichiro, Tokyo, Japan
Franks, Ivor S., Holborn, London, W.C.1

PROBATIONARY MEMBERSHIP

Gehr, Terence P., Streatham, London, S.W.16
Himsworth, Robert M., York
Jochems, Cornelie, The Hague, Holland
Siripala, D. D. M., Ipoh, Perak, Malaya
Utian, Yvan Leo, Johannesburg, S. Africa

RHODESIAN GEM AND MINERAL SOCIETY

The Rhodesian Gem and Mineral Society has become affiliated to the Association. The Society fosters and encourages the study of minerals and gemstones and the appreciation of their beauty. Eventually the Society will institute courses which will enable members to sit for the Gemmological Association examinations.

PRESENTATION OF AWARDS

The 1963 presentation of awards (preceded by a reunion of members) will be held at Goldsmiths' Hall, London, on 28th October.

GEM DIAMOND EXAMINATION

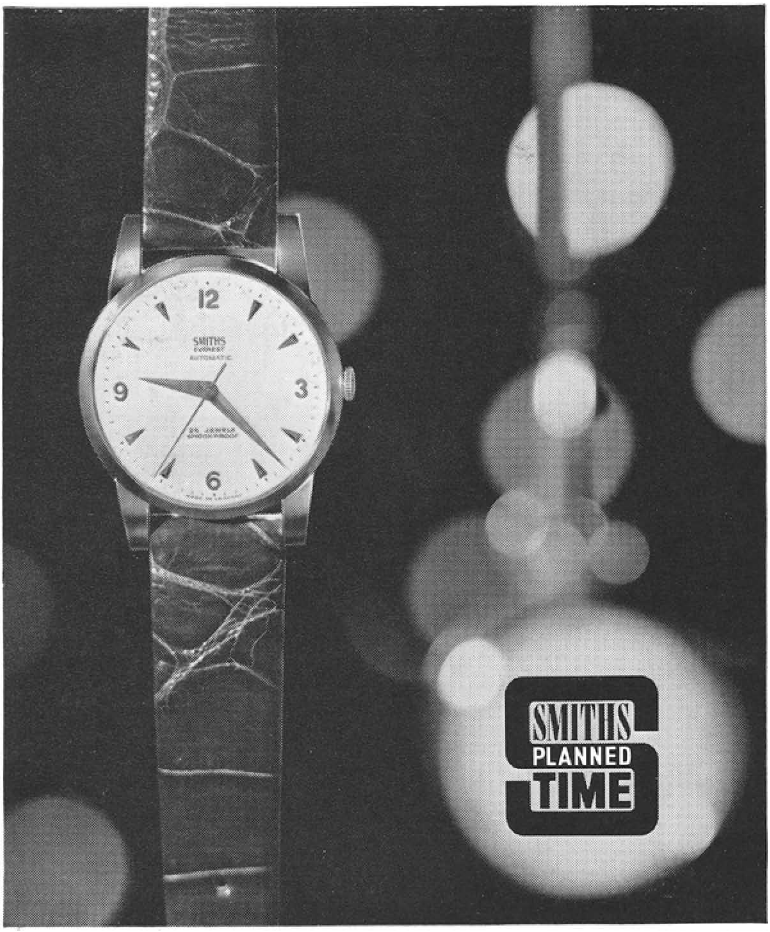
In September 1962 a specialist course in gem diamonds was commenced at the School of Jewellery and Silversmithing, Birmingham, under the instruction of Mr. Norman Harper, Vice-Chairman of the Gemmological Association. The course, the first of its kind established in Europe, was restricted to Fellows of the Association.

The first examination was held in June in Birmingham and the thirteen candidates who entered were successful in obtaining the qualifying standard. Professor S. Tolansky, D.Sc., F.R.S., Royal Holloway College, University of London, assessed the theoretical papers, and Mr. Cyril Ginder, M.A., of Cyril J. Ginder and Co. Ltd., and the Hon. Iain Balfour, M.A., of De Beers Consolidated Mines Ltd., assisted with the preparation and assessment of the practical section of the examination.

Professor Tolansky composed a searching theoretical paper and in the practical section candidates were required to assess the colour, purity, make and weight of cut diamonds, the colour, purity and shape of diamond crystals and to identify diamond simulants.

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

BATTY, Jack	Birmingham
GRYSKA, Stephen	Worksop
JONES, David C. B.	Leamington Spa
HOSKYNS, Kenneth	Handsworth, Birmingham
LEAKE, Douglas M.	Nuneaton
MARSHALL, John F.	Sutton Coldfield
PEPLOW, Miss Sarah A.	Worcester
PEPLOW. William A.	Stourbridge
PEPLOW, William R. H.	Worcester
SALLOWAY, John M. S.	Lichfield
TURTON, George G.	Bromsgrove
TURTON, Philip J. F.	Solihull
WESTON, Raymond W.	Lapworth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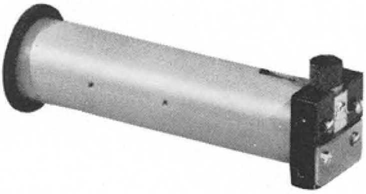

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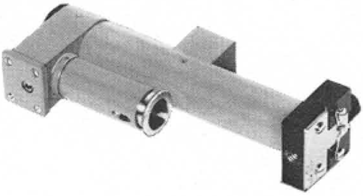

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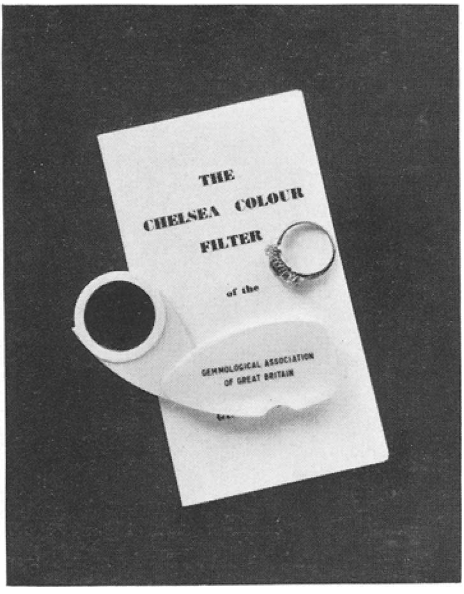
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of the
GEMMOLOGICAL ASSOCIATION
OF GREAT BRITAIN

Vol. IX
No. 3
July, 1963

C O N T E N T S

Printed by F. J. Milner & Sons Ltd., Brentford and London