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and

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OF GREAT BRITAIN

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OF GREAT BRITAIN
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TELL-TALE INCLUSIONS IN A PHENAKITE FROM BRAZIL

By E. GÜBELIN, Ph.D., C.G., F.G.A.

The following report on a detailed investigation of fluid inclusions in a phenakite from Brazil is intended as an additional contribution following two previous publications(2, 3) about the determination of fluid inclusions and the conclusions to be drawn from their analyses.

Always greatly inspired by any new inclusion found in a gemstone I became vividly interested by Pete Dunn's description(1) of acicular aikinite inclusions in some phenakites from San Miguel Di Piricicaba in Brazil (Figure 1). As I had never seen aikinite inclusions before and also since this combination appeared to be extremely rare, I summoned the courage to ask Mr Dunn to send me a specimen for inspection. He not only responded positively to my request but most generously sent me three different phenakite crystals—all containing aikinite needles. I am sincerely grateful for his courteous cooperation. The largest crystal proved to be extraordinarily interesting in that one of two adjacent and well-shaped, pencil-like aikinite crystals was part of a multiphase inclusion (Figure 2). This aikinite jutted into a slender cavity filling it

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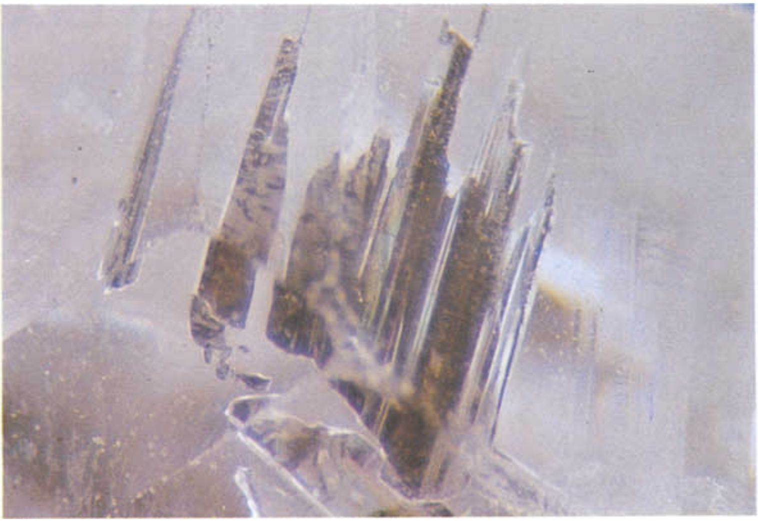

FIG. 1. Group of slender to broad stalks of aikinite crystals in a phenakite. Note the characteristic striation parallel to the long crystal axis and the interference colours of the tarnish. (Bright field, 20 ×).

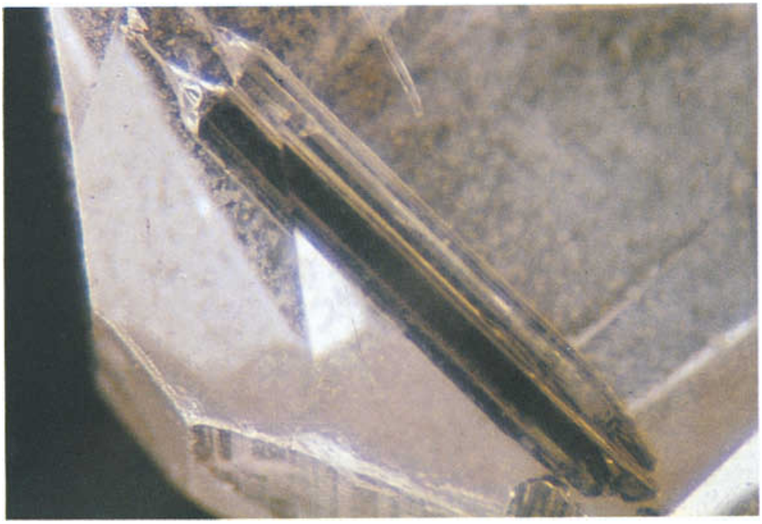

FIG. 2. Two adjacent, pencil-shaped aikinite crystals in parallel position, each one jutting into a slender cavity. Note the copper-brown tarnish colours and the liquid-filled cavity at the head of the darker aikinite. (Dark field, 40 ×).

to about 98% of its volume, while the remaining space was filled by a liquid and a gas bubble (Figure 3). Indubitably, this inclusion was a *primary* multiphase inclusion. Besides, the cavity contained another solid phase which was anisotropic, yet could not be determined.

Since aikinite normally occurs together with gold on quartz veins and thus suggests hydrothermal descent, this unusual existence in a liquid inclusion in phenakite justified the hope of gaining some increased knowledge about the conditions of formation—not only of the inclusions but also of the host crystal itself. Further very close examination of the phenakite crystal disclosed that apart from the above-mentioned multiphase inclusion there were a few minute acicular crystals of greenish colour as well as numerous syngenetic liquid inclusions of secondary origin (named pseudosecondary inclusions) (Figure 4).

A careful electron microprobe analysis of the tiny green needles indicated the presence of the elements Pb, Cu, Bi and S, thus pointing to aikinite again. In disintegrated state aikinite turns green. We may therefore assume that these green aikinite crystals had existed and disintegrated before they were enclosed by the growing phenakite crystal and consequently represent protogenetic inclusions.

The primary syngenetic as well as the secondary syngenetic fluid inclusions were then subjected to the same method of microthermometry as previously described in detail in this *Journal.*(2) The primary fluid inclusion at the top of one of the fresh aikinite needles consisting of a liquid and a large gas bubble (Figure 3) was first cooled down to −140°C and then slowly warmed up to +60°C. This process was repeated twice, and the following alterations of phases could be observed:

at a temperature of −2.5°C the ice started melting,

at approximately +8°C dissociation of a hydrate (=CO_2−hydrate) occurred,

and between +20°C and +50°C some minute solid grains disappeared.

The anisotropic phase did not dissolve when heated up to +60°C.

These incidents lead to the interpretation that the liquid in this particular inclusion was a relatively weak, watery but saline solution with 4.2 equivalent weight per cent of NaCl. A content of

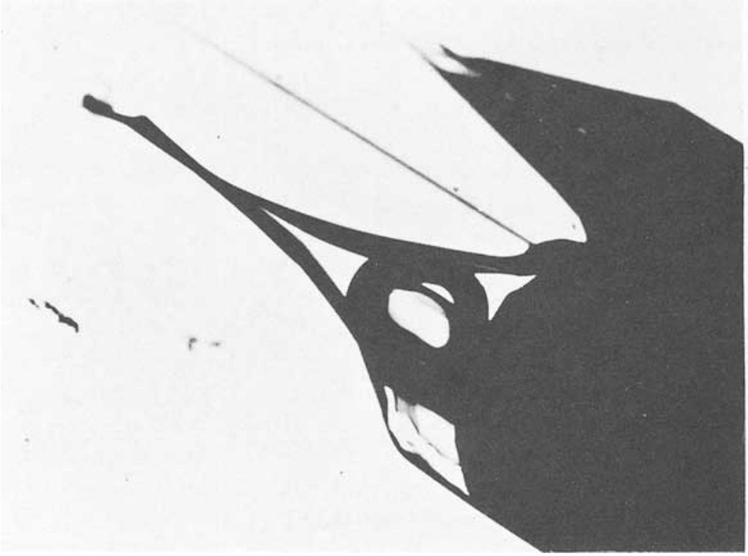

FIG. 3. Strong magnification (250 ×) of the head part of the darker aikinite crystal clearly depicting the large gas bubble in the fluid of the triangular cavity. (The anisotropic body is concealed behind the broad relief of the vesicle).

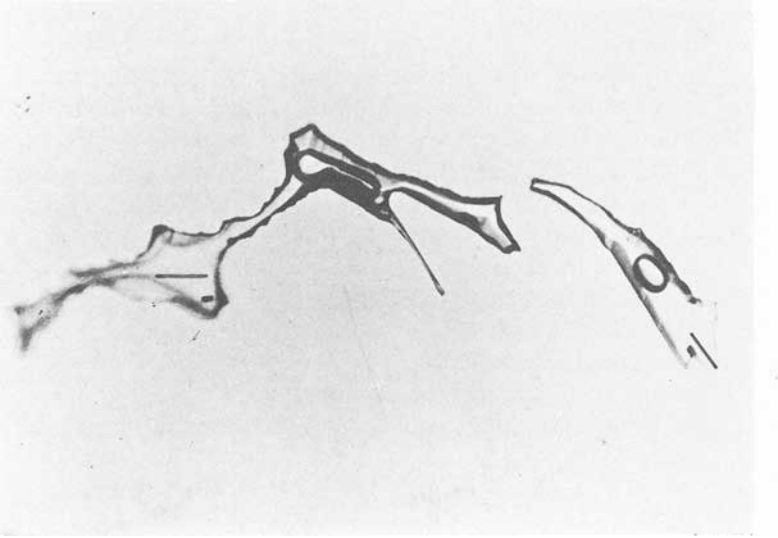

FIG. 4. The two largest and complexest of the pseudosecondary fluid inclusions. The anisotropic phase is situated at the right end of the larger gas bubble. The black needles and the black grains (inked in)* are probably sulphosalts (aikinite?). (250 ×).

*Inked in because, though perfectly clear when viewed under the microscope, they were out of focus in the photograph when the more important details were sharp.

CO_2 was just detectable (below 6 wt % of CO_2). The nature of the minute grains, which slowly disappeared between +20° and +50°C, could not be identified.

The *pseudosecondary* inclusions constituted the 'undigested' fluid drops on the curved plane of a partially-healed fracture. In size they measured between 5 and 350μm, and they all appeared to be of the same composition as the primary inclusion in that they comprised a liquid with a gas vesicle and three different solid precipitations. The gas bubbles totalled up to about 5 vol % (Figure 4).

The method of investigation was the same as applied to the primary inclusion, i.e. first they were cooled down to −140°C and then annealed to +30°C. The process was repeated just once. The course of events was very similar to that with the primary inclusion:

at a temperature of −2.1°C the ice began to melt,

at approximately +9°C dissociation of the CO_2–hydrate took place (liquid or solid CO_2 could not be observed during the cooling process).

Here too, the anisotropic phase did not dissolve when heated up to +60°C.

The result gained from this treatment reveals that the liquid is a weak watery but saline solution with 3.5 equivalent weight per cent of NaCl, while the content of CO_2 is exactly the same as in the primary inclusion. This interesting piece of new knowledge manifests that no great difference intervened in chemical composition of the mother liquor—and perhaps also in time—between the formation of the primary and the secondary inclusions.

The hydrothermal solution from which the phenakite crystal formed presents itself today in these residual inclusions as a relatively weak saline solution. The original composition of the mother liquor must have been of a very complex nature, which is indicated by the minute daughter grains, some of which disappeared while others remained inert at higher temperatures. The exact composition of these daughter crystals was unfortunately not possible to ascertain.

Apart from this informative investigation of the fluid inclusions it was interesting to observe three generations of inclusions in this phenakite crystal, namely:

(a) protogenetic green disintegrated aikinite needles which must have existed before the phenakite formed,

(b) syngenetic primary inclusions of two kinds:
    (b.1) primary mineral inclusions represented by fresh aikinite needles (Figures 1& 2),
    (b.2) primary fluid inclusion floating round the head of one of the primary pencil-shaped aikinite needles (Figure 3),

(c) syngenetic secondary (so-called pseudosecondary) fluid inclusions also containing mother liquor because the fissure occurred during the growth—at least before the growing process of the phenakite crystal had come to an end, yet not as an immediate consequence of the actual formation (Figure 4).

This exciting examination of protogenetic, syngenetic primary and secondary (pseudosecondary) inclusions in one and the same phenakite crystal—yet formed during three distinctly different periods—has enabled us to collect valuable information about the growth phases as well as about conditions and environment of the host mineral during its growth; also to acquire the definite corroboration of what the aikinite inclusions already told us—namely that the host phenakite was of hydrothermal origin.

ACKNOWLEDGMENT

I am indebted to Prof. Dr A. H. Stalder, of the Museum of Natural History in Berne, without whose technical help and reliable comment this study could not have been completed.

REFERENCES

(1) Dunn, Pete L. (1976) Gemmological Notes *J. Gemm.*, **XV**, 3, 114.
(2) Gübelin, E. J. (1976) Notes on Mono- and Bi-Phase Inclusions in Amethyst. *J. Gemm.*, **XV**, 4, 165-71.
(3) Gübelin, E. J. (1977) Further Notes on Mono- and Bi-Phase Inclusions in Amethyst and Topaz. *J. Gemm.*, **XV**, 6, 289-94.

[*Manuscript received 27th July, 1978.*]

OBSERVATIONS ON GEM MANGANOTANTALITE FROM MORRUA, MOZAMBIQUE

By S. HORNYTZKYJ, F.G.A., and K. T. KORHONEN, M.Sc.

Although a red transparent variety of manganotantalite (ideal formula $MnTa_2O_6$) is reported from a number of localities,(1) all the material that has been cut, mainly for collectors, has presumably come from Morrua mine, Zambesia, Mozambique. Some time ago we had an opportunity to examine three specimens from this source, two transparent prismatic crystals weighing 2.458 grams (12.29 carats) and 2.722 grams (13.61 carats) and a small brilliant-cut stone weighing 0.116 grams (0.58 carats).

At first one of the crystals was studied by means of x-ray diffraction. A cleavage fragment from the crystal of dimensions $1.5 \times 0.5 \times 0.4$ mm was subjected to x-ray analysis using nickel-filtered CuKα-radiation ($\lambda = 1.5418$ Å) and operating voltage of 35kV and 13mA. From the oscillation x-ray diffraction photographs we determined one of the three dimensions of the unit cell. The crystal system and other cell dimensions were determined from equi-inclination Weissenberg photographs. The crystal system was orthorhombic with cell dimensions, a 14.450 Å, b 5.772 Å, c 5.098 Å. These cell dimensions agree well with those previously mentioned in mineralogical literature concerning manganotantalite from Morrua.(1, 2) The formula of manganotantalite from Morrua is $Mn_{0.97}(Ta_{1.72}Nb_{0.29}Ti_{0.01})_{2.02}O_6$.(2) It is found there together with tantalite in a pegmatite.

The habit of the examined crystals was prismatic. One of the crystals had an obvious resemblance to the cross-shaped interpenetrate twin in which the crystals cross one another at nearly 60 degrees. The cleavage was perfect, the cleavage plane being parallel to the plane at which the *a* and *c* axes are located, {010} plane. The fracture seemed subconchoidal. The hardness is 5½-6 on the Mohs scale.(2) Hydrostatic weighing of the examined crystals in carbon tetrachloride using a Mettler H10-balance (accuracy±0.001 carat) gave us the specific gravity 7.73-7.97. The specific gravity according to literature is 7.52-7.92.(1, 2)

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Because the refractive index of the cut specimen was over the scale of the standard refractometer we employed the real depth/apparent depth method to get a rough idea of the refractive index. This was done with a Leitz SM-Pol petrological microscope. The average of several measurements was 2.16. The refractive indices according to Knorring *et al.*⁽¹⁾ are $\alpha = 2.14, \beta = 2.15, \gamma = 2.22$, the biaxial positive birefringence being 0.08. However, the refractive indices may be as high as 2.17-2.25.⁽²⁾

The colour of the examined specimens was scarlet red, the dispersion was strong and the lustre somewhat metallic. The colour was red under the Chelsea colour filter but dark green under the light coming through a saturated copper sulphate solution. The pleochroism observed with a Rayner dichroscope was weak, the main colours being deep red and pale pink. The absorption spectrum seen through a Rayner prism spectroscope showed a broad absorption band in the yellow green and in the violet. All the three examined stones were inert under long-wave and short-wave ultraviolet light and under x-rays. The microscope investigation of the cut specimen revealed a group of negative crystals with two-phase fillings parallel to the *c* axis. This orientation was determined by using the same petrological microscope as mentioned before.

We should like to offer our sincere thanks to Professor Th. G. Sahama for his valuable advice and to Mr Rurik Peura, Koru-Kivi Co. Ltd, Helsinki, for his kindness in allowing us to examine the specimens described.

REFERENCES

(1) Knorring, O., Sahama, Th. G., Saari, E. A note on the properties of manganotantalite. *C. R. Soc. Geol. Finlande,* **38,** 47-50, 1966.

(2) Harrison, R. K., Horne, J. E. T., Atkin, D. Manganotantalite from Morrua, Mozambique. *Bull. Geol. Surv. Gt Britain,* **25,** 77-84, 1966.

[*Manuscript received 13th February, 1978.*]

NOTES FROM THE LABORATORY: ENJOYING GEMMOLOGY

By A. E. FARN, F.G.A.

The Gem Testing Laboratory, London Chamber of Commerce and Industry

I was listening recently to a discussion of the standards (low) of examinees in gemmology and to discussions of the merits and demerits of teaching parrot-fashion and non-essay-type answers to questions and the (apparent) unimportance of correct spelling. I found this somewhat depressing, but was fairly promptly wafted into the upper echelons of gemmology by some excellent articles in our *Journal of Gemmology,* including an impressive discussion of a new type of gem-testing equipment. However, much modern technology does tend to lack the charm of some rule-of-thumb methods.

Equally recently (and much seems to happen in landslide conditions) we have had some very enjoyable practical gemmology, needing experience and basic skills—some learning and a memory for structures, etc. I always find the positive identification of a gemmological item by means of heft and lens plus basic gemmological knowledge very satisfying and rewarding. As an instance (no affront meant to the much respected customer) we had a large, clear, colourless sphere, 4 inches in diameter, to test. As I took it in my hand, it clouded over (the sphere). I wiped it and saw the edge of my thumb doubled in outline. On that evidence I would have written a certificate to state 'a colourless quartz sphere', my reasoning being that it was a colourless doubly refracting material of suitable heft and size and *stone cold.* (In the Laboratory, of course, I would take a distant vision reading plus a density.) A possibility that it could be topaz was discounted by reason of topaz's ready cleavage. We have a topaz crystal about 25 lb in weight which has developed a cleavage crack just lying flat in a display cabinet!

That, of course, was comparatively obvious and easy gemmology, but isn't it nice to steer clear of those dreadful formulae and equations? This week we were requested to determine a series of densities by the hydrostatic method, using balance, ethylene dibromide and temperature correction. This is basic stuff but very

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enjoyable work—three of us agreed figures (without comparison of workings—strictly individual efforts) to three places of decimals. This pleased us all—me particularly, because SG work is so fundamental. Having the equipment helps a lot, it is true. Because of the number of workings involved we used a small calculator, but I feel pleased to think I can still rapidly work out problems by old-fashioned methods. Computers, of course, are only as accurate as the information fed into them. It pleased me to do one or two samples by old fashioned methods to find if the little electronic gadget was accurate (it was).

In the last few days the telephone has rung and callers have called, all with a sudden surge of interest in a problem far from new but in a fresh guise. It seems that surges of interest come and go, fashion providing the *diktat.* And now pearls are back with a flourish—although flourish is hardly the word for that perfection of sheen arising from those microscopically thin overlapping platelets of nacre which form the 'orient' of pearl.

We had a stone dealer in with a fine cameo, difficult to decide by eye. Was it superb shell finely polished or banded agate? No marks were awarded for this particular determination: since we employ only non-destructive methods, I defy anyone to find the imprint of a dot of acid or the abrasion of a hardness point. These tests, using a microscope, are quite precise, practical gemmology.

The subject of shells, pearls and pearly products, nacreous and non-nacreous, reminds me of a most useful book I am pleased to have purchased. In it I found adequate answers to back up findings recently on two slightly unusual 'pearls'.

One was what looked like a white clam pearl with a red band of colour, looking as if a pink conch pearl had been drained of colour except for one band of pink on a white background. This was found to be a bead turned from conch *shell.* Until you have seen one, you just don't know.

The second item—much more intriguing—was what at first sight looked like a bluish grey 'mabe' pearl in an old-style pendant. The 'pearl' was in a close-backed setting, probably late Victorian/Edwardian. By using the ubiquitous 10× lens an interesting curved banded exterior structure fanning outwards could be seen faintly. It was a difficult proposition to x-ray since it had to be done sideways. This meant the pearl was very proud of the film, leaving only a small chance of determination, since over-exposure to allow for depth would mean a very darkened negative. We were pleased to find that, using only a small permissible portion of the edge of a film slipped under and supported, we were able to obtain sufficient evidence in structure to identify what is termed a pearly nautilus, *Nautilus pompilius*. This is briefly but adequately described in *Gems and Jewellery*, by Ove Dragsted, F.G.A., Crown Jeweller to the Danish Court. This is the book I have found so fascinating and rewarding: it describes some very unusual gem materials, especially among the ornamentals—from dried beetle wing-cases to bronze-pearl-like squids' eyes!

To return, however, to the pearly nautilus, it was memory which helped hold the door. Many years ago I purchased from a street market stall a very pretty nacreous shell of distinctive shape which my old friend and colleague Robert Webster instantly recognized as a nautilus shell. It was seldom that he was ever stumped by being presented with an 'unusual' to identify. He took an x-ray photograph of it and made a print which hangs close to our x-ray set, showing the structure very sharply (see Figure 1). It vividly prompted my memory on seeing this particular item which

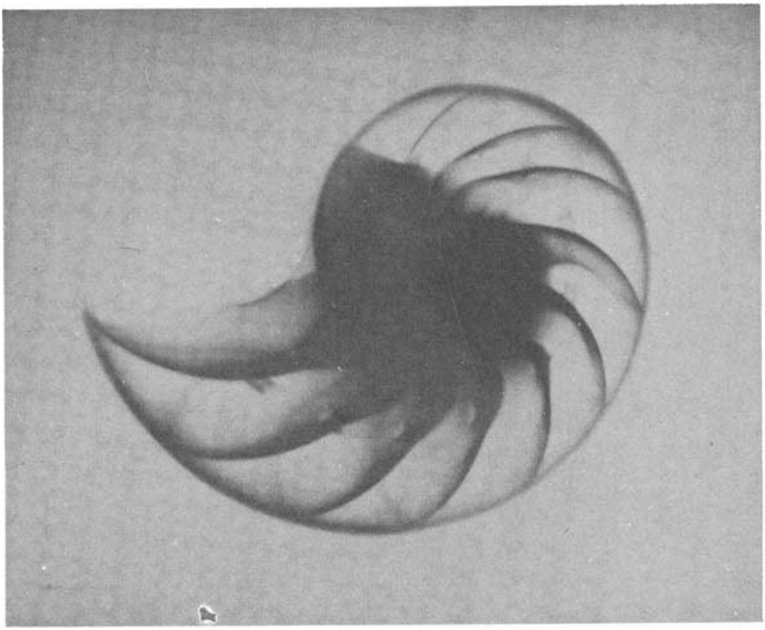

FIG. 1. X-ray photograph of Pearly Nautilus *(Nautilus pompilius)*—from negative by R. Webster.

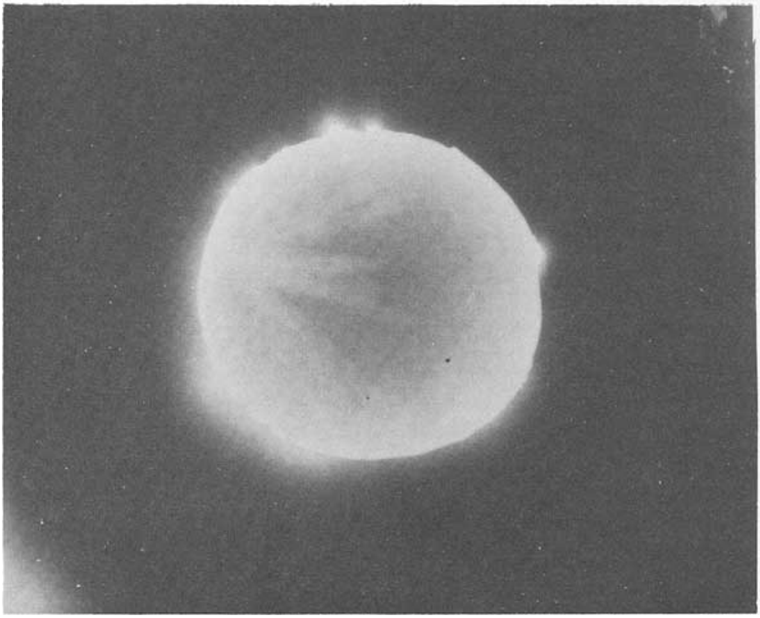

FIG. 2. Eight drill-holes in a cultured pearl taken from a ring.

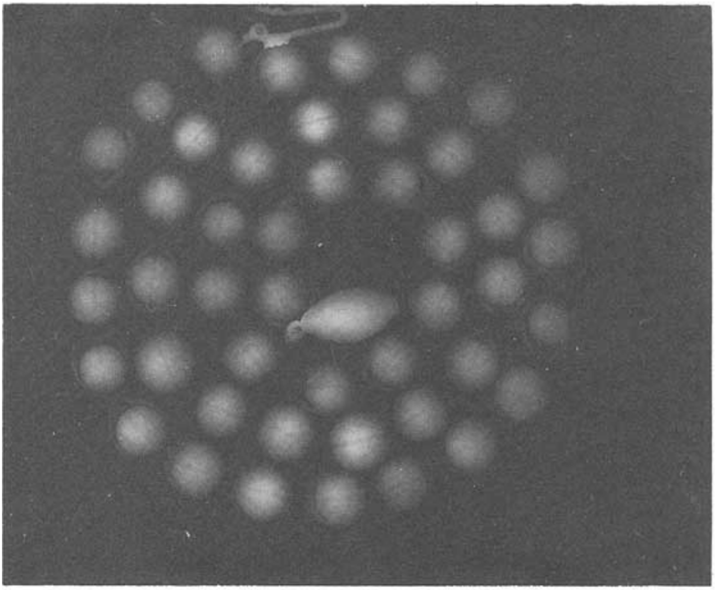

FIG. 3. A necklace of extremely baroque cultured pearls, showing large drill holes and huge gaps between m.o.p. bead and nacreous outer layers.

we were currently examining. Certainly it was the first time for all of our staff and the second time for me. The memory made me search for Ove Dragsted's book, in which it is depicted. He gives the Indian Ocean, off Indonesia and the Philippines as being the provenance. Further reading of *Molluscs and Brachiopods* by Cooke, Shipley and Reed, added to my knowledge. Under the heading 'Order Tetrabranchiata' they state 'Cephalopoda (the highest class of mollusc exclusively marine) with four branchia and four kidneys; animal inhabiting the last chamber of an external multilocular shell: found consisting of two separate lobes; tentacles numerous, without suckers or hooks; no ink sac'. Not exactly a selling *spiel* for a keen salesman!

The outer shell of the nautilus is porcellanous. This is stripped to reveal the beautiful nacreous layer of the large inner chamber and *septa,* the *septa* being a series of chambers or divisions all having a nacreous layer. These *septa* are often removed and engraved as jewellery. An adequate reproduction of *our* x-ray photograph cannot be produced, but it is worth looking up Ove Dragsted's book just to refresh one's knowledge of some very enjoyable gemmology. As Thomas Gray might have had it, 'far from the madding crowd [of erudite gemmologists] they keep the noiseless tenour of their way'.

The concentric and radial structure of a natural pearl necklace is evidenced by the fine precision of the drill holes which meet dead centre with geometric precision. The banded structure of the spherical bead of mother of pearl which is the huge nucleus of most cultured pearls has a diverting effect on the direction of the pearl drill—usually the drill tries to take the line of least resistance, as is seen in the various attempts at drilling in or at the drill holes of many cultured pearls (see Figures 2 and 3). Reading an x-ray negative of a cultured-pearl necklace which shows no apparent bead or skin outer layer can be assisted in determination by the 'dog leg' nature of the string canals which is repeatedly seen—this being just plain basic gemmological knowledge of the structure of natural and cultured pearls. Basic gemmology and a 10× lens will still be detecting when the batteries run out in the calculators.

[*Manuscript received 21st March, 1978.*]

DIAMOND NOTES

By P. G. READ, F.G.A.

There have been several occasions in the past when controversy has arisen over the question of whether the colour of a particular diamond was natural or whether it was the result of electron or neutron irradiation of the stone followed by heat treatment.

One of the diagnostic indications of this type of artificial coloration has been the presence of a line at 595nm(1) in the diamond's absorption spectrum. While this indication still remains valid, work carried out by Dr A. T. Collins, of King's College, London, has shown that the absence of this line does not necessarily mean that the diamond's colour is natural.

In a paper read at the De Beers annual Diamond Conference in July 1978 (and in a previous letter published in *Nature*(2)), Dr Collins has revealed that if the annealing temperature of electron-irradiated Type I diamond is raised above the normal range of 800-900°C, the 595nm absorption line begins to weaken, finally disappearing completely and permanently at 1000°C.

The presence of the original 415.5 line system (if the stone was originally of the Cape series) together with lines associated with the new colour at 504nm and 498nm, would in combination still, however, provide evidence of artificial coloration. Although these lines are faint, A. E. Farn has indicated that they can be enhanced by cooling the diamond with the aid of liquid nitrogen, and he is currently using these techniques in the Gem Testing Laboratory of the London Chamber of Commerce and Industry.

The improvement of a diamond's colour by means of nuclear irradiation generally depends on the modification of the initial radiation-induced colour by subsequent heat treatment. In effect, the heat treatment increases the mobility of the radiation defects in the diamond, enabling them to regroup within the lattice.

A similar mobility effect is a feature of another possible colour enhancement technique reported by R. M. Chrenko, R. E. Tuft

(1) This is given as 594nm by E. Bruton in his book *Diamonds,* and as 592nm in R. T. Liddicoat's book *Handbook of Gem Identification.*

(2) 'Investigating artificially coloured diamonds', *Nature,* Vol. 273, No. 5664, 1st June, 1978.

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and H. M. Strong, of General Electric, in an article in *Nature*(3). Their work showed that the high temperature/high pressure annealing of diamond can be used to increase the mobility of the dispersed nitrogen in a yellow Type Ib diamond, allowing it to aggregate into the nitrogen platelets which are the main feature of Type Ia diamonds.

Unlike dispersed nitrogen, which is responsible for the yellow tints of Cape series diamonds, nitrogen platelets only absorb light at the UV end of the spectrum. Significantly, the General Electric team reported that after heat treatment(4), which was for periods ranging from hours to days, the deep yellow colour of a Type Ib crystal had faded considerably. They also suggested that large yellow Type Ib synthetic diamonds, which are grown slowly to obtain gem quality stones, could be turned into colourless crystals by proper annealing at high pressure.

While it may not be possible in future to identify diamonds whose colour has been 'improved' in this way, the technique does imitate the natural geological process of nitrogen migration in diamond, and as it appears to be equally permanent, perhaps the question of identification is, after all, irrelevant.

[*Manuscript received 5th September, 1978.*]

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(3) 'Transformation of the state of nitrogen in diamond', *Nature*, Vol. 270, No. 5633, 10th November, 1977.

(4) 2000°C (2273K) at 55-65 kilobar.

MAGNETIC RESONANCE— A NON-DESTRUCTIVE PROBE OF GEMSTONES

By D. R. HUTTON, B.A., M.Sc., Ph.D.

Department of Physics, Monash University, Australia

INTRODUCTION

The basic instruments of the gemmologist have changed little over the last 50 years. However, modern technology has recently made available a number of new instruments, e.g. the electron microprobe (Dunn 1977), the x-ray and electron microscopes, the Mössbauer spectrometer and magnetic resonance spectrometers, which although primarily designed for research purposes to determine 'the reasons why', are becoming increasingly available to the practising gemmologist for diagnostic and identification purposes.

This article aims to outline the principles and techniques associated with the phenomena of magnetic resonance and to show how the information of this newer spectroscopy can help solve the problems of today's practising gemmologist.

MAGNETISM IN GEMS

Many gems show magnetic effects, in that they may affect a compass needle or be attracted by a magnet, and Anderson (1971) has shown how these effects may be used to differentiate between more or less magnetic stones of similar appearance. His method, shown in Figure 1, relies upon measuring with a sensitive balance the magnetic force on a gem sitting in a non-uniform magnetic field.

Five kinds of magnetism are well known, each kind depending on the interactions between the atoms or ions of the solid with the magnetic field and with each other.

Diamagnetism (or negative magnetism) is due to the tendency of electrical charges (e.g. atomic electrons) partially to shield the interior of a body (e.g. the atom) from an applied magnetic field. With Anderson's balance it would show up as a weak repulsion or downwards force. Diamagnetism occurs in all materials including gems.

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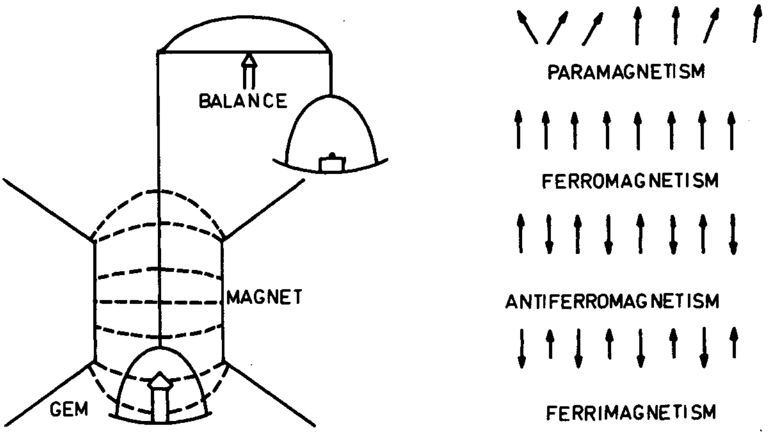


(a) (b)

FIG.1. (a) Gouy balance for measuring magnetic susceptibility.
(b) Spin ordering in various magnetic materials.

Paramagnetism (or positive magnetism) shows up as an attraction into the magnetic field and hence a loss of weight due to an upwards force. It only occurs in atoms, ions of molecules with unpaired or odd numbers of electrons (or in nuclei with odd numbers of neutrons and protons) and is of particular importance for atoms and ions with partly filled inner electron shells, i.e. the transition elements. All these atoms or ions have a resultant spin angular momentum and so, being charged, they act like little magnets and therefore in turn interact with a magnetic field. Thus this magnetism is induced by the applied magnetic field, is proportional to it, and disappears when the field is turned off. It also increases at low temperatures. Many gems are paramagnetic due to the inclusion of transition metal or rare-earth ions in their structures, e.g. ruby which has Cr^{3+} ions in Al_2O_3.

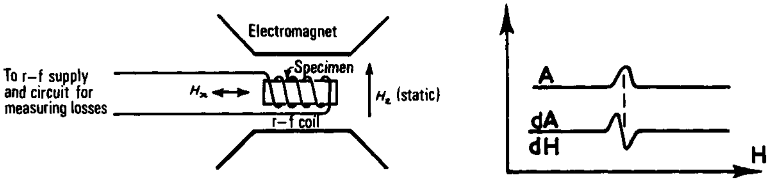
Then there are two kinds of magnetism which depend on an internal interaction between neighbouring paramagnetic atoms or ions in the material. *Ferromagnetism,* e.g. as found in some garnets, arises when the internal interaction tends to line up the spins of, for example, the iron ions in the same direction, as shown in Figure 1b, giving a very strong positive effect, which may even be spontaneously present in zero applied field and hence capable of affecting a sensitive compass needle. *Antiferromagnetism* and *ferrimagnetism* arise, e.g. in spinels, when the internal interaction between neighbouring spins tends to align them in opposite directions (Figure 1b). The magnitude and direction of the resultant magnetism depends on the relative magnitude of the oppositely directed coupled ionic spins; if they are equal we have antiferromagnetism and if different ferrimagnetism, which like ferromagnetism also is a strong positive magnetism.

All of these different kinds of magnetism exist in various gems and have resonance phenomena associated with them. The most useful experiments are associated with paramagnetism of the electrons (Electron Paramagnetic Resonance—EPR; or Electron Spin Resonance—ESR) or of the nucleus (Nuclear Magnetic Resonance—NMR).

PARAMAGNETIC RESONANCE

A gem material containing paramagnetic ions (or nuclei) and magnetized by placing it in a magnetic field, is found to strongly absorb certain wavelengths (or frequencies) of electromagnetic radiation. For normal laboratory-sized magnetic fields of about one tesla* these resonant absorptions are found to occur at microwave frequencies for ESR and at short-wave radio frequencies for NMR. Figure 2 illustrates the basic arrangement needed to observe such magnetic resonant absorption. In it the gem sample sits in a strong magnetic field usually generated by an electromagnet and is at the same time subjected to a strong alternating radio frequency (RF) field at right angles to the strong steady field.

The resonance phenomenon may be viewed in two ways, each of which helps us understand different aspects of it. First of all, classically, it is found that the magnetism of the tiny para-magnets



(a) (b)

FIG. 2. (a) Schematic arrangement for spin resonance absorption experiments.
(b) The observed spectrum is a plot of absorption (or more often rate of change of absorption) versus frequency or magnetic field.

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*The S.I. unit for magnetic flux density is the 'tesla' (symbol 'T'), which is defined as kg s^{-2} A^{-1}.—Ed.

in the gem precesses or rotates at an angle to the magnetic field at a frequency f which is proportional to the steady magnetic field H, i.e. $2\pi f = \gamma H$, where γ is a constant called the gyromagnetic ratio. If now the rotating RF field is tuned into the same frequency as the precession (this is called resonance) then the magnetism will change direction and energy will be absorbed by the sample from the RF field. The magnetic resonance spectrometer measures this absorption and at the same time measures f and H, which allows γ, a characteristic of the spins, to be calculated.

The second, or quantum, way of viewing magnetic resonance may be even more readily understood by the gemmologist since it is akin to the familiar view of optical absorption spectroscopy (Troup 1969). As in the optical case, the energies of the magnetic spin states of the material are calculated, and then resonant absorption occurs when the energy gaps ΔE between the levels equal the quantum energy hf of the incoming radiation, i.e. $\Delta E = hf$ at resonance. And since the magnetization and hence the magnetic energy gaps are usually proportional to applied magnetic field then the result is the same as above

$$f = \frac{\Delta E}{h} = \frac{\gamma}{2\pi} H$$

NUCLEAR MAGNETIC RESONANCE, NMR

Nuclear paramagnetism is due to the presence in the gem of nuclei which have odd numbers of nucleons (neutrons and protons). Since each nucleon has a half unit of spin then the total nuclear spin depends on how many unpaired nucleons there are. Table 1 lists some nuclei and their resultant spins.

TABLE 1 Magnetic nuclei often found in gem minerals.

Nucleus	*Spin I*	*Resonant frequency in 1 tesla Field*	*Gems*
H^1	$\frac{1}{2}$	42.6 MHz	Zoisite, Topaz, Beryl
Be^9	$\frac{3}{2}$	6.0 MHz	Beryl, Chrysoberyl
B^{11}	$\frac{3}{2}$	13.7 MHz	Tourmaline
F^{19}	$\frac{1}{2}$	40.1 MHz	Topaz
Al^{27}	$\frac{5}{2}$	11.1 MHz	Corundum, Spinel, etc.

To determine the spectrum of a given gem we need to know the magnetic energy levels of the nuclei and these are calculated using the equation

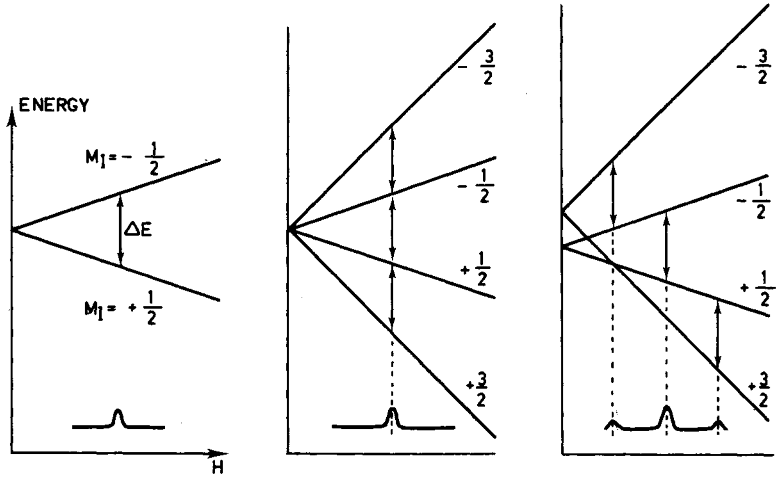
$$E = -M_I \frac{h\gamma}{2\pi} H$$

where M_I is given in turn all the values between $+I$ and $-I$ differing by unity. Let us illustrate by considering the energies of H or F nuclei. Here $I = \frac{1}{2}$, and so M_I can be $+\frac{1}{2}$ or $-\frac{1}{2}$ and the possible energies are therefore $+\frac{1}{2}\frac{h\gamma}{2\pi} H$ and $-\frac{1}{2}\frac{h\gamma}{2\pi} H$. These values are graphed in Figure 3a. Now resonant absorption occurs between these two levels when

$$hf = E_2 - E_1 = +\frac{1}{2}\frac{h\gamma}{2\pi} H - \left(-\frac{1}{2}\frac{h\gamma}{2\pi} H\right)$$

i.e. if $$f = \frac{\gamma}{2\pi} H \qquad \text{as before.}$$

The NMR experiment is done with equipment somewhat more complex (Varian staff 1960) than, but similar in principle to, Figure 2. Usually the field is held constant and the frequency scanned until resonant absorption is found, but alternatively the frequency may be held constant and the field scanned. In either case the frequency and field need to be measured accurately.



(a) (b) (c)

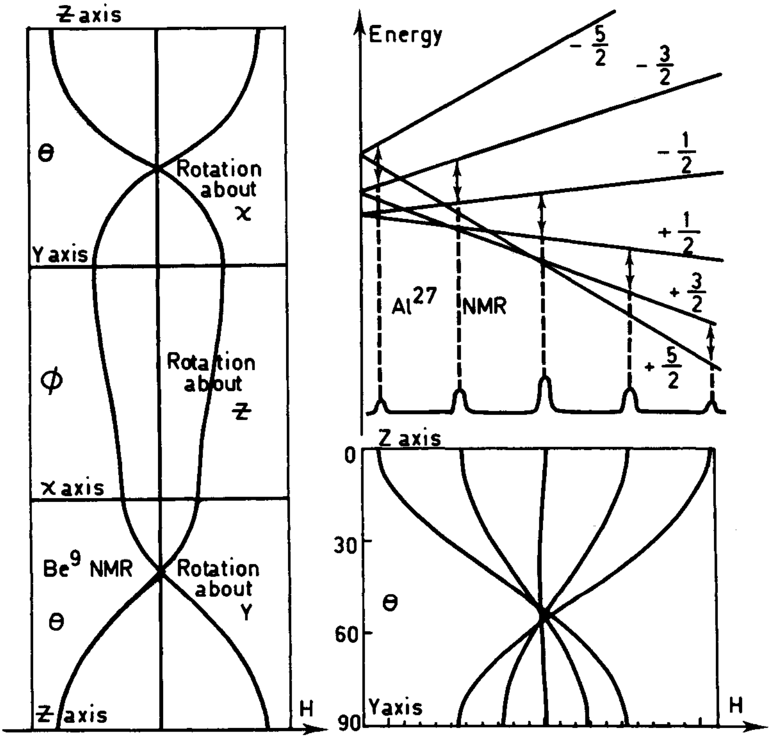
FIG. 3. Magnetic energy levels and resulting spectra for
(a) $I = 1/2$
(b) $I = 3/2$
(c) $I = 3/2$ with quadrupole interaction.

For H and F nuclei a single line will be observed in the scan for each crystallographic site and rather subtle interpretation is needed to deduce information about the surrounding gem material.

For nuclei with more unpaired spins I will be larger and the situation more complex but as a consequence of greater value to mineralogy. For example consider the beryllium nucleus. This has $I = \frac{3}{2}$. Therefore $2I + 1 = 4$ energy levels are now possible, i.e. $\frac{h\gamma}{2\pi}H$ multiplied by $+\frac{3}{2}$, $+\frac{1}{2}$, $-\frac{1}{2}$, $-\frac{3}{2}$, as shown in Figure 3b. If the magnetic interaction was the only one present we would once again get only a single resonance line 6 MHz in 1 tesla field as shown in Figure 3b, but fortunately there is another and more important interaction also present as illustrated in Figure 3c. This is the interaction between the nuclear quadrupole moment or the 'out of roundness' of the nucleus and the electric field gradient generated by the gem's internal structure. This results in a splitting between the $\pm\frac{3}{2}$ levels and the $\pm\frac{1}{2}$ levels in zero magnetic field, and the consequent formation of a $2I = 3$ line spectrum, instead of 1 line. The outer lines (Figure 3c) are called quadrupolar satellites and a gem NMR study would normally be most concerned with seeing how the quadrupolar splittings vary with the angle between the magnetic field and the crystal axes. For example Figure 4 illustrates the results obtained by Brown and Williams (1956) for beryllium and aluminium in beryl. For aluminium $I = \frac{5}{2}$ so we have $2I + 1 = 6$ energy levels $2I = 5$ lines in the spectrum including two pairs of quadrupolar satellites. Detailed study of such satellites gives much information about the gem mineral such as the location of the magnetic nuclei in, and the symmetry of, the crystal structure.

ELECTRON PARAMAGNETIC OR SPIN RESONANCE, EPR, ESR

Many atoms and ions have unpaired electrons in their outer electron shells and because the electron mass is so much smaller than that of nucleons the associated electron spin precesses at a much higher frequency in the same magnetic field. Thus the associated gyromagnetic ratio is much greater and electron resonance absorption occurs at microwave frequencies 10 000 MHz. So that although the spectrometer principle is the same as that shown in Figure 2, the mechanical appearance is different because instead of wires and cables, waveguides are used to convey the RF field to and from the gem sample which is now placed in a



(a) (b)

FIG. 4. NMR energy levels and spectral variations with angle for
(a) Be^9 in beryl.
(b) Al^{27} in beryl.

resonant microwave cavity instead of a coil. Figure 5 (after Varian 1960) is a block diagram of an ESR spectrometer capable of giving out recorded spectra, Figure 6 shows a typical machine's layout and Figure 7 shows how a small sample (approx size 0.1 cc or 1 carat) is mounted for the experiment which will in no way destroy or otherwise affect it. Since it is difficult to tune microwave systems it is normal experimental practice to use a fixed frequency or wavelength and to vary the magnetic field to find the resonance lines, cooling the sample to 77K or 4K to improve the sensitivity if necessary.

Such high frequency ESR is very sensitive, about 10^{14} magnetic centres with spin $= \frac{1}{2}$ being detectable at room temperatures; thus ESR is distinguished by many valuable features (Low 1968):—

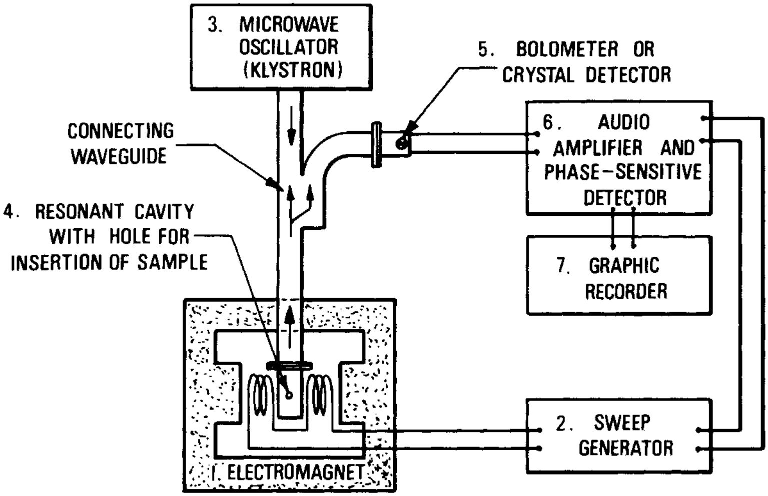


FIG. 5. Block diagram of EPR spectrometer. At resonance the power absorbed by the sample increases and so that detected by the crystal detector decreases. The output is displayed on a CRO or can be recorded graphically.

a. It detects minor impurities in diamagnetic minerals; in many cases, picogram* impurities can be detected.
b. It determines the point symmetry of the paramagnetic ion, in particular whether this ion is in a substitutional or interstitial position.
c. It discriminates easily between different paramagnetic ions.
d. It determines the valence state of the ion.
e. It measures the abundance of the paramagnetic impurities as well as the relative abundance of different paramagnetic impurities or different valence states of a given impurity, in a given mineral.
f. In many cases, one can establish the degree of order and disorder in the mineral, the effects of strains in the crystal.

Now since paramagnetic ions and defects (particularly ions of the transition metal series) are responsible for most colouring of allochromatic gems it can be seen that ESR should greatly help the gemmologist's 'why coloured?' questions of the various gem varieties.

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*pg = 10^{-12}g.—Ed.

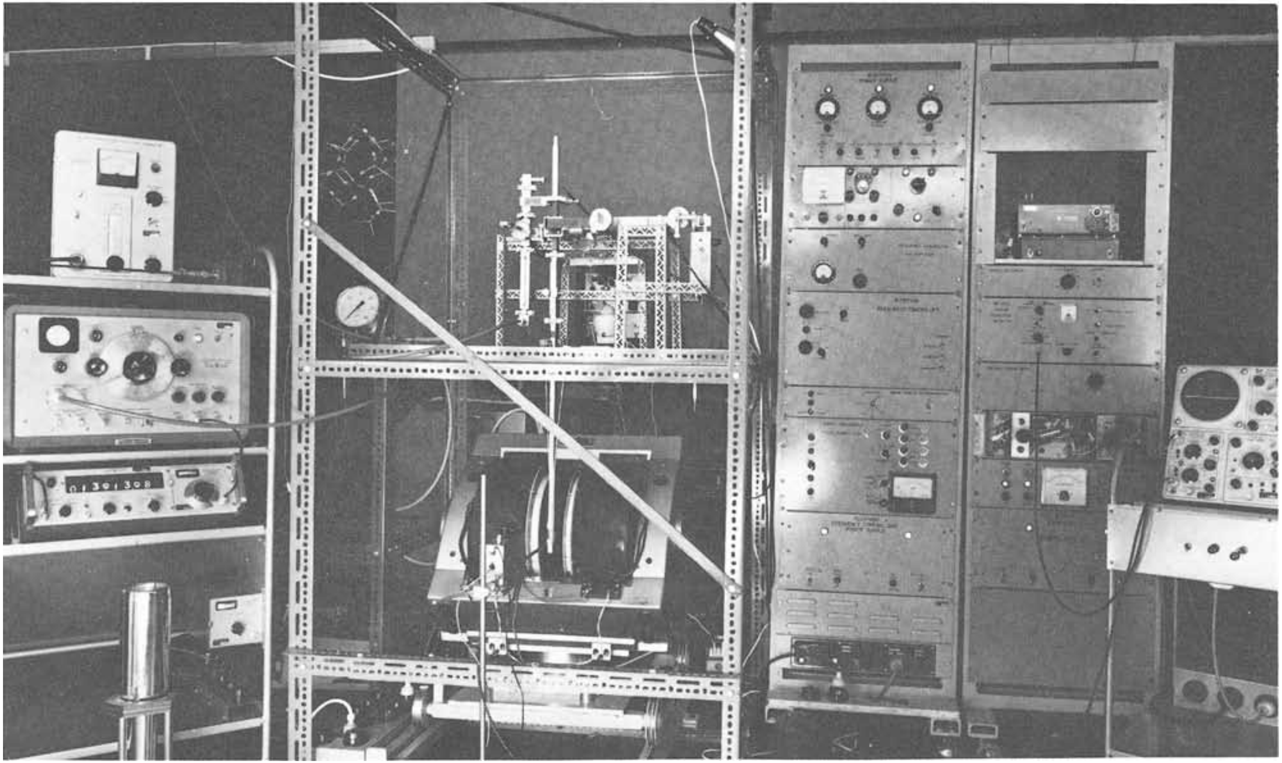

FIG. 6. Photograph of Monash University X band (10 000 MHz) ESR spectrometer. The microwave cavity can be seen between the magnet pole tips and the microwave generator and bridge above the magnet. Frequency measuring equipment is to the left and on the right are the detecting, recording and display systems. A dewar flask at lower left allows the sample to be cooled if necessary.

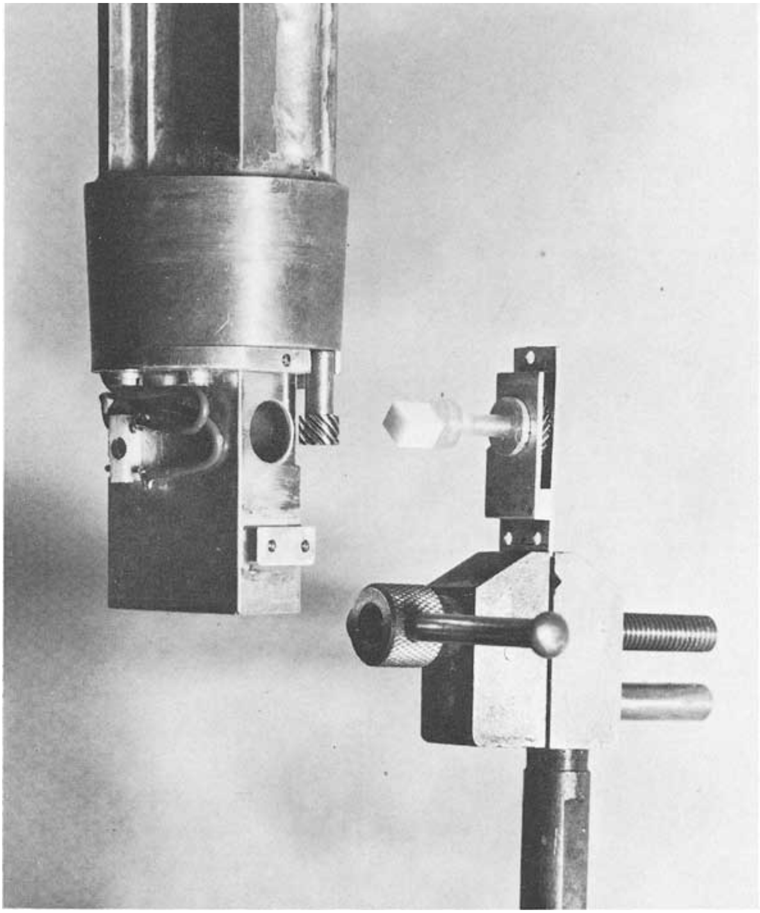

FIG. 7. A block of feldspar mounted on a perspex holder ready for insertion into the microwave cavity of the ESR spectrometer.

The interpretation of ESR spectra can be a complex process, but some of the features are easily understood. First of all, as with NMR, an ion of spin S gives 2S + 1 energy levels and so 2S spin or fine structure resonance lines. For example if $S = \frac{1}{2}$ then there are 2 levels and 1 resonance line in the spectrum. Secondly, the variation of line positions (so called g value) with angle between magnetic field and the gem crystal axes gives the symmetry properties of the defect site. Thirdly, many lines split into multiple components called hyperfine structure, due to an interaction between the

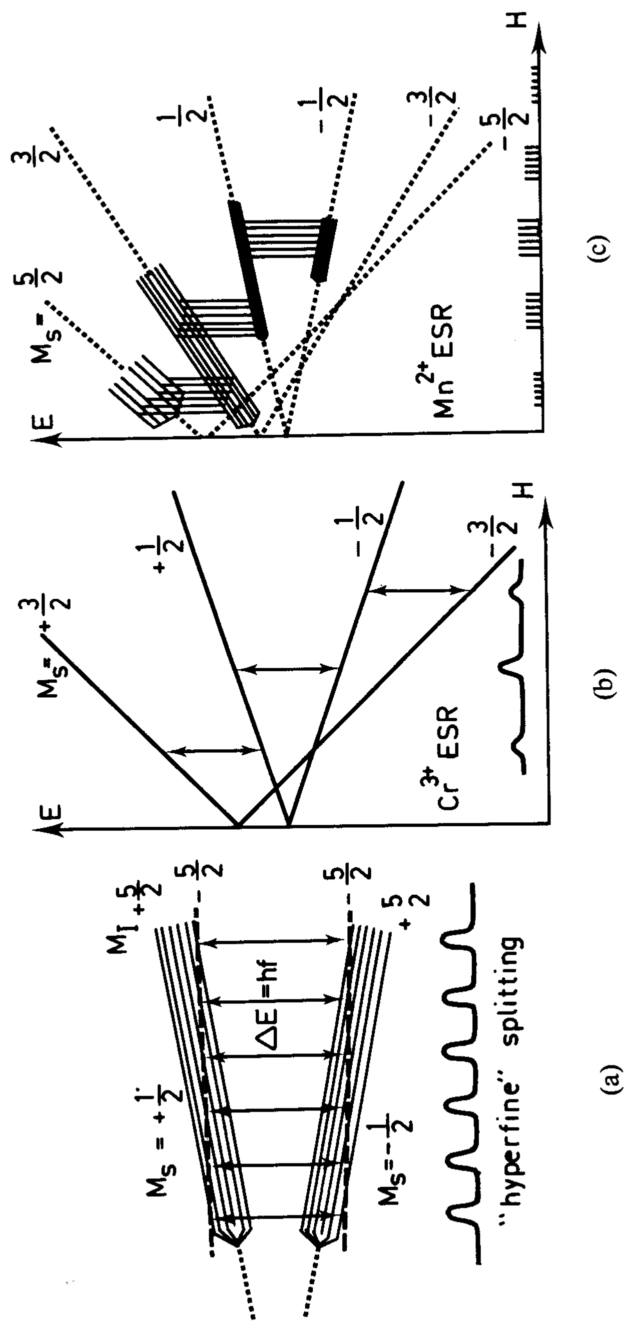

FIG. 8. ESR Energy levels and spectra for
(a) S = 1/2, I = 5/2
(b) S = 3/2
(c) S = 5/2, I = 5/2

spinning electron magnet and a nearby magnetic nucleus. If this nucleus has spin I then there will be $2I+1$ hyperfine components in each fine structure line.

Figure 8a illustrates the energy levels and spectrum for smoky quartz. ESR shows (O'Brien 1955) that the smoky colour is caused by the absence of an electron from an oxygen ($S = \frac{1}{2}$) which is next to a defect aluminium ($I = \frac{5}{2}$) substituted for silicon in the structure. Similarly nitrogen donor impurities in diamond (Smith *et al.* 1959) give beautiful 3 line spectra since $I = 1, 2I+1 = 3$, and substitutional yttrium ($I = \frac{1}{2}$) in irradiated brown zircon (Barker and Hutton 1973) gives doublet lines.

Figure 8b illustrates the energy levels and spectra for the Cr^{3+} ion in a gem. This ion has 3 unpaired electrons ($S = \frac{3}{2}$) and so $2S = 3$ fine structure lines. Notice that the splitting between these lines depends on the difference in energy between the $\pm\frac{1}{2}$ and $\pm\frac{3}{2}$ levels in zero magnetic field, which splitting in turn depends on the strength of the crystal field at the Cr^{3+} site (compare with Figure 3c where the nuclear quadrupole splitting in NMR depends on the electric field gradient). Thus the ESR spectra (Geusic *et al.* 1959) clearly show that the splitting for Cr^{3+} in green beryl (emerald) is very much greater than that in red corundum (ruby).

Similar arguments show that Mn^{2+} and Fe^{3+}, both with 5 unpaired electrons ($S = \frac{5}{2}$), will have a 5 line fine structure spectrum, but still these appear quite different in ESR since the manganese nucleus has $I = \frac{5}{2}$ and this will split each fine structure line into $2I = 6$ hyperfine components as illustrated in Figure 8c.

It should be apparent that many of the valuable features of ESR as listed above arise because of the ease of identifying specific paramagnetic impurities in gems from their characteristic spectra or 'fingerprints'. Also the width of the resonance lines gives information on the order or disorder in the mineral and may give clues as to the conditions during crystal growth. Thus ESR information may be able to differentiate between gems of the same variety but from different localities or sources, due to differences in abundances of paramagnetic impurities or formation conditions. For example the ESR spectra of emeralds (Hutton and Barrington 1977) clearly differentiate the better ordered synthetic emeralds from the natural, and also differentiate between Gilson and Chatham synthetics by the presence of an iron ESR spectrum in the Gilson stones. Yellow and golden corundums have been similarly

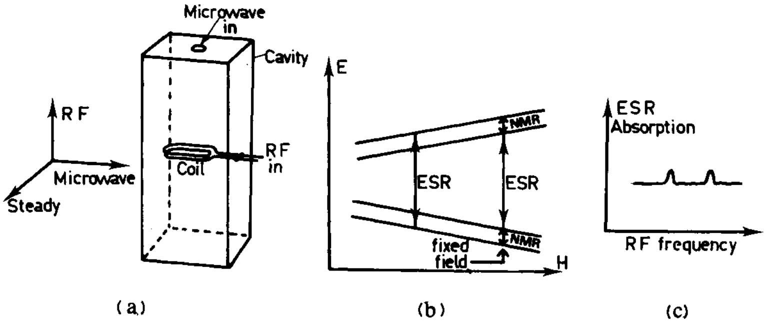

FIG. 9. Electron nuclear double resonance ENDOR
(a) arrangement of fields,
(b) transitions for S = 1/2, I = 1/2 in a fixed field H,
(c) spectrum for S = 1/2, I = 1/2.

differentiated by Scala and Hutton (1975).

The detection and analysis of some spectra may be very difficult, and more advanced techniques may be necessary. Very low temperature measurements are usually necessary for ions with even numbers of electrons since these interact strongly with the diamagnetic gem lattice, and if crystal field effects are large a second higher-frequency spectrometer (e.g. 35 000 MHz) may be needed to resolve the spectra.

ELECTRON NUCLEAR DOUBLE RESONANCE (ENDOR)

For many ESR spectra the hyperfine effects are very small and unresolved and so little can be deduced from them. ENDOR allows direct, accurate measurements of nuclear moments and hyperfine couplings and hence the identification of nearby nuclei and in many cases the detailed mapping of atomic and defect positions.

An ENDOR spectrometer is really only an ESR spectrometer with an added NMR RF source and RF coil around the sample, Figure 9. In operation the magnetic field is set on an ESR line and the RF frequency is scanned while monitoring the strength of the ESR line. NMR transitions are then seen, with high sensitivity, as changes of ESR absorption.

This technique has been very fruitful in, for example, confirming the nature of the nitrogen defect in type 1b diamonds (Cook and Whiffen 1966), the aluminium defect in smoky quartz (Barker 1975), and in elucidating the nature of the centres in red-brown zircon (Barker and Hutton 1973), and in topaz where the electron spin of the Fe^{3+} ions interacts with many surrounding fluorine nuclei (Barry and Holuj 1973).

These spectrometers are examples of an increasing suite of instruments which are helping to elucidate some of the mysteries of gemmology. We hope this article may help gemmologists to understand magnetic resonance, since they are likely to see increasing numbers of articles which refer to it and soon may even, themselves, be using the techniques in more difficult diagnostic work.

REFERENCES

Anderson B. W., (1971). *Gem Testing,* 8th edn, pp.287-9, London, Butterworths.

Barker P. R., Hutton D. R., (1973). A colour centre in natural zircon, *Phys. Stat. Solidi,* **b60,** K109-11.

Barker P. R., (1975). Hyperfine parameters of the Al centre in smoky quartz, *J. Phys. C., Solid State Physics,* **8,** L142-4.

Barry W. R., Holuj F., (1973). ESR spectrum of Fe^{3+} in Topaz III Endor of $^{19}F^{1}$, *Canad. J. Physics,* **51,** 95-101.

Brown L. C., Williams D., (1956). The quadrupole splitting of the Al^{27} and Be^{9} magnetic resonances in beryl crystals, *J. Chem. Physics,* **24,** 751-6.

Cook R. J., Whiffen D. H., (1966). Electron nuclear double resonance study of a nitrogen centre in diamond, *Proc. Roy. Soc.,* **A295,** 99-106.

Dunn P. J., (1977). The use of the electron microbe in gemmology, *J. Gemm.,* **15,** (5), 248-58.

Geusic J. E., Peter M., Schulz-du Bois E. O., (1959). PMR spectrum of Cr^{3+} in Emerald, *Bell System Tech. J.,* **38,** 291-6.

Hutton D. R., Barrington E. N., (1977). ESR of emeralds, *Aust. Gemmol,* **13,** (4), 107-18.

Low W., (1968). Electron Spin Resonance—a tool in mineralogy and geology, *Advances in Electronics and electron Physics,* **24,** 51-108.

O'Brien M. C. M., (1955). The structure of the colour centre in smoky quartz, *Proc. Roy. Soc.,* **A231,** 404-14.

Scala C. M., Hutton D. R., (1975). A definitive test for golden sapphires, *Aust. Gemmol.,* **12,** (5), 160-1.

Smith W. V., Sorokin P. P., Gelles I. L., Lasher G. J., (1959). ESR of nitrogen donors in diamond, *Phys. Rev.,* **115,** 1546-52.

Troup G. J., (1969). The radio frequency spectra of gemstones, *Aust. Gemmol.,* **10,** (7), 19-22.

Varian Staff, (1960). *NMR and EPR spectroscopy,* Pergamon Press.

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NEW GEMMOLOGICAL INSTRUMENTS AND TECHNIQUES

By PETER G. READ, C.Eng., M.I.E.E., M.I.E.R.E., F.G.A., F.I.S.T.C.,

Former Technical Manager of the Diamond Trading Company, now a Consultant

(being the substance of a talk given to the Gemmological Association of Great Britain at the Central Electricity Board Cinema, Newgate Street, London, E.C.2, on the 4th April, 1978)

When the Gemmological Association was founded in 1908 as the Education Committee of the National Association of Goldsmiths, commercial instruments suitable for gem testing were few and far between. The compound microscope had already become a sufficiently versatile tool to require no modification for gemmological use, but probably the first commercial instruments specifically designed for gem testing were the Bertrand and Herbert Smith critical angle refractometers. These were followed by the Tully version in 1925, and, eleven years later, by the first Rayner refractometer.

The initial slow development of gemmological instruments was no doubt due to the very limited demand that existed in those days, the rare new instruments being developed out of necessity rather than for economic reward. Today the growing consumer demand for jewellery has not only increased the number of retail outlets, but has resulted in an increased market for gem testing instruments. This is reflected in the wide range of instruments available; taking the critical angle refractometer as an example, the choice now includes the Rayner Dialdex, the G.I.A. Duplex II, the Japanese Okamo and Topcon models, and various German models marketed by Krüss, Hans-Günter Schneider, and Eickhorst.

In recent years a new class of instrument, the reflectivity meter, has been introduced. This instrument combines optics and electronics to give a quantitive measurement of a gemstone's surface reflectivity or lustre. The usefulness of the reflectivity type instrument in the identification of gemstones depends on the relationship between the reflectivity of a polished gemstone and its refractive index. This relationship is expressed in Fresnel's simplified equation, which shows the reflectivity as being equal to the ratio of the intensity of the reflected ray to that of the incident ray.

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$$R = \frac{Ir}{Ii}$$

This in turn is equal to $$\frac{(n-a)^2}{(n+a)^2}$$

where 'n' is the refractive index of the gemstone and 'a' is the refractive index of the surrounding medium (that is, for air, 1.0). Although the Fresnel relationship between reflectivity and RI was formulated for isotropic substances and for normal incidence of the rays, it works well enough in practice for anisotropic stones and for reflection at angles other than 90 degrees to the surface. However, as it is reflectivity and not refractive index which is being measured on this type of instrument, the surface condition of the stone being measured is all important. This is because the instrument can only measure the stone's *effective* reflectivity or lustre. If dirt or scratches on the gem's surface cause this lustre to be less than the *potential* lustre of the stone, the relationship between reflectivity and RI will break down and a low reading will result.

Because of their high efficiency and convenient size, solid state infrared emitting diodes are used as the source of incident rays in electronic reflectivity meters, and the reflected ray is detected by a photo-diode or photo-transistor. The peak output in the emission of the infrared diodes is in the region of 930nm. This is another reason for not using the readings of the reflectivity meter as a direct indication of a stone's RI, as this is defined in terms of yellow monochromatic light at 589.3nm.

Another difficulty in relating the reflectivity of a gem to its refractive index when using this type of instrument occurs when the gem has an appreciable amount of dispersion, as indicated by the difference in the index of refraction measured at the B and G Fraunhofer wavelengths of 686.7nm and 430.8nm. The refractive index of a gemstone is conventionally given in terms of sodium light at 589.3nm. If a gemstone has very little dispersion, its index of refraction will not be very much different if measured at other wavelengths. However, for gems having appreciable dispersion, the use of wavelengths above or below 589.3nm will modify the measured refractive index considerably. At the infrared wavelength of 930nm, as used in reflectivity meters, the 'RI' readings of strontium titanate (RI = 2.41) and diamond (RI = 2.42), will be found to be well separated, with strontium titanate reading much lower than diamond because of its greater dispersion. In this case, the separation of two almost identical refractive indices works to advantage when distinguishing strontium titanate from diamond.

There are at least four makes of reflectivity meter on the market, and although they all use infrared light and the same basic measuring techniques, there are several interesting differences between them.

The first instrument to be introduced was the 'Gemeter' by Sarasota Instruments.* This is a single-range desk model, and is the only reflectivity meter whose scale is directly calibrated in RI values. (Figure 1).

The 'Jeweler's Eye' by Hanneman Specialties is a dual range pocket model.† The circuit is similar to that of the 'Gemeter', but the calibration presets are connected in series with the LED and not the meter. (Figure 2).

No attempt is made with any of these instruments to measure absolute reflectivity

$$(\text{i.e. } \frac{Ir}{Ii}).$$

Instead, the intensity of the incident 'light' is assumed to be constant, and that of the reflected ray is displayed as a measure of relative rather than absolute reflectivity. For this reason all reflectivity meters have pre-set adjustments which allow them to be calibrated against standards such as spinel and diamond.

The newer 'Diamond Eye' by Hanneman (Figure 3) is another pocket meter, using the same basic circuit as the 'Jeweler's Eye' but calibrated only for diamond and diamond simulants.

Dr Hanneman has also introduced a meter (Figure 4) calibrated solely in terms of relative reflectivity using a 0 – 6.0 lustre scale of his own devising. This, rather like Mohs scale of hardness, is based on standard gems. In this case YAG, GGG, strontium titanate and diamond are chosen, and have been given lustre values of 1 to 4. This instrument is called a Lustermeter and is also available as a desk model,‡ as is his 'Jeweler's Eye'.

Another relative reflectivity meter of interest is the Martin Gem Analyser.§ In this instrument an attempt is made to make the

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* See Fig. 2, J. Gemm., 1975, **XIV**, 8, 380.

† See Fig. 1, J. Gemm., 1976, **XV**, 1, 19.

‡ See Fig., J. Gemm., 1978, **XVI**, 4, 240.

§ See J. Gemm., 1978, **XVI**, 1, 50-54.

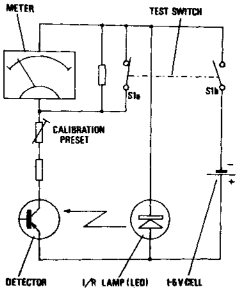


FIG. 1. 'Gemeter' circuit diagram.

FIG. 3. 'Diamond Eye'.

FIG. 4. 'Lustermeter'.

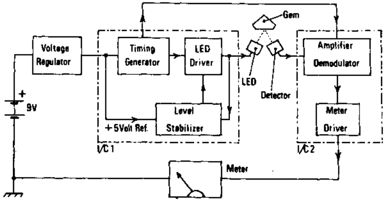


FIG. 5. Martin 'Gem Analyser' circuit diagram.

FIG. 6. Tatsumi 'Diamond Tester'.

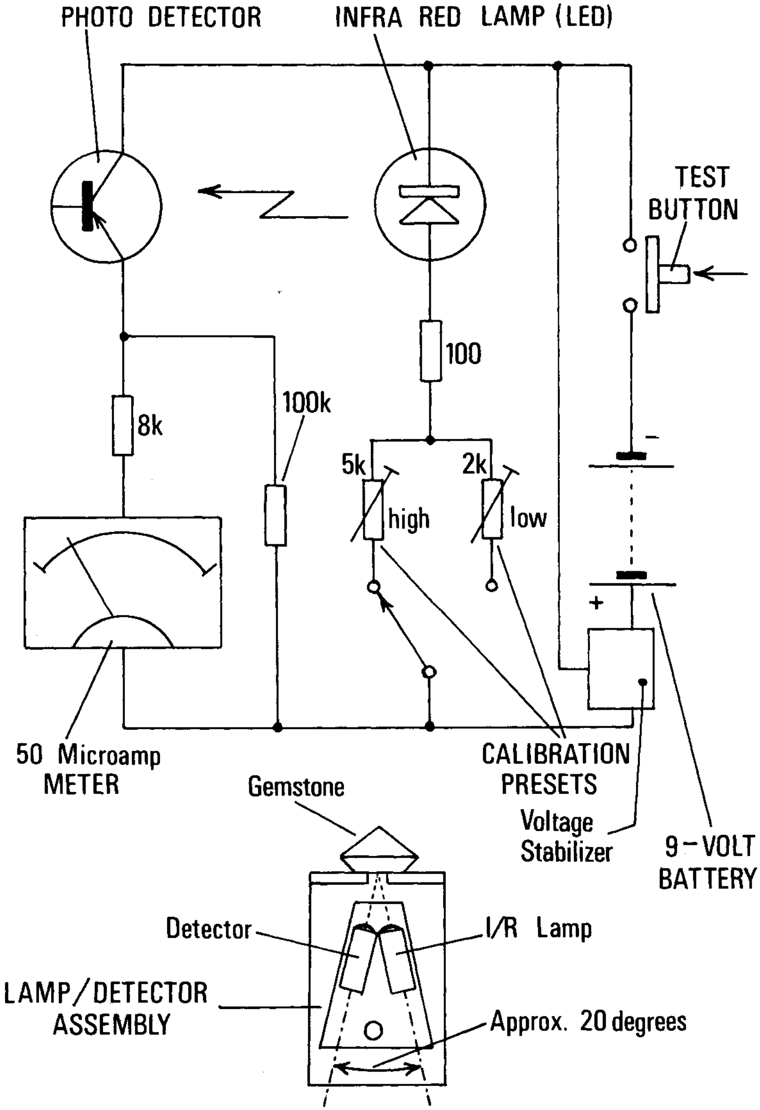


FIG. 2. 'Jeweler's Eye' circuit diagram.

readings independent of both battery voltage level and ambient lighting (Figure 5). This has been done by stabilizing both the voltage fed to the electronic circuits and the current supplied to the infrared source. Protection from the effects of ambient light is achieved by modulating the infrared beam and using the same modulation to decode the output of the detector. Even so, the manufacturer advises that the gemstone under test be shielded from strong light.

The Tatsumi 'Diamond Tester' (Figure 6) is a Japanese reflectivity meter made by the Japan Institute of Gemological Science, and is similar to the Hanneman instruments in design and operation.

While these instruments are very convenient for checking gemstones whose RIs are above the range of the critical angle refractometer, they cannot compete with the accuracy or amount of information that can be extracted from the standard refractometer. It is not possible for instance, to measure double refraction, optical character or optical sign on the reflectivity meter.

Before leaving the subject of reflectivity and refractive index, there are two items of interest which are relevant to the critical angle refractometer. For some years Rayner offered special versions of their refractometer which were fitted with 'glasses' made of synthetic spinel, blende and diamond. The spinel 'glasses' opened up the scale and permitted more accurate readings and the blende and diamond versions allowed higher RI's to be measured. Of these three variants, only the diamond version is now made to special order.

With the appearance of the new diamond simulant, cubic zirconium oxide, having an RI of 2.18 and a hardness of 8.5, it is now theoretically possible to make a refractometer 'glass' which is less expensive than diamond and which would give the refractometer the advantage of both an extended scale and a durable test surface. If such a refractometer is marketed, and if the chemists could be persuaded to produce a non-toxic contact liquid with an RI in the region of 2.2, this would provide a very useful scale extension, enabling readings to be taken on YAG, zircon, sphene and the high-reading garnets.

While it is possible to measure a gem's dispersion on a refractometer by using a monochromator to supply blue and red light at the B and G Fraunhofer wavelengths, not many gemmologists have such an instrument available. However, the measurement of dispersion has been made to an accuracy of 0.001 using interference filters. Mr Suhner, who reported his work in 1977 in the journal of the German Gemmological Association, used standard interference filters of 480nm and 654nm. Although interference filters are expensive, the size needed for the light port of a standard refractometer is small and the provision of two interchangeable filters would make a useful optional extra. Alternatively, such filters could be inserted sequentially into the light path between the refractometer glass and the eyepiece.

There are now many microscopes, particularly of the stereo zoom variety, which have been developed specifically for the examination of gemstones and the grading of polished diamonds. Recently we have seen a move towards a microscope design which is more convenient for immersion work. When inspecting the interior of a gemstone, particularly when using the higher magnifications, trouble is often experienced because the illuminating light is reflected back from the facets of the stone, thus making it difficult to see into the stone. Dark-field illumination often overcomes this problem, but when difficulties are experienced with facet reflections, these can be eliminated by placing the gemstone in a glass immersion cell and filling the cell with a liquid having a refractive index somewhere near to that of the stone. In some commercial microscopes, the lens assembly has been designed so that the light path of the objective is horizontal. This is done to facilitate the use of a deep immersion cell, which allows the stone holder to be inserted into the cell vertically.

The Eickhorst Gemmoscope (Figure 7) is an example of a microscope which has been developed so that its optical head can be used either with a conventional vertical objective stand or with one designed for horizontal work. In the horizontal-format, the light source can be pivoted radially round the stone holder to give light-field, dark-field or incident illumination. The immersion cell stage is provided with controls for vertical and horizontal alignment and a third control rotates the stone holder. The stage can also be fitted with a polarizing filter attachment. Two controls are positioned at the side of the stand for focus and light intensity adjustment. An adaptor is also available which enables the G.I.A. Gemolite optical head to be fitted to the horizontal stand.

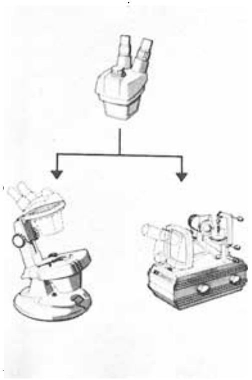


FIG. 7. Eickhorst 'Gemmoscope'.

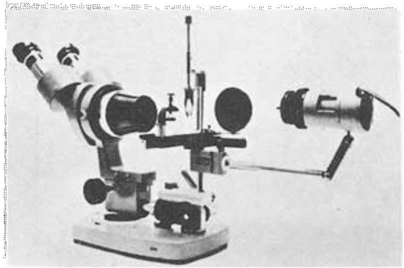


FIG. 8. Krüss model KA8 microscope.

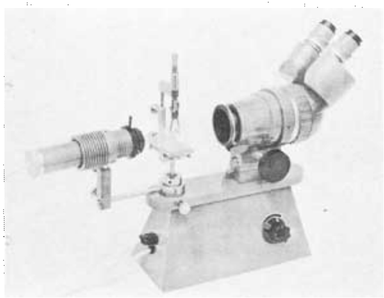


FIG. 9. Hans Günter Schneider model SZ1 microscope.

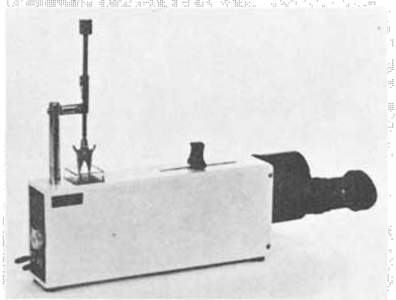


FIG. 10. Krüss portable model KA4 microscope.

FIG. 11. Krüss portable model KA4 microscope.

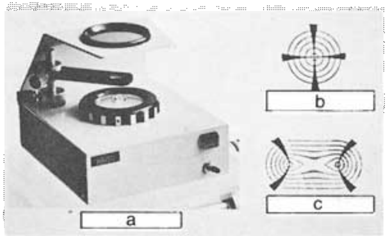


FIG. 12. Krüss combined polariscope and konoscope, and interference patterns.
(a) Polariscope with konoscope attachment
(b) Double refraction, uniaxial
(c) Double refraction, biaxial

Horizontal-format microscopes are also available from Krüss and from Hans-Günter Schneider (Figures 8 and 9). An interesting variant made by Krüss is the portable version KA-4 (Figures 10 and 11). This can be supplied in a carrying case with a full range of accessories including a tripod stand, a dichroscope eyepiece and a selection of immersion fluids. The light source is powered by rechargeable batteries.

Another new instrument by Krüss (Figure 12) is a combined polariscope and konoscope which, in addition to the usual light source and polarizing filters, includes a converging lens. This lens enables the optical axis of gems to be made visible by means of interference patterns.

I want to review now the latest instruments and techniques used in the 'fingerprinting' of diamonds. One of the problems with the buying and selling of diamonds is that the buyer often requires a certificate with his purchase (particularly if it is an unmounted stone bought for investment purposes). Such certificates are issued by many organizations and grading laboratories, and vary from a simple authenticated statement of the diamond's colour and clarity grading and weight, to a dossier of sophisticated tests and measurements. Such a certificate not only acts as an assurance to the buyer of the stone's worth, but, if it contains sufficient detail, can be used as a method of identifying that particular stone should the need ever arise.

Means of irrefutably proving a diamond's identity is also very much in the interest of insurance companies, police, and jewellers themselves, who could become involved in disputes over gems left for re-setting or cleaning. There have been many claims made over the years for special methods of 'fingerprinting' diamonds so that they can be positively identified. One commercial equipment that has reached the market and has been put into use by retail jewellers is the Gemprint (Figure 13). This instrument was invented and developed at the Weizmann Institute of Science in Israel, and is exclusively manufactured by Kulso Ltd, of Haifa. The North American marketing rights for the Gemprint were granted to Mr W. Levine, of Chicago, who founded Gemprint Ltd to establish a central registry of identifications for every gem recorded by Gemprint instruments.

In the Gemprint the scientists and engineers at the Weizmann Institute have used a laser to produce a pattern of reflected and refracted light spots, which is unique to each gem. The instrument records on film the unique pattern of light spots caused by minute and individualistic differences in symmetry and polish on a stone's facets.

The basic components of the Gemprint machine (Figure 14) are:

1. A small low-power laser
2. Shutter
3. First lens
4. Polaroid film holder
5. Pinhole screen
6. Second lens
7. Adjustable gemstone holder.

Light generated by the laser passes through a polarizing filter and a shutter, and is then focused by the first lens onto the pinhole screen. Laser light passes through the pinhole to the second lens which provides a parallel light beam. When the gemstone is placed in this beam, reflections and refractions from the facets return through the lens and appear on the front (gem) side of the pinhole screen (Figure 15). The gem must be positioned in its holder so that the reflection from the gem's table is directed into the pinhole. As there is only one position in which this reflection can be orientated with the pinhole, this enables subsequent prints of the same gem to be matched with the original. When the gemstone is correctly positioned, a recording of the spot pattern is made using Polaroid film on the pinhole screen.

A fingerprinting technique using a modified version of Nomaski interference contrast has been developed by Diamond Grading Laboratories Ltd, of Hatton Garden. This system uses a special form of microscope illumination in which the surface contrast of a diamond's facets can be enhanced to a point where both its surface features and the underlying crystal structure can be made clearly visible. Photographic records of these unique features are used as a means of identifying individual diamonds.

Another technique which can be included under the heading of fingerprinting has been developed commercially by the Okuda Jewelry Technical Institute Co. Ltd, of Tokyo. It is radically different from the gemprint method in that it identifies a polished diamond by printing an individual code on the table facet of the diamond. This code, which includes the diamond's colour grade,

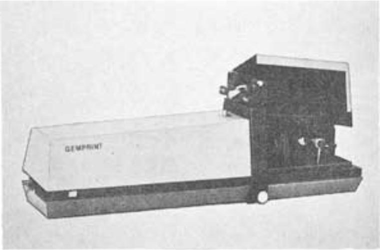


FIG. 13. 'Gemprint'.

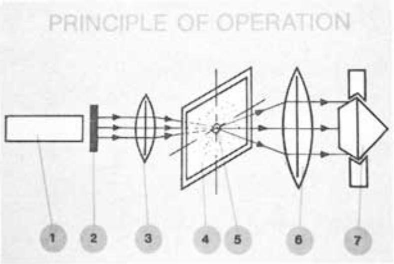


FIG. 14. 'Gemprint'—principle of operation.

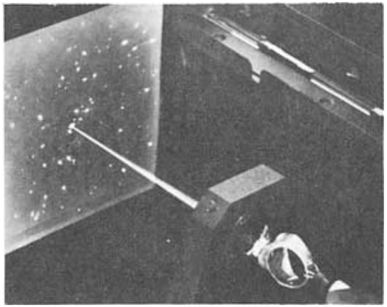


FIG. 15. 'Gemprint'—laserlight returns through lens to screen.

FIG. 16. 'SPD' (Scientifically Printed Diamond).

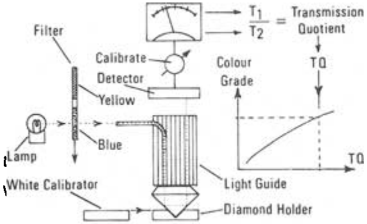


FIG. 17. Eickhorst colorimeter (diagram).

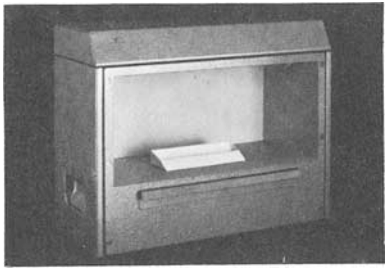


FIG. 18. 'Koloriskop G & S' grading lamp/cabinet.

clarity grade, and carat weight, is printed into the surface of the diamond using a metal fusion process. The printed code can only be made visible by means of a microscope having a 400× magnification and using special illumination. It is applied to the surface of the diamond's table by means of photomask etching techniques as employed in the semiconductor industry. The table is first coated with a photo-sensitive emulsion, and the code characters from a microfilm are exposed onto this surface. Grains of a special metallic preparation are deposited on the exposed area and are fused into the diamond's surface. Finally the emulsion layer is dissolved away, leaving behind the fused metallic code letters. The printing process takes about two hours.

The printed code (Figure 16) is only 1-1.5nm thick, and the width of the printed characters is 500nm. The fingerprinting method is called S P D (Scientifically Printed Diamond) and is backed by a comprehensive group which includes a grading committee, certifying organizations, qualified distributors and affiliated retailers. As the metal fusion process is specific to diamond it cannot be physically applied to simulants, so that its presence on a stone alone proves that it is a diamond. Each diamond bearing the printed code also has a serially numbered diamond card carrying the same identifying information.

As 'fingerprinting' relies on those features and characteristics that are unique to a particular diamond, it is relevant to include the instrumental measurement of colour as one of these features. There are three basic methods of determining the colour of diamond. Two of these rely on the measurement of the light absorption characteristics of diamond, and the third analyses the nitrogen content of Cape series diamonds.

Using one of the two light absorption measuring techniques, the Eickhorst Diamond Photometer and the now obsolete G.I.A. Shipley colorimeter are examples of commercial instruments designed specifically for measuring the degree of yellowness in Cape series stones. The appearance of yellowness in such a diamond is caused by absorption lines at the blue (415.5nm) end of the spectrum.

The Eickhorst colorimeter uses monochromatic yellow and blue light to compare the absorption of the diamond at these wavelengths. As can be seen in the diagram (Figure 17), the yellow and blue light is directed, in turn, into the table facet of the diamond by means of a glass-fibre light guide. Use is made of the optics of the brilliant-cut stone to achieve total internal reflection of the sampling light, which is then collected as it emerges from the table facet by a second concentric light guide. The output of this second light guide is fed to a photo detector which is connected to a meter to indicate the intensity of the yellow and blue light. These two intensities are called T1 and T2, and the ratio of these two figures is called the transmission quotient (by taking the ratio of T1 and T2, the effects of path length differences in diamonds of different size are cancelled out). The transmission quotient number is then converted to the appropriate diamond colour grade by means of a graph on the front of the instrument. Before each measurement is made, a white calibration plate is placed under the fibre optic head (in place of the diamond), and the calibration controls are adjusted for a 100% transmission reading on the meter. In the MkII version of the Diamond Photometer, the meter is to be replaced by a digital readout.

One of the problems with the measurement of diamond colour by using the yellow/blue absorption ratio is that it takes no account of the bluish fluorescence which may be stimulated in a diamond by the UV content in white light. Diamonds which fluoresce blue in white light will therefore appear to have a whiter body colour than indicated by the instrument. With instruments such as the Eickhorst and the G.I.A. Shipley colorimeter, it is necessary first to check each diamond for fluorescence under a UV lamp before inserting it in the colorimeter. This, however, is more a problem of colour grading than of colour measurement for 'fingerprinting' purposes.

Having touched on the subject of colour grading, I will briefly mention the new Koloriskop grading lamp (Figure 18), originally developed from a specification by Dr Gübelin and Mr Schiffmann. It comprises a colour grading cabinet which is fitted with fluorescent tubes having a colour temperature of 5000K, and meets the ISO Standard 2243 which has been considered by C.I.B.J.O. for the colour grading of diamonds.

The other method of quantifying the body colour of a diamond is to measure its entire absorption spectrum by means of a spectrophotometer. For 'fingerprinting' purposes, this gives a unique set of spectral absorption lines and can be used for diamonds of any colour. The Zeiss PM1D (Figure 19) is an example of one of the simpler spectrophotometers and covers the range of 320-750nm. The Zeiss PMQ3 (Figure 20) is an example of the more complicated research version. It is capable of measuring absorption characteristics from 180nm to 3000nm with a combination of light sources and monochromators. Its output can also be connected to a computer. An earlier and modified version of the PMQ3 is installed in the Idar-Oberstein laboratory of the German Gemmological Association. An adaptation of a Zeiss spectrophotometer is also used by Diamond Grading Laboratories Ltd to colour-grade Cape series diamonds to very fine limits.

One of the nore unusual research methods of measuring the 'yellowness' of a Cape series diamond is to analyse its nitrogen content. Following research into fundamental diamond characteristics at the Diamond Research Laboratory, Johannesburg, in the 1950s, the Director of Research, Dr J. F. H. Custers, proposed that the existing classification of diamonds into nitrogen-contaminated Type I and the purer nitrogen-free Type II should be further subdivided into Type I, Type IIa and Type IIb, the latter to include nitrogen-free diamonds which contain aluminium in their structure. Because of the aluminium impurity in the Type IIb's these diamonds possess semi-conductor properties and are thus capable of passing an electric current. Subsequent work showed that both nitrogen and aluminium affect the body colour of diamond. Nitrogen absorbs light at the blue end of the spectrum, and causes the yellow tints which are seen in the Cape series, and aluminium in the rare Type IIb diamonds produces the natural blue stones as obtained fron the Premier mine at Cullinan near Pretoria, South Africa.

For a while there appeared to be a conflict of data, as it was known that some Type I diamonds existed which contained relatively large amounts of nitrogen, but which were of top colour and not a deep yellow as experimental results implied. It was then found that there were two ways in which nitrogen atoms are grouped in the diamond lattice. If the nitrogen content of the diamond is low, the nitrogen atoms are dispersed throughout the crystal lattice, and produce a yellowish body colour. However, if the nitrogen content is high, the majority of the nitrogen atoms are not dispersed in this manner but are grouped together in small clusters of atoms called 'platelets'. These have no effect on the diamond's colour as they only absorb light at the ultraviolet end of

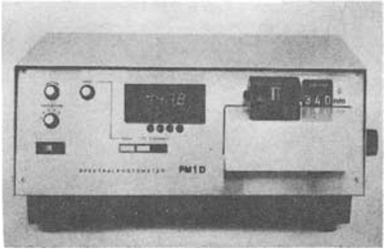


FIG. 19. Zeiss PM1D spectrophotometer.

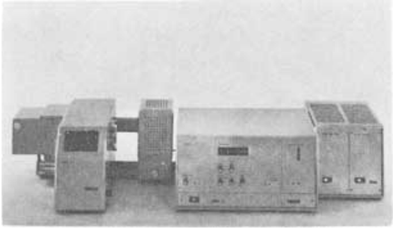


FIG. 20. Zeiss PMQ3 spectrophotometer.

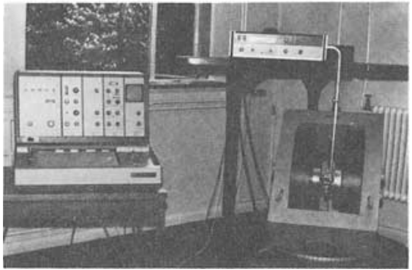


FIG. 21. Varian E109 spectrometer.

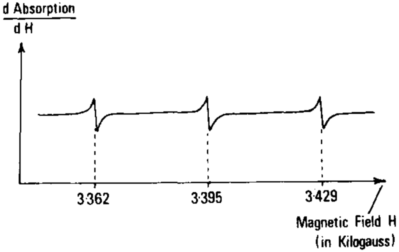


FIG. 22. Typical E.S.R. spectrum for diamond.

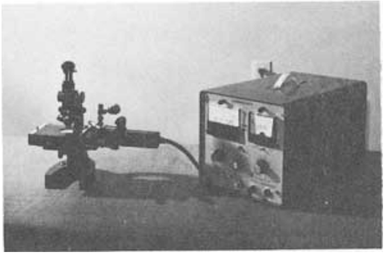


FIG. 23. 'Luminoscope'.

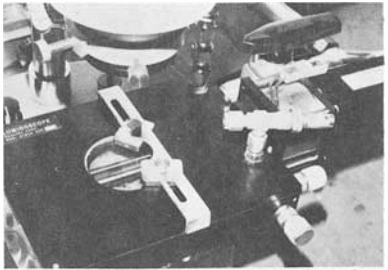


FIG. 24. 'Luminoscope' vacuum chamber and electron gun.

the spectrum. The colour of these diamonds is therefore due to the small amount of dispersed nitrogen and not the much larger amount of nitrogen in platelets. From this evidence, it was possible to subdivide Type I diamonds into Type Ia, which contains nitrogen mainly in platelets, and is the category to which the majority of natural diamonds belong, and Type Ib which is a much smaller group of diamonds containing nitrogen only in dispersed form.

The direct relationship between the amount of dispersed nitrogen in a diamond and the yellowness of that diamond was established at the D.R.L. by the use of an electron-spin resonance spectrometer, which provides a non-destructive means of measuring the amount of the dispersed nitrogen atoms in the diamond lattice. The carbon atom in the diamond lattice has a valency of four; that is, it has an electron orbital shell containing four electrons which enables it to link to four other carbon atoms to form a geometric crystal lattice. In Type I diamonds, each dispersed nitrogen atom replaces a carbon atom in the diamond lattice, and as nitrogen has a valency of five, this results in a free uncommitted electron associated with the nitrogen atom. This free electron behaves like a tiny bar magnet and, under the influence of the nitrogen nucleus, has distinguishing magnetic resonances in the 9.5 GHz microwave region of the electromagnetic spectrum. These resonances can be detected and quantified on the E.S.R. spectrometer.(1)

The Varian E109 spectrometer shown in Figure 21 is typical of a modern E.S.R. instrument and consists of three basic parts:

1. A magnet assembly, having a maximum field strength of 10 kilogauss, with a specimen module positioned in a cavity between the pole pieces.
2. A microwave generator/bridge. This contains a tunable klystron valve which generates the microwave energy, and a microwave bridge to detect the absorption of that energy by the specimen. The output of the microwave generator is fed to the specimen cavity in the magnet assembly.
3. A control unit which, among other things, enables the field of the magnetic assembly, and the scanning range over which the field is to be swept, to be adjusted. This unit also contains a chart recorder to plot the microwave absorption spectrum of the specimen and thus reveal (by

the level of absorption) the amount of nitrogen present in its lattice.

The E.S.R. spectrometer analysis is made as follows. First the diamond under test is placed in the specimen module, and the klystron in the microwave bridge is tuned to the resonant frequency of the magnet cavity. The bridge is then adjusted for an exact balance. For work on nitrogen defects in diamond, the resonance is adjusted to 9.5 GHz, the field strength of the magnet assembly is set to approximately 3.4 kilogauss, and the range over which the field is swept is set typically to ±50 gauss. When the test is run, the magnetic resonances in the nitrogen defects result in microwave energy being absorbed at characteristic field strengths as the magnetic field is swept across the scanning range. This absorption unbalances the microwave bridge, the unbalance being recorded as the vertical component on the chart. The amount of absorption, and hence the quantity of nitrogen and degree of yellowness in the diamond, is therefore indicated by the vertical deflexions in the recorded trace.

A typical E.S.R. spectrum for diamond is shown in Figure 22. The single differentiated peak in the centre is due to the spin resonance of the nitrogen electron, while the two outer responses are due to the modifying effect of the nitrogen nucleus on this resonance. The spectrum was taken with the magnetic field parallel with the cubic (100) plane. Spectra taken with the field parallel with the dodecahedral (110) and octahedral (111) planes show twin outer responses.

It is interesting to note that C. A. Schiffmann,(2) of the Gübelin Laboratory, Lucerne, used a prototype E.S.R. spectrometer in the laboratory of Beckman Instruments, Geneva, to distinguish between genuine sea-water pearls and cultured salt-water pearls having mother-of-pearl nuclei. The genuine pearls showed an almost flat E.S.R. trace containing low amplitude high-frequency 'noise', while the cultured pearls showed traces containing peaks of a much higher amplitude and lower frequency. The irregular absorption peaks in the latter were thought to be due to a small content of manganese.

Another research technique, which could have an application not only in diamond fingerprinting but also in the identification of gemstone simulants, uses the phenomenon of cathodoluminescence. This is the visible fluorescence produced when a beam of electrons strikes the surface of a specimen. The fluorescent display can yield much information about a specimen since both the colour and intensity are dependent on very small changes in the concentration of trace impurities, as well as on the matrix substance and the way in which the impurities are incorporated in the base material.

Cathodoluminescence is used in studies concerning the concentration of rare earths(3, 4) to six parts in one thousand million, the degree of perfection of synthetic crystals, and the identification of minerals in conglomerates.

The Luminoscope (Figure 23) manufactured by the Nuclide Corporation, U.S.A., is a compact instrument designed for use in the microscopic examination of cathodoluminescence. It consists of a specimen vacuum chamber and a control unit. The specimen chamber is flat enough to permit it to be placed on a microscope stage, but is still capable of taking a specimen up to 51 × 76 × 13 mm in overall dimensions. A 3 mm-thick lead glass window in the top and bottom of the chamber permits incident or transmitted illumination of the specimen under observation. A stage is provided for the specimen within the chamber and this can be indexed in the X and Y directions by means of two external controls.

The electron beam is generated by a low work-function cold cathode 'gun' mounted at the right-hand end of the chamber (Figure 24), which is pumped down to the relatively 'soft' vacuum of 15-25 millitorr ($1.5\text{-}2.5 \times 10^{-2}$mm of mercury). The gas ions produced in this soft vacuum leak away any static charges developed on non-conducting specimens. The control unit contains the E.H.T. supply for the gun cathode, which is variable from 0 to 18 kV. A current limit control is provided which can be adjusted from 8 microamps to 2 milliamps to set the current level at which the E.H.T. voltage is tripped off. A push button is provided which switches off the E.H.T. and turns on the microscope light to enable rapid alternate observation of the specimen under visible light or electron bombardment. Provision is also made for the control of a vacuum pump, which can be quite a small one as the pumping capacity and the vacuum requirements are modest. Chamber pressure is displayed on a meter which is fed from a transducer on the chamber.

The gun is fitted with collimating anodes, and an electrostatic lens electrode gives control of the electron beam focus via a knob on the control unit. The electron beam is guided and deflected downwards onto the specimen by means of a permanent-magnet deflexion assembly which can be moved laterally across the top of the chamber. When in use, the electron beam can either be defocused so as to irradiate a group of specimens, or it can be focused to a spot of approximately $4mm^2$ to energize a single stone.

The luminoscope shown in Figures 23 and 24 is the one in use in the Crystallography Department at University College, London. It is used there to investigate the cathodoluminescence (CL) properties of diamonds, and to act as a selector for diamonds having special features, which are them investigated in detail on a scanning electron microscope. Diamonds appear to be one of the most interesting minerals to be observed in CL. There is an indication that only diamonds with lattice imperfections can radiate visible CL, and that the particular colour produced suggests the type of defect. Natural Type Ia and IIb diamonds often show two contrasting shades of blue. The variation in shade in a specimen indicates a mixture of Type I and II material.

CL colour can be used for the detection and identification of many gem materials. It can also be used in quality control in the growth of synthetic crystals. By using a broad beam, parcels of mixed stones can be examined and sorted.

Finally, I should like to describe a research technique which is particularly relevant to the fingerprinting of diamonds, as it is entirely dependent on the internal crystal structure and lattice defects in the diamond, and is not affected by subsequent surface changes such as repolishing. Work done by Dr A. R. Lang and Dr G. S. Woods(5) in the H. H. Wills Physics Laboratory at Bristol University has demonstrated that x-ray topographic 'maps' of internal defects in a diamond's lattice can be used to identify a polished stone with the rough stone from which it was cut. This work has also shown that an x-ray topographic recording on film can serve to identify a polished gem even though it may have been recut. It is this aspect of x-ray 'fingerprinting' which is of particular interest to anyone who may become involved with disputes over the identification of polished diamonds.

Unfortunately, the equipment used to produce an x-ray topographic photograph of a diamond is both bulky and expensive. In the present state of the technique's development, it is therefore more in the province of the research laboratory than the grading

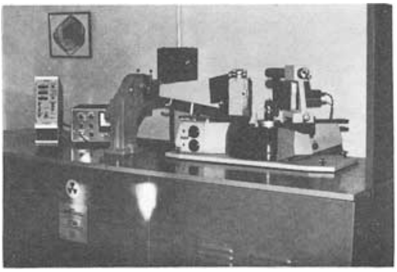


FIG. 25. **Bristol-Lang Topography Camera and GX20 Rotating Anode X-ray Generator.**

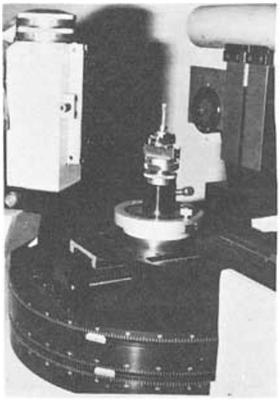


FIG. 26. **Bristol-Lang camera in more detail.**

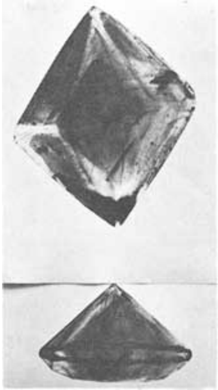


FIG. 27. X-ray topography photographs of a brilliant-cut diamond (below) and 1 ct rough (above) from which it was cut.

laboratory. Depending on the intensity of the x-ray source and the sensitivity of the photographic emulsion, the time taken to produce an x-ray topographic print may be hours rather than minutes. However, it is possible that further development of the equipment and the technique may reduce both the bulk and the time factors to a more practical level.

A suitable equipment for x-ray topography work is shown in Figure 25. The bulk of the equipment comprises a GX20 Rotating Anode X-Ray Generator, manufactured by the Neutron Division of Elliott Bros (London) Ltd, at Borehamwood. On the unit is mounted a Bristol-Lang Topography Camera. Figure 26 shows the Bristol-Lang camera in more detail. The camera consists of a spectrometer type table on which the angular positions of the specimen and the film holder can be adjusted relatively to the source. The source in this case is a vertical ribbon-like beam of collimated x-rays (10 to 100 microns wide) which emerge from the slit on the left-hand side of the diamond specimen.

The two most important x-ray topographic techniques for use in the fingerprinting of diamonds result in the production of a 'section' topograph and a 'projection' topograph. In the section topograph, the thin ribbon of x-rays is used to penetrate a slice of the diamond. The diamond is orientated so that the x-rays are diffracted by the atomic layers in the crystal lattice and emerge at an angle to the incident beam. The emerging x-rays fall on a photographic plate placed close to the diamond, but shielded from the direct beam. Any defects in the crystal lattice will deflect the beam more strongly and be recorded as darker areas on the photographic plate. A photographic record is therefore produced which reveals a pattern of crystal defects in the slice of the crystal penetrated by the x-rays.

In the projection topograph, the diamond and the frame holding the photographic film or plate are together moved backwards and forwards through the x-ray beam. In effect, the ribbon-like beam scans the whole of the diamond, and the image formed on the photographic plate is a parallel-beam projection of the internal lattice defects of the complete diamond.

Two typical x-ray topography photographs are shown in Figure 27. The upper photograph shows a series of lattice defects in a 1 carat rough diamond crystal of octahedral shape, and having no visible flaws. A large defect is seen in the upper half of the stone, with several needle-like defects crossing the large one and pointing towards the centre. In the centre of the stone is a nail-shaped defect. The lower photograph shows a polished brilliant-cut diamond produced from the rough stone in the top photograph. The brilliant has been cut from the upper part of the octahedron, and the large defect, the lines and the nail-shaped image are still clearly visible. From the photographs it is fairly obvious that no amount of re-polishing of the stone will remove these defects as they are within the body of the stone (this is shown by taking similar x-ray topographs in different directions).

It is fortunate that the refractive index of diamond is virtually unity at the x-ray wavelengths used for fingerprinting, as this removes any problems that might have been caused by irregular shape or surface roughness in the diamond specimen. Refraction of the x-ray beam may, however, take place if the technique is applied to other gemstones whose RI is considerably lower than that of diamond, and unless x-rays of an appropriate wavelength can be used this may restrict the technique to the fingerprinting of diamonds. Despite this drawback, x-ray topography has been used to distinguish natural from synthetic emerald.(6)

The absorption by diamond of the radiations used in x-ray topography is so low that even very large diamonds can be completely irradiated without the x-ray beam suffering excessive attenuation. Nor is there any damage done to the diamond by the radiation. Some diamonds have in fact been x-rayed so often that their accumulated x-ray dose would be equivalent to several hundred fingerprinting operations, and no detectable colour change has been produced.

I should like to close this review of instruments and techniques by looking to the future. We have already seen the use of electronic devices such as LEDs, photo transistors and integrated circuits in the new reflectivity meters. The most recent milestone in the history of electronics has been the emergence of the microprocessor. As these miniaturized computing elements become cheaper and more versatile, it is possible that an instrument, similar to a small hand-held calculator, could be produced containing a microcomputer which would give diagnostic information on gemstone constants and characteristics.

Already small home computers, built round the microprocessor, can be purchased for under £200. I am working at the moment on a computer program for such a unit which, when presented with a set of test readings, will compare these with the information in its memory and read out an identification. Alternatively, it can be made to read out all available data on a specific gem mineral. Such a diagnostic microcomputer as this can be regarded as an extension to the gemmologist's memory, leaving him (or her) free to apply skills and experience to best advantage.

REFERENCES

(1) Smith, W. V., Sorokin, P. P., Gelles, I. L., Lasher, G. T. Electron-spin resonance of nitrogen donors in diamond, *Physical Review*, September 1959.

(2) Schiffmann, C. A. Pearl identification: some laboratory experiments, *J. Gemm.*, 1971, **XII**, 7, 284-96.

(3) Kniseley, R. N., Laabs, F. C., Fassel, V. A. Analysis of rare earth materials by cathodoluminescence spectra excited in an electron microprobe, *Analytical Chemistry*, 1969, **41**, 1.

(4) Wickersheim, K. A., Buchanan, R. A., Sobon, L. E. Cathode luminescence as an analytical technique in the determination of rare earths in Yttria, *Analytical Chemistry*, 1968, **40**, 4.

(5) Lang, A. R., Woods, G. S. Fingerprinting diamonds by x-ray topography, *Industrial Diamond Review*, March 1976, 96-103.

(6) Schubnel, H.-J., Zarka, A. X-ray topography of a natural emerald and a synthetic emerald, *J. Gemm.*, 1971, **XII**, 7, 300-4.

GEMMOLOGICAL ABSTRACTS

Bank (H.), Banerjee (A.), Pense (J.), Schneider (W.), Schrader H.-W.). *Sogdianite—ein neues Edelsteinmineral?* (Sogdianite—a new gem material?) Z. Dt. Gemmol. Ges., **27**, 2, 104-5, 1978.

The mineral was found in the Wessel mine near Hotazel in the North Cape Province, South Africa. It was a violet centimetre-thick layer grown onto some black material and was shown to be sogdianite. E.S.

Bank (H.), Schmetzer (K.), Maes (J.). *Durchsichtiger, blau-rot changierender Korund aus Kolumbien.* (Transparent, blue-red changing corundum from Columbia.) Z. Dt. Gemmol. Ges., **27**, 2, 102-3, 1978.

The transparent, cut stone was blue with a trace of red when viewed in daylight, but intensive red in artificial light, i.e. it had a typical alexandrite effect. It was a natural corundum from Columbia. It showed surprisingly little pleochroism (dichroism). E.S.

Bill (H.), Calas (G.). *Color centers, associated rare-earth ions and the origin of coloration in natural fluorites.* Physics and Chemistry of Minerals, **3**, 117-31. 6 figs, 1978.

Optical absorption and EPR methods were used to study the cause of colour in natural fluorites. The colours observed were attributed to rare-earth ions and/or oxygen with formation of complex colour centres. Yttrium-associated F-centres gave blue, yttrium and cerium associated F-centres acting together gave yellowish-green, the (YO_2) centre gave rose and the O_{-3} molecule ion gave yellow. Colour is also given by divalent rare-earth ions such as Sm^{3+}, which gives green. Eu^{2+} gives a strong fluorescence. M.O'D.

Bläzek (M.C.). *Is your amber real?* Rocks & Min., **52**, 315-6, 1977.

In this general discussion of amber, tests are given for distinguishing between the true substance and common substitutes like copal, bakelite, and other plastics. Pressed and heat-treated amber (ambroid) is also considered. R.S.M.

Bukanov (V.V.), Platonov (A.N.), Taran (M.N.). *The colour of gem spinels from the Kukhilal deposit.* Zap. Vses. Min. Obshch., **106**, 565-71, 5 figs, 1977. (In Russian.)

Gem spinels occur in the Kukhilal deposit in magnesite marbles near their contact with migmatites and granitic gneisses. Mössbauer and optical absorption spectroscopy were used to study the colour of the spinels. They are chromian (rose) and Fe-Cr (rose-violet) varieties containing, respectively, Fe 0.1, 0.6; Cr 0.04, 0.004%. The intensity of colour is attributable to the amount of Fe and Cr present. R.A.H.

Cassedanne (J.-P.), Cassedanne (J.-O.). *La pétalite de Itinga (Minas Gerais).* (Petalite from Itinga, Minas Gerais.) Revue de Gemmologie, **55**, 14-16, 3 figs, 1978.

Petalite with an S.G. of 2.40, R.I. 1.504, 1.510, 1.516, birefringence 0.012, has been found in the Itinga district of Minas Gerais, Brazil. This material shows no orange luminescence as has been reported from other places, nor does it show the band at 454.0nm. M.O'D.

CHIKAYAMA (A.). *Natural and synthetic gemstones newly appeared after the 2nd World War.* J. Gemm. Soc. Japan, **1**, 32-42, 27 figs; Ibid, **1**, 65-70, 1974. (In Japanese with English summary.)

Gemmological properties and keys for identification of new gemstones, both natural and synthetic, which have been discovered or appeared in the gem market after the 2nd World War are described briefly, together with short descriptions of the histories of their discovery and syntheses. Descriptions are given of the following: brazilianite, amblygonite, greened amethyst, chrysoberyl cat's-eye and alexandrite from Brazil, Brazilian emerald, Brazilian opal, Brazilian (or Maxixe) aquamarine, taaffeite, sinhalite, ekanite, painite, chrome-diopside, Russian emerald, tugtupite, blue zoisite, grossular, rhodolite, Tanzanian corundum, chrome tourmaline, Manyara emerald and alexandrite, red tourmaline from Kenya, nephrite cat's-eye, green dyed quartzite. Also man-made diamond, synthetic ruby, synthetic red spinel, synthetic emerald, colourless synthetic stones for diamond imitation, Gilson turquoise, Gilson opal, synthetic alexandrite, synthetic blue quartz, synthetic citrine, synthetic amethyst. I.S.

FRIDJHON (Harold). *De Beers' new diamond mine in commission.* The Times newspaper, no. 60792, p.18, 29th August, 1978.

De Beers have commenced production on the Namaqualand coast where 810 000 tons of overburden will be stripped each month to reach the Koingnaas orebody, expected to yield over 500 000 ct yearly of good quality but small diamonds (average 0.25 ct.). Great planned expansion of the group's operations is reported, with increased production at Jwaneng, Letlhakane and Orapa in Botswana.

J.R.H.C.

FUJISAKI (Y.). *Identification of gemstones by means of x-ray transmission (x-radiography).* J. Gemm. Soc. Japan, **4**, 4, 11-23, 15 figs, 1977. (In Japanese with English summary.)

Reviews the use of x-rays in general gem testing and discusses the interpretation of intensity photographs using the Sakura PDA-81 intensity meter. X-lide is the name given to a new apparatus which measures this intensity. The apparatus is claimed to be able to identify diamonds and their imitations, whether mounted or unmounted, imitation and natural coloured stones, natural and cultured pearls and composite stones. M.O'D.

GÜBELIN (E.J.), MEYER (H.O.A.), TSAI (H.-M.). *Natur und Bedeutung der Mineral-Einschlüsse im naturlichen Diamanten.* (Nature and significance of mineral inclusions in natural diamonds.) Z. Dt. Gemmol. Ges., **27**, 2, 61-101, 18 coloured photomicrographs, 6 diagrams, 13 tables, bibl. of 101 items, 1978.

Several minerals occur as inclusions in natural diamond. The historical identification and significance are discussed as well as relevant mineralogy and major element chemistry. Division of inclusions into primary (pre- or syngenetic) and secondary (epigenetic) is considered as is also the subdivision of primary inclusions into ultramafic and eclogitic suites. The relation of diamond inclusion research to the understanding of the genesis of diamond and the formation of kimberlite and associated xenolites, and to the mineralogy of the upper mantle, is revised. Certain results have been ascertained. (1) Most of the primary mineral inclusions are small, mono-mineral homogeneous crystals whose morphology is dependent on the crystal structure of the host diamond. (2) Many inclusions are similar to those minerals occurring free in the accompanying kimberlite or xenolites, but show in detail to be of different chemical composition. (3) The difference in the chemical composition between the mineral inclusion and the free minerals in the kimberlite is mainly additional chromium in the inclusion mineral. (4) There are two quite definite groups of mineral inclusions, the ultramafic and the eclogitic, and they never occur in the same diamond. (5) Based on the chemical composition of the inclusions and on the values of the trace elements, it could be assumed that the diamond and its mineral inclusions in the primary stage have crystallized from a melt which corresponded either to a lherzolite or an eclogite. (6) Pressures and temperatures of the diamond genesis as calculated from research of the inclusions lie within the field of stability of the diamond and correspond generally with the stability-temperatures of the xenolites in the kimberlite. As proof for this could be mentioned that diamonds crystallize in the upper mantle between 150-200km, and not during the genesis of the kimberlite. (7) Future research should be directed towards the determination of isotope quantities in the inclusion, solving the date of genesis of the inclusion and the host mineral, showing details of the diamond genesis and occurrences in the upper mantle. E.S.

JENSEN (K.E.). *Minerals which look like jade.* Rocks & Min., **52,** 551, 1977.

Among minerals often resembling jade are serpentine ("bowenite"), vesuvianite ("californite"), grossular, amphibole ('smaragdite"), chrome mica ("verdite"), and prehnite. R.S.M.

KAGAYA (B.). *Fingerprint of diamond.* J. Gemm. Soc. Japan, 2, 51-61, 10 figs, 1975. (In Japanese with English summary.)

Two-circle goniometric measurements of many brilliant-cut diamonds have demonstrated that there is not a single stone which gives exactly the same ϱ, ι values of facets. This is naturally expected, since diamonds are cut manually. Probability calculations have shown that the probability of two stones having exactly the same ϱ, ϕ values for 8 bezel facets is 2.13×10^{-27}. Therefore, the ϱ, ϕ values of bezel facets can be used as a method for fingerprinting cut stones. A new reflection theodolite goniometer is designed to diminish time required for goniometric measurements. It is possible to measure a stone with this goniometer in less than 15 minutes. I.S.

KOMATSU (H.), AKAMATSU (S.). *Differentiation of black pearls.* Gems and Gemology, **XVI,** 1, 7-15, 15 figs in colour, 1978.

Title refers to naturally coloured black pearls *cultivated* in the very large black-lipped pearl oysters (pinctada margeritifera) produced with some difficulty on a small scale off the Nipponese Islands of Yaeyama and off Fiji and Tahiti. Authors show that photographing black cultured pearls on infrared colour-film allows these naturally coloured blacks to be differentiated from those made by staining with silver nitrate by their image colours. The stained pearls give a lighter and greener image while the natural blacks give darker and bluer images on this type of film. Stained pearls are also said to be more brittle than the natural blacks. (Abstracter believes that other stains are also in use to blacken cultured pearls. Have authors investigated these?) R.K.M.

KRAUS (P.D.). *Opal and tourmaline; birthstones for October.* Lapidary Journal, **30**, 7, 1609-24, 1976.

Both stones are reviewed with summaries of their properties, main locations and references to the literature. Tourmaline crystals are illustrated in colour.

M.O'D.

LOWELL (J.), RYBICKI (T.). *Mineralization of the Four Peaks amethyst deposit, Maricopa County, Arizona.* Mineral. Record, **7**, 72-77, 7 figs, 1976.

Large gem-quality crystals of amethyst have been found with colourless and smoky quartz, fluorapatite, and specular hematite in a fault breccia in Mazatzal quartzite, on the southernmost peak of the crest of the Mazatzal Mountains, Maricopa County, Arizona. G.W.R.

MEDENBACH (O.), SCHMETZER (K.), KRUPP (H.). *Spessartin aus den Taita Hills, Kenia.* (Spessartine from the Taita Hills, Kenya.) Aufschluss, **29**, 275-6, 1978.

A spessartine variously coloured yellow, orange-red or reddish brown has been found in the area of Salt Lick Lodge in the Taita Hills of southern Kenya. MnO content was measured at 31.2%. M.O'D.

MEIXNER (H.), PAAR (W.). *Ein Vorkommen von Väyrynenit-Kristallen aus 'Pakistan'.* (An occurrence of väyrynenite crystals in 'Pakistan'). Zeitschrift für Kristallographie, **143**, 309-18, 3 figs, 1976.

Gem quality rose-red crystals of the beryllium manganese phosphate väyrynenite were seen at Chitral, West Pakistan, in a bazaar. Physical and chemical constants agree with those for mineral which was previously known from a pegmatite vein in Finland. M.O'D.

MIURA (Y.). *Labradorescence.* J. Gemm. Soc. Japan, **4**, 4, 3-11, 11 figs, 1977. (In Japanese with English summary.)

The writer has studied the iridescence of labradorite and found that gem-quality material from deep-seated plutonic and metamorphic rocks shows periodic lamellar structure. Colour changes over the range ultraviolet to near infrared depend on anorthite content, according to the Bøggild rule. Labradorescence depends upon this lamellar structure. M.O'D.

MUMME (I.A.). *The Little River Sapphire lease.* Australian Gemmologist, **13**, 6, 177-9, 182-5, 1978.

Abridged report largely concerned with historical notes on an area originally worked for gold. Sapphire interest developed only in past 20 years. Topographic and geological information given. R.K.M.

MUMME (I.A.), BALL (R.A.). *Notes on sapphires from stream gravels at Frazer's Creek in Glen Innes area, New South Wales.* Australian Gemmologist, **13**, 6, 173-6, 5 figs, 1978.

The sapphires are often dark, patchy with strong colour-zoning about the *c* axis. Some stones can be made lighter in colour by heating to 1500°C in an oxidizing atmosphere. Figures show surface structures without explanations. Gallium is present in greater amounts than were found in a previous analysis. A separately headed spectrophotometric list at the end of the paper needs further explanation if it is to substantiate the findings of the text. R.K.M.

NASSAU (K.). *Comment on 'Water as a gemological tool'.* Lapidary Journal, **32**, 2, 580, 1978.

Discredits the reports by Hanneman (Lapidary Journal, **31**, 12, 2576-8, 1978, abstracted J. Gemm., **XVI**, 4, 275, 1978) and Tjwan (Lapidary Journal, **23**, 624, 1969, and J. Gemm., **XI**, 6, 205-10, 1969) on the grounds of carelessness and misapprehension of the nature of the material used. M.O'D.

NASSAU (K.). *The origins of color in minerals.* Am. Miner., **63**, 219-29, 8 figs, 1978.

Discusses crystal field theory, molecular orbital theory, band theory and various operations of physical optics giving colour in minerals; among these are diffraction, scattering, dispersion and interference. M.O'D.

NASSAU (K.), PRESCOTT (B.). *Growth-induced radiation-developed pleochroic anisotropy in smoky quartz.* Am. Miner., **63**, 230-8, 7 figs, 1978.

Anomalous pleochroism has been observed in smoky quartz crystals grown on seeds cut parallel to the face of the minor rhombohedron. Smoky means irradiated in this context. The anomalous pleochroism is attributed to site-selective distribution of Al ions during growth on minor rhombohedral faces. Charge compensation with other ions may also occur. M.O'D.

PABIAN (R.K.). *Inclusions in agate and their origins and significance.* Gems & Gemology, **XVI**, 1, 16-28, 17 figs in colour, 1978.

Author has studied similarities and differences in over 3900 agates from ten New World and one African source. There are similarities between agates from widely different localities but the paper is largely a precis of the various and sometimes conflicting opinions of other authorities on the interesting subject of agate formation. The colour plates are excellent but cannot possibly illustrate the information and pattern variations in so large a sample. Agates are essentially three dimensional and it is not easy to interpret modes of formation from the two dimensional pattern seen at the polished surface of a usually random section.

R.K.M.

PETERSEN (O.V.). *The twin formation of tugtupite; a contribution.* Mineralog. Mag., **42**, 251-4, 4 figs, 1978.

Tugtupite is a member of space group $I_{\bar{4}}$ and belongs to the crystal class 42m. Pseudotrigonal contact triplets are described. M.O'D.

QUIGLEY (Desmond). *Total of 173 diamonds* [sic] *so far in CRA's Australian strike.* The Times newspaper, no. 60 400, p.24, 7th September, 1978.

Conzinc Riotinto of Australia disclosed the discovery (by Ashton Joint Venture group in the Kimberley Region of Western Australia) of 173 ct of diamonds (largest about 3.3 ct), but it was not known to what extent they were of gem quality. They were recovered during the first stage of tests involving taking samples of about $100m^3$ from the surface of each hectare of those kimberlite pipes judged to be of potentially economic size, some $1918m^3$ having been treated so far. J.R.H.C.

SCHUBNEL (H.-J.). *Le diamant en Inde.* (Diamond in India.) Revue de Gemmologie, **55**, 11-13, 7 figs, 1978.

Describes the working of the diamond mine at Majhgawan in the Panna district of India with some remarks on the commercial handling of the production. M.O'D.

SUNAGAWA (I.). *Gem fingerprinter.* J. Gemm. Soc. Japan, **2**, 62-5, 1975. (In Japanese with English summary.)

In connexion with the article by B. Kagaya on gem fingerprinting by means of goniometry, a new apparatus of gem fingerprinting recently devised by the Weizmann Institute, Rehovot, Israel, is critically described. The apparatus is based on the same principle as Kagaya's method, but a laser beam is used and the rotation methods are original. I.S

SUNAGAWA(I.). *Cubic zirconia.* J. Gemm. Soc. Japan, **4**, 3, 14-19, 3 figs, 1977. (In Japanese with English summary.)

Describes physical properties, polymorphism and compares cubic zirconia with diamond. Growth by the skull-melting technique is reviewed. M.O'D.

TAKUBO (J.). *Refractive indices and specific gravities of beryls.* J. Gemm. Soc. Japan, **4**, 3, 3-8, 7 figs, 1977. (In Japanese with English summary.)

Compares constants for natural and synthetic beryls and discusses the effects of high temperatures, high pressures and impurities. Water pressure applied during manufacture has a marked effect on the refractive indices and specific gravity of synthetic beryls. Using a high pressure technique a synthetic emerald with constants as high as those for the natural material can be made. M.O'D.

TAKUBA (H.), KOIZUMI (M.). *Specific gravity, refractive indices and depth of formation of natural emeralds.* J. Gemm. Soc. Japan, **4**, 4, 24-33, 4 figs, 1977. (In Japanese with English summary.)

It was found that specific gravity increased with increase in refractive index and that deviation from the curve (postulated by the Lorentz-Lorentz law) depended upon the amount of inclusions present. Emeralds from schists and some from pegmatite deposits showed higher refractive indices than any synthetic material. Stones from vein deposits and metasomatic-type deposits have constants similar to hydrothermally-grown stones and higher than flux-grown emeralds. Emeralds with high specific gravity and refractive indices occur in those schists and granitic pegmatites where granite and ultrabasic intrusives are found. High-pressure experiments assuming that load pressure and water pressure are equal show that schist-type stones from Pakistan, India, South Africa and Rhodesia are formed in a region deeper than 60 km, that stones from Colombia and Brazil (vein- and metasomatic-type) are formed in a region shallower than 30 km and that stones from Austria, Tanzania, the Urals and Zambia were formed at an intermediate depth. M.O'D.

TAKASU (S.). *Synthetic gemstones . . . principles and methods.* J. Gemm. Soc. Japan, **1**, 24-31, 10 figs, 1974. (In Japanese with English summary.)

The basic problem of finding an appropriate method to grow synthetic crystals for gem purposes is discussed, using garnet as an example. Representative methods for single-crystal growth are reviewed briefly, which include slow cooling, Bridgman, Verneuil, pulling, zone melting, flux, hydrothermal, vapour growth, and high-temperature-high-pressure methods. The methods for synthesizing polycrystalline gemstones such as opal and jadeite are also discussed. There are many potential gem materials among those which have been originally developed for semiconductor or optoelectronic purposes. I.S.

TATSUMI (T.). *On the refractive and reflective indices in identifying a gemstone.* J. Gemm. Soc. Japan, **2**, 105-9, 5 figs, 1975. (In Japanese with English summary.)

Since the refractive index is a function of reflective index, an instrument has been designed to measure high refractive index using the value of reflectivity. Measurement on several gemstones with high refractive index by this instrument showed that they could be identified, provided that they had a refractive index > 1.81. I.S.

TOMBS (G.A.). *Heat treatment of Australian blue sapphires.* Australian Gemmologist, **13**, 6, 186-8, 4 figs, 1978.

Sapphires sliced in order to have one half as control. The other half raised to white heat (2300°F) for short periods of time. Surfaces tended to melt. Colour became greener and there was some loss of pleochroism and some improvement in clarity in certain stones. Author is more concerned about detection of treated stones than with colour improvement and gives little information on the latter aspect. (The paper is spoiled by characteristic printers' errors, which make nonsense of part of the text.) R.K.M.

WEBER (R.H.). *Turquoise in New Mexico.* Ann. Rept. New Mexico Bur. Mines Min. Resrcs., 1974-1975, 25-8, 1 map, 1975.

The principal deposits of turquoise in New Mexico that have been sources of significant production are the Cerrillos district, Santa Fe County; the Burro Mountains and Eureka (Hachita) districts, Grant County, and the Orogrande (Jarilla) district, Otero County. Minor occurrences have been recognized in the White Signal and Santa Rita districts, Grant County, the Organ district, Dona Ana County, and the Nogal district, Lincoln County. Deposit characteristics, turquoise physical properties, history, and production for each of the above districts are discussed. J.E.T.

WILSON (W.E.), DUNN (P.J.). *The Kalahari manganese field.* Mineral. Record, **9**, 3, 137-53, 38 figs (9 in colour), 1978.

This field lies in the northern part of Cape Province, Republic of South Africa, and produces, among many varied mineral species, exceptional crystals and crystal groups of rhodochrosite. The mines chiefly concerned with rhodochrosite are the N'Chwaning and Hotazell mines. From the former come fine groups consisting of individual scalenohedrons ranging from rich pink to deep orange-red; from the Hotazell mine rhodochrosite is deep rose-red to yellowish-pink. Stones are fetching from US $30.00 to US $60.00 a carat. M.O'D.

Pitiable condition of Rajasthan emerald mines. Gem World, **4**, 9, 33-4, 1977.

Production is said to be 500 g per year compared with 10 kg some years ago. Kala Guman in the Udaipur district is said to be the best of the mines but is at present filled with water which hinders the open-cast workings. New sources of emerald have been found at Tikhi and Goan Guda in the same district. M.O'D.

BOOK REVIEWS

ALT (D. D.), HYNDMAN (D. W.). *Roadside geology of northern California.* Mountain Press Publishing Co., Missoula, Montana, 1978. pp.xii, 244. Illus. in black-and-white. $6.95.

This is an authoritative and well-produced book which sets out to describe geological features in simple terms. The authors are members of the Department of Geology at the University of Montana and present the subject in areas defined by the main roads of the state—these appear as running heads so that the reader can see at once which area is being discussed. Photographs are good and maps clear. Much of the area described is of interest to gemmologists since many of the beaches yield pebbles of jade and agate. M.O'D.

ALT (D. D.), HYNDMAN (D. W.). *Roadside geology of the northern Rockies.* Mountain Press Publishing Co., Missoula, Montana, 1978. pp.280. Illus. in black-and-white. $6.95.

A companion book to *Roadside geology of northern California,* this includes such interesting areas as the Butte and Coeur d'Alene mining districts, as well as the Yellowstone National Park. Layout is similar to that in the other volume. M.O'D.

BARSANOV (G. P.), YAKOVLEVA (M. E.). *Mineralogiya Yashm SSSR.* (Jasper minerals in the U.S.S.R.) (In Russian.) Akademiya Nauk SSSR, Moscow, 1978. pp.86. 56 figs (15 in colour). 95 copecks.

A short guide which gives the occurrences and composition of the types of jasper found in the U.S.S.R. There is a short bibliography. M.O'D.

BLANKENBURG (H.-J.). and others unspecified. *Quarzrohstoffe.* (Rough quartz.) VEB Deutscher Verlag für Grundstoffindustrie, Leipzig, 1978. pp.243. Illus. in black-and-white. M47.

This book gives a useful survey of the properties and synthesis of quartz with good illustrations of both the natural and synthetic material. Details of occurrences and methods of recovery are given and there is a bibliography. M.O'D.

BRUTON (E.). *Diamonds.* 2nd edn. N.A.G. Press, London, 1978. pp.xiv, 532. 548 illus. in black-and-white: frontispiece and 16 other pages in colour. £12.50.

In a review (April 1971) of the first edition of 'Diamonds' in this *Journal* it was averred that the book possessed 'the quality and dimensions of a future classic', and in its new and greatly enlarged form that tribute is shown to be fully justified. Bound, as before, in the somewhat unusual Royal octavo format, it now contains no fewer than 160 extra pages as well as a further 218 text illustrations, and with the heavy glazed paper used to ensure good reproductions of the fine range of photographs the volume now weighs more than three pounds avoirdupois. An attractive innovation is the addition of sixteen pages in colour. These are unnumbered and unlisted and presumably derive from photographs taken by the author during his extensive travels in the diamond fields together with several showing very successfully the appearance of fluorescent diamonds under ultraviolet light.

The chapter headings remain the same, though each section contains additional material, except that between the former chapters 19 and 20 a new one has been inserted on 'Famous Diamonds'. Other and useful features are the additional references given at the end of most chapters and a 'Glossary of Terms' at the end of the book.

Much of the new material concerns information on the newly-opened diamond mines and developments in the techniques of prospecting, mining and recovery. The author's personal experiences in visiting so many of the main diamond localities during recent years has added to the authenticity of his descriptions, while the long list of authorities from whom he has sought and obtained information and illustrative material testifies to the immense pains he has taken to make the book both accurate and (for the lazy-minded) attractive to browse through as a picture-book on the subject.

Developments in the grading of cut diamonds have also received full treatment. The international committee conveniently known as C.I.B.J.O., which has replaced the old B.I.B.O.A., has now produced its own grading system, which takes its place beside the very successful G.I.A. and Scan. D systems. Some of the wisest and most helpful pages in Mr Bruton's book concern the valuation of diamonds and their importance to the public as a form of investment. The true perspective provided in these pages has been very much needed. A diagram prepared from data provided by A. Monnickendam Ltd, which is reproduced on page 341, shows the alarmingly steep increase in the selling price of investment quality diamonds even over the short period since 1964.

On the more scientific side, the successful production in Switzerland, America and Russia of cubic zirconia (marketed as 'Djevalite', 'Phainite' etc.) in recent years has provided the most formidable contender so far for the 'similarity to diamond' award, and a full description of its properties and those of other synthetics of high refractive index is naturally to be found in this book, together with suggestions for their detection. Perhaps the most easily applied and most effective means to this end has been provided by a reflectivity meter designed by Dr W. W. Hanneman and named by him the 'Diamond Eye'.While Mr Bruton names and illustrates the 'Diamond Eye', one feels he might have given rather more information about its use and added some cautionary remarks that the stone surface to be tested must be above a certain minimum diameter and be scrupulously clean if accurate readings are to be obtained. Another Hanneman product, an ingeniously designed beam balance which enables a hydrostatic determination of diamond or its substitutes (provided they are unmounted) to be made quickly and without calculation, is illustrated in a brilliantly conceived line drawing which shows with complete clarity and without the need for descriptive text how the apparatus is put into effect. The author remarks that 'another, but fussier, method is to use heavy liquids'. The reviewer can see nothing very 'fussy' about a trial in Clerici solution, provided this has been mixed to match the density of diamond. In such a solution quite tiny stones can be tested against a known diamond indicator and with an accuracy quite impossible with hydrostatic weighing. Incidentally, Mr Bruton claims that only sphene amongst those stones which resemble diamond at all plausibly in appearance has a density at all close to that mineral. While this is true for cut stones, experience in the Gem Testing Laboratory has shown that rolled pebbles of colourless topaz are not infrequently claimed as diamond by prospectors, who are misled by their considerable hardness and rather similar (3.56) density.

Still on the subject of density, in his chapter on the physical properties of diamond Mr Bruton quotes some interesting determinations on its specific gravity which made an astonishing claim to an accuracy of four of five places of decimals and to have shown that there is a significant difference between the density of Type I and Type II diamonds. Though the three workers concerned have names as Russian as could be wished, the author is wrong in assuming that this delicate work (employing Clerici solution with elaborate precautions) was carried out in the U.S.S.R. The investigation was actually done in the Massachusetts Institute of Technology and reported (in excellent English) in the *Journal of Applied Physics.*

One may be allowed to disagree with another small point, in this case concerning diamonds coloured green by exposure to radium salts or emanations, of which there are very few extant. Mr Bruton remarks that in these stones the residual radioactivity (by which they can readily be detected) 'is not harmful, as after treatment a diamond loses about half its radioactivity every ten minutes'. Such a rapid decay may be true of a diamond after cyclotron treatment, but since some radium treated stones retained appreciable activity after fifty years or more the decay cannot surely have been as rapid as all that.

The index, which of course is an important factor in a book of this kind, contains around 1300 entries and must thus be considered a good and full one. It was probably the law of cussedness that led the reviewer to look up 'density', 'dispersion' and 'lustre' and in each case fail to find an entry.

It will of course be realized that the above criticisms are matters of trivial importance. The fact remains quite clear that this is a book altogether worthy of its great subject. B.W.A.

GOODMAN (C. H. L.), ed. *Crystal growth: theory and techniques.* Vol. 2. Plenum Press, New York, 1978. pp.x, 191. Illus. in black-and-white and in colour. $29.00.

Part 3 of this useful book will appeal to gemmologists with the necessary background knowledge. It deals with the Verneuil process and lists the materials grown, with details of the various snags which have had to be overcome. Of special interest is the section on mechanisms inducing stress; coloured photographs illustrate isochromatics seen in thin sections of spinel, depicting the operation of stress. Other chapters in the book deal with silicon epitaxy, growth effects in the heteroepitaxy of III-V compounds and an additional note on subsidiary electrical heating for Verneuil furnaces in the U.S.S.R. M.O'D.

GRAMACCIOLI (C. M.). *Die Mineralien der Alpen.* (Minerals of the Alps.) Kosmos, Stuttgart, 1978. 2 vols, pp.503. Illus. in black-and-white and in colour. Dm120.00.

Collectors have long needed an authoritative work covering the whole Alpine region. Although many guides have been produced for various countries none have had the scope and quality of this one, which should be in every collector's library. Several preliminary chapters introduce minerals, their composition and classification, and minerals are then followed through the rest of the book in traditional order, beginning with the elements. Many important species have their typical crystal form illustrated in coloured diagrams; photographs include the size of specimen depicted; species described have constants given down to space groups. Each chapter includes a short bibliography. The quality of the photographs is excellent—all those depicting actual specimens are in colour. M.O'D.

GÜBELIN (E. J.). *Im Edelstein eingeschlossen.* (Trapped in a gemstone.) Kirschgarten-Druckerei AG, Basel, 1978. Unpaged. 12 coloured plates. Price on application.

This set of 12 photographs forms part of a calendar from which it is detachable, enabling it to be used as a book. The photographs are taken from the author's *Innenwelt der Edelsteine (Internal World of Gemstones)* but are on a slightly larger scale. This is indeed a beautiful production and an original conception. M.O'D.

HAMMONS (L.). *Mineral and gem localities in Arizona.* Arizona Maps and Books, Sedona, Arizona, 1977. pp.112. Illus. in colour. $5.95.

The book consists of 30 coloured maps giving details of gem and mineral locations in Arizona. A list of minerals is appended to each map. Introductory notes mention brief details of specimens likely to be found. M.O'D.

HANAUER (E.). *Rocks and minerals of the western United States.* Barnes, New York: Yoseloff, London, 1976. pp.237. Illus. in black and white and in colour. £5.50.

Each state is discussed and the important mineral locations illustrated by a sketch-map. The directions given could possibly lead the searcher directly to the mineral required but they are not really sufficiently precise, nor are the notes on the species themselves. The coloured illustrations are of poor quality. M.O'D.

HOCHLEITNER (R.). *Mineralien Kompass.* (Mineral guide.) Gräfe und Umser Verlag, Munich, 1978. pp.79. Illus. in colour. Dm8.80.

A pocket-sized guide to the commoner minerals, this can be recommended on account of the excellence of the coloured illustrations. Chemical composition, hardness, specific gravity, cleavage, occurrence, locality and colour are given for each example as is the actual size of the specimen shown. There is a short glossary and a bibliography. M.O'D.

HOLFERT (J.). *A field guide to topaz and associated minerals of Topaz Mountain, Utah.* New revised edn. Published by the author, Bountiful, Utah, U.S.A., 1978. pp.66. 10 figs. Price on application.

An excellent pocket-sized guide to one of the well-known U.S. localities for topaz. Maps and photographs illustrate the area; together with topaz Mn-bearing red beryl, pseudobrookite, garnet and bixbyite are found. M.O'D.

KALDIS (E.), ed. *Current topics in materials science.* Vol. 1. North-Holland Publishing Co., Amsterdam, 1978. pp.xi, 761. $(U.S.)115.50.

The opening chapters deal with crystal growth and its associated problems with special reference to alkali halides; chapters 4 and 5 cover semiconducting materials and chapter 6 new work in high-temperature chemistry. Both chapters 7 and 8 deal with lithium niobate and Nb-H alloys and chapters 9 and 10 with non-stoichiometry. References are given after each chapter and there is a materials index. M.O'D.

LIEBER (W.). *Der Mineraliensammler. 7 Auflage.* (The mineral collector. 7th edn.) Ott Verlag, Thun, 1978. pp.314. 112 figs, 24 plates (16 in colour). Price on application.

This seventh edition of an old favourite is enlarged and contains more coloured plates than its predecessors. It covers the same ground, geology, mineralogy, the formation and classification of crystals, fashioning of gemstones and descriptions of the more important minerals and gems. The section dealing with localities (especially West Germany) is amplified by maps and the list of museums and the bibliography have been brought up-to-date. Since the book still remains the only general guide to the mineral localities of the world it would be good to see a translation into English. M.O'D.

MICLEA (I.), BLEAHU (M.). *Cristalele Romaniei.* (Crystals of Romania.) Editura Sport-Turism, Bucharest, 1977. pp.xiv, 33. 89 figs (all in colour). Lei 80.

Coloured illustrations of Romanian minerals include opal, beryl, garnet and amber. Short descriptions are given. M.O'D.

ROBINSON (G.), ALVERSON (S.). *Minerals of the St Lawrence Valley.* Published by the authors, Potsdam, New York, 1971. pp.42. Illus. in black-and-white. $2.50.

This small book describes 25 localities in the state of New York with short notes on 15 others. The important sites of DeKalb (diopside), the St Joseph Lead Mines (fluorescent minerals) and the titanite location at Fine are included. There is a short bibliography. M.O'D.

ROOIJMANS (C. J. M.), ed. *Crystals for magnetic applications.* Springer, Berlin, 1978. pp.139. Illus. in black-and-white. Dm58.00.

This is the first in a new series entitled 'Crystals; growth, properties and applications.' The aim, according to the publishers, is to present critical reviews of recent developments in the field of crystal growth with special reference to techniques, mechanisms and theories. This present volume includes chapters on the growth of magnetic garnets from high-temperature solutions, on the hydrothermal crystallization of magnetic oxides, on the growth of magnetic single crystals by the Bridgman technique and on gadolinium gallium garnet—the first general review of this important substance.

It is interesting to see that the author of this chapter believes that GGG is the most perfect single crystal material currently being grown; earlier difficulties with coloration and with dislocations have been identified and to a great extent eliminated. Since gallium oxide is expensive, other materials have been considered as possible replacements for GGG—the only possible one so far seems to be the compound $Ca_3Ga_2Ge_3O_{12}$. M.O'D.

RUPPENTHAL (A.) *Wunder aus dem Reich der Mineralien.* (Wonders of the mineral Kingdom.) Ruppenthal (KG), Idar-Oberstein, 1973. pp.88. Illus. in colour. £8.50.

The text of this beautifully-produced book is in German but this should not deter the prospective purchaser. Designed to show off the range of minerals sold by this celebrated German firm, it succeeds in presenting fine quality specimens, arranged chemically, with details of composition, hardness, specific gravity and, by no means least, the actual size of the piece shown. M.O'D.

SCHLEE (D.), GLÖCKNER (W.). *Bernstein und Bernstein-Fossilien.* (Amber and amber fossils.) Stuttgarter Beiträge zur Naturkunde, Series C, 8. Staatliche Museum für Naturkunde, Stuttgart, 1978. pp.72. 26 figs. (16 colour). Price on application.

This is the best-illustrated work on amber that this reviewer has seen. The various areas from which the material can be obtained are discussed and the 16 coloured plates illustrate the inclusions, mostly insects, that can be found. Simulants and testing are covered and there is a bibliography. The emphasis is scientific rather than decorative. M.O'D.

SPERO (S.A.). *Diamonds, love and compatibility. (So you think you've got a gem!)* Exposition Press, Hicksville, N.Y., 1977. pp.119. $7.50.

An attractive and amusing book which sets out to link the sale of diamond (cut) to the personality of the female buyer or wearer. Notwithstanding the title there is quite a lot of commonsense in the book, and it is recommended to counter salesmen. M.O'D.

STALDER (H. A.), EMBREY (P.), GRAESER (S.), NOWACKI (W.). *Die Mineralien des Binntales.* (Minerals of the Binntal.) Naturhistorisches Museum der Stadt Bern, Bern, 1978. pp.143. 28 plates (5 in colour), 53 figs. Price on application.

This is an up-to-date account of the minerals of the Binntal, a famous mineralized area of Canton Valais, Switzerland. It is especially noteworthy for the sulpho-salts found at the quarry of Lengenbach and these minerals are given extensive treatment. The arrangement of the book is alphabetical by name of mineral; there is a bibliography and excellent photographs in black-and-white and in colour. M.O'D.

STRASSER (A.). *Salzburger Mineralogisches Taschenbuch.* (Mineralogical pocket-book for the Salzburg area.) Eignverlag Strasser, Salzburg, 1975. pp.85. Maps. Price on application.

The first section lists minerals alphabetically, referring them to their localities which are themselves described in the second section. The third and fourth sections provide a glossary and list of mineral species arranged alphabetically and giving their chemical composition. Various tables and maps complete the book which should be obtained by those intending to visit the areas described. M.O'D.

TAIT (H.), GERE (C.). *The jeweller's art: an introduction to the Hull Grundy gift to the British Museum.* British Museum Publications, London, 1978. pp.23. 48 figs (16 in colour). £3.95.

The Hull Grundy gift to the British Museum covers the period 1700-1930 and thus includes a number of art nouveau pieces which are illustrated in this short catalogue. The collection also includes some gold boxes of high quality, tortoiseshell, Berlin ironwork, 'botanical jewellery' and toys. The collection formed the subject of an exhibition during the latter part of 1978 and a full catalogue is promised. M.O'D.

TAYLOR (G.), SCARISBRICK (D.). *Finger rings from ancient Egypt to the present day.* Lund Humphries, London, 1978. pp.100. Illus. in black-and-white and in colour. Price on application.

This attractive book is the catalogue to an exhibition of the same title held at the Goldsmiths' Hall and later at the Ashmolean Museum during 1978. Many of the pieces illustrated and described come from two collections, those of Sir John Evans and of Charles Drury Fortnum. The introduction deals with the history of these collections, and notes on the specimens themselves are left to the individual entries. The whole catalogue is excellently produced and the black-and-white reproductions are especially clear. M.O'D.

VAUGHAN (D. J.), CRAIG (J. R.). *Mineral chemistry of metal sulfides.* Cambridge University Press, Cambridge, 1978. pp.xv, 493. £19.50.

The lucidity of this excellent book makes it worth while for the student to consult if not buy it. Students of any type of mineral will profit by reading the chapters on electronic absorption and reflectance spectra in particular, but other chapters are equally interesting. A bibliography is provided at the end of each section, and appendices give mineralogical data for the materials covered in the text and other information on the sulphides. M.O'D.

WADIA (M.D.N.). *Minerals of India.* 3rd rev. edn. National Book Trust, New Delhi, India, 1976. pp.xi, 224. R 11.25.

A general description of the types and whereabouts of minerals in India with a chapter devoted to gemstones, in which diamond, ruby, sapphire, chrysoberyl, garnet and zircon are discussed. M.O'D.

International opal journal. Impart Publishers, Reno, Nevada, U.S.A., 1977. pp.76. Illus. in colour. $2.95.

The first of this attractively-produced journal contains articles on the formation, buying, history and photography of opal. The many coloured illustrations are of high quality. So far this is the only issue produced (as at July 1978) and the publishers, in a communication to the reviewer, state that it is now to be issued annually. M.O'D.

ASSOCIATION NOTICES

GORDON F. ANDREWS—AN APPRECIATION

The sudden death on 5th January 1979, of Gordon Andrews, aged 66, secretary of the Gemmological Association from 1939 until his retirement in 1973, which was reported briefly in the January issue of this *Journal*, will have deeply shocked all who knew him.

I first met Mr Andrews in 1932 when he was introduced to the gemmology class at Chelsea Polytechnic as 'the Tully Medallist for 1931'. He and I were almost exactly the same age, but it was quite a few years before I lost the awe which the phrase inspired at that time, despite acquiring the same award myself two years later.

It was entirely fitting that Gordon should have been among the first to gain gemmology's top honour, for he had started his business career in the Bond Street shop originally owned by B. J. Tully, in whose memory the medal is awarded. Tully died in 1928 and I am not sure whether Mr Andrews ever actually knew him, but he certainly worked for Mrs Tully and with J. H. Stanley, one of the early instructors on the G.A. Correspondence Courses. In 1931 he was with Hunt & Roskell Ltd, of Old Bond Street, part of the J. W. Benson organization.

A serious minded, intelligent, quietly spoken and very personable young man, Gordon Andrews was an obvious choice to succeed E. Trillwood as secretary to the National Association of Goldsmiths in 1939. As most readers will know, the N.A.G. was the parent of the Gemmological Association and they shared offices, staff and secretary from the earliest days. The G.A. was eventually given an entity of its own, but the same arrangement held good in respect of staff and accommodation. Mr Andrews organized this change of emphasis in 1947 and later applied for letters patent and commissioned the designing of a suitable coat of arms for our Association.

After War service with the R.A.F. he returned to run both Associations from a sequence of offices and eventually from neat prefabricated premises on a bomb-site behind Goldsmiths' Hall. In 1955 both Associations moved to their present home at Saint Dunstan's House, Carey Lane, EC2. Meanwhile Gordon Andrews had launched the *Journal of Gemmology* in 1947. He remained its editor until his retirement. Later he formed the marketing company, Gemmological Instruments Ltd, which provides the retail outlet for the Rayner range of instruments. In his N.A.G. capacity he masterminded the big Clearing House Scheme which has proved so beneficial in retail accounting. He became a member of the Institute of Chartered

Secretaries and was even more qualified for the important trade position he was to occupy for so many years. Throughout those years he was ably and loyally assisted by the brothers, Harry and Douglas Wheeler, all three working as a team to bring the various innovations to successful fruition. Mr Harry Wheeler succeeded Mr Andrews as secretary.

Gordon was one of the founders of the Retail Jewellers' Course which was started initially as a rehabilitation measure for service men returning to the Trade after the War. He acted as instructor on this Course from its inception, retaining this interest and an advisory editorial interest in our *Journal* even after he had retired. He was a Liveryman of the Worshipful Company of Goldsmiths.

Taking an early retirement, largely for family reasons, he went to live in Norfolk. It is perhaps the more tragic that his death came at a time when he and Mrs Andrews were literally on the point of going to Australia to join their son, Nigel.

Gordon Frederick Andrews, always a highly respected man, was a good friend to a great many people. He contributed enormously to the well-being and development of the gem trade both here and overseas. I feel proud and, indeed, honoured to have known him for nearly 45 years. He will be greatly missed. I am sure that all readers will join in expressing sincere sympathy to Mrs Margaret Andrews and her family at this sad loss.

R. Keith Mitchell.

OBITUARY

Mr Douglas J. Ewing, F.G.A. (D.1945), Edinburgh, died suddenly on 13th March, 1979. He had been a member of Council for 25 years. Mr Ewing started evening classes in gemmology in Edinburgh in 1947 and was an instructor for many years. He was also responsible for establishing the Edinburgh Branch of the Association.

Mr Clive J. Taylor, F.G.A. (D.1973), Gravesend, died on 29th November, 1978.

Mr Edward R. Robson, F.G.A. (D.1973), Nairobi, Kenya, died on 29th December, 1978.

MEMBERS' MEETINGS

London

On Monday, 12th March, 1979, at the Central Electricity Generating Board Theatre, London E.C.1., Mr Alan Hodgkinson, F.G.A., gave a talk based on his article 'Visual Optics' (J.Gemm., **XVI**, 5, 301, 1979).

Midlands Branch

On Saturday, 27th January, 1979, a dinner and dance was held at the Allesley Hotel, Coventry.

On Friday, 23rd February, 1979, at the R.I.C. Headquarters, Birmingham, Mr E. A. Jobbins, B.Sc., F.G.A., gave an illustrated talk on the ruby and sapphire deposit of Pailin, Cambodia.

On Thursday, 22nd March, 1979, at the R.I.C. Headquarters, Birmingham, a film entitled 'Gem Fun and You' was shown. The film covered an introduction to gem collecting, gem-making tools used in cutting and polishing, and ways in which they are used. Following the film Mr D. Price, F.G.A., a prominent stone cutter, and Mr D. Morgan, F.G.A., former Branch Chairman and noted lapidary and teacher of gemmology, gave demonstrations and answered questions arising from the film.

North-West Branch

On Saturday, 3rd February, 1979, a buffet supper dance was held at the Shaftesbury Hotel, Liverpool.

On Thursday, 15th March, 1979, at Church House, Hanover Street, Liverpool, a selection of diamond simulants was available for examination by members.

South Yorkshire Branch

On Thursday, 25th January, 1979, the Annual General Meeting of the Branch was held at Sheffield City Polytechnic, Sheffield. Dr M. W. Eldridge, F.G.A., was re-elected Chairman and Mr B. Butler, F.G.A., elected Secretary. This was followed by a practical session when specimens were available for examination and discussion.

NEWS OF FELLOWS

In January, 1979, Mr A. E. Farn, F.G.A., of the London Chamber of Commerce Gem Testing Laboratory, was interviewed in the B.B.C. radio programme 'World at One' on djevalite and asked to compare it with diamond.

On the 12th February, 1979, a seminar was held at the Rudyard Hotel, Manchester, organized by Openshaw Technical College in collaboration with Mr A. Hodgkinson, F.G.A.

During September and October 1978 Mr M. J. O'Donoghue, M.A., F.G.S., F.G.A., led a mineralogical tour to Norway, Sweden, Finland and the U.S.S.R., visiting a number of famous localities (Kongsberg, Iveland, Evje, Långban, Outokumpu, etc.) and meeting museum curators in many places.

PRESENTATION OF AWARDS

Opening the proceedings at the annual Presentation of Awards in Goldsmiths' Hall on 20th November, 1978, the Chairman, Mr D. N. King, congratulated the candidates who had been successful in the Association's examinations, which this year had been held in no less than 32 countries as well as the United Kingdom. He welcomed those who had come to the Hall that evening to receive their awards, including a contingent from Spain, some from other European countries, America, the Middle East and Sri Lanka, and one each from Japan and New Zealand. He also welcomed the Association's distinguished guests, Mr Richard T. Liddicoat, Jr, (President of the Gemological Institute of America—himself a F.G.A.) and Dr W. W. Hanneman (also from the U.S.A.) as well as Miss Margaret Biggs, F.G.A. (President of the National Association of Goldsmiths).

Miss Biggs presented their awards to successful candidates in the Association's examinations and having performed this pleasant duty recalled that this year was for her a golden celebration in gemmology, for she had taken her examinations fifty years ago in that very Hall. At that time there was no Gemmological Association but only a gemmological section of the N.A.G.: the Association had been formed some time later and had since grown into an international organization of high repute.

Miss Margaret Biggs and Mr B. G. Amarasinghe (Sri Lanka).

Sir Frank Claringbull and Mr Norman Harper.

Dr W. W. Hanneman
with *(left)*
Mrs Jean Smith
and *(right)*
Mr B. W. Anderson.

Dr W. W. Hanneman and Mr Richard T. Liddicoat, Jr.

The president, Sir Frank Claringbull, then made a presentation of a silver 'Armada' dish engraved with the Association's coat-of-arms to Mr Norman Harper, recently retired from the Chairmanship for reasons of health. When he first started in gemmology, said the President, one young man's name kept on appearing—that of Norman Harper: he had trained as an artist, was educated in history, adept as a musician, had flown in races with the Royal Aero Club and had interests in many other activities and possessed many other skills, which he had demonstrated not only in the offices he held in the Association and in the N.A.G.—he became Chairman of both—but also in lecturing and promoting the education of their members. He obtained his Fellowship with distinction in 1934 (but was 'pipped at the post' for the Tully medal by Keith Mitchell) and in 1946 was awarded the Greenough Trophy by the N.A.G. At about that time he went to the School for Jewellers in Birmingham to take a refresher course and subsequently found himself appointed the senior lecturer in gemmology. He was a freeman of the Goldsmiths' Company and had made great contributions to raising the standards of the retail jewellery trade.

The Chairman, after explaining that Mr Harper, who was not in good health, had asked to be excused for not expressing his thanks and appreciation in public, then proceeded to the last item on the agenda, the presentation by Dr Hanneman of the Hanneman Awards—which he had instituted and named in memory of his father—for outstanding contributions to the literature of gems and minerals. Eleven trophies—a symbolic prospector's hammer mounted on a slice of agate—had been designed and made for him by a well-known American artist, although Dr Hanneman said he did not yet know who all the recipients would be. The first one was in honour of the work of the late Robert Webster and was received by his daughter, Mrs Jean Smith. The second was presented by Dr Hanneman to Mr B. W.

Anderson and the third to Mr Richard T. Liddicoat, who had made a special effort to be present in London to receive the award from another American!

In closing the proceedings the Chairman expressed the thanks of the Association to the Worshipful Company of Goldsmiths for allowing the use of their magnificent Hall for this notable meeting.

COUNCIL MEETING

At a meeting of the Council held on Wednesday, 31st January, 1979, it was agreed to appoint Mrs Mary Burland as Editorial Assistant, and the following were elected to membership:

FELLOWSHIP

Amendra (née Rubesinghe), Savithri P. K., Mount Lavinia, Sri Lanka. 1978
Armitage, Kevin P., Rotorua, N.Z. 1978
Bates, Adrian J., Sutton Coldfield. 1978
Birch, John W. de Gray, Hillcrest, Natal, S. Africa. 1978
Dillimuni, Dayananda, Colombo, Sri Lanka. 1978
Fuster Casas, Miguel, Barcelona, Spain. 1978
Horkel, Dorothea, Vienna, Austria. 1978
Kan, Neville Y. C., London. 1978
Seevaratnam, Nagalingam, Colombo, Sri Lanka. 1978
Stanislaus, Saverimuttu J. L., Colombo, Sri Lanka. 1978
Ueta, Kouji, Osaka, Japan. 1978
Vargas Perez, Manuel de, Barcelona, Spain. 1978
Yamaguchi, Takashi, Osaka, Japan. 1978

TRANSFERS FROM ORDINARY MEMBERSHIP TO FELLOWSHIP

Celades Colom, Roberto, Barcelona, Spain. 1978
Verduyn-Walter, Laetitia, Capelle, Holland. 1978

ORDINARY MEMBERSHIP

Barlow, Peter C., Kidderminster
Barnett, Paul A., Johannesburg, S. Africa.
Benguira, Daniel, London.
Boreen, Henry I., Rydal, Pa, U.S.A.
Bradley, Ivon, Chesterfield.
Carson, Constance, London.
Chan, Thomas C., Maidstone.
Christensen, Ove G., London.
Clare, Vanessa J., St Albans.
Cotton, Sarah N., Kitwe, Zambia.
Derry, Catherine E., Nottingham.
Dix, Neil R., Opio, France.
Donohoe, Edward, London.
Duke, Paul E., Singapore.
Emms. Eric C., Brentwood.
Fjordgren, Olle, Gothenburg, Sweden.
Fondyga, Eugeniusz W., Sutton Coldfield.
Forbes, Maureen, St Albans.
Freeman, Darlene M., Belmont, Ca, U.S.A.
Giannella, Donata, Rome, Italy.
Gunther, Bernhard, Basel, Switzerland.
Gustine, Richard R., Richmond, Va, U.S.A.
Hakamada, Tetsuo, Hokkaido, Japan.
Harada, Hirotaka, Tokyo, Japan.
Haria, Ashok P. M., Mombasa, Kenya.
Hirst, Rosalind, Johannesburg, S. Africa.

Horwitz, Stephen T., Atlanta, Ga, U.S.A.
Huges, James P., Launceston, Tasmania.
Joynt, James, Hereford.
Kessler, Paul, London.
Komahashi, Shinobu, Chiba City, Japan.
Lam, C. W., Hong Kong.
Lo, Tung Man, Kettering.
Lodhia, Babulal D., London.
Low, Teck K., Kuala Pilah, N. Sembilan, W. Malaysia.
Mai, Lionel, D'Heres, France.
McLerie, Robin E., London.
Medagoda, Alfred S., Maccesfield.
Metters, George H., Ascot.
Mountfort, Donald, Kingsford, N.S.W., Australia.
Moxon, Michael D., Palmerston North, N.Z.
Newman, Kathryn J., Tahunanui, Nelson, N.Z.
Noach, Louis, London.
Okamoto, Yoshitaka, Osaka, Japan.
Ow, Evelyn, Singapore.
Peel, Charles D., Midland, Tex., U.S.A.
Phillips, Ian, Nottingham.
Pickering, Caroline A., Nairobi, Kenya.
Pickett, David J., Southsea.
Price, Stephen A., Ipswich.
Rankin, Roderick W. G., Whangarei, N.Z.
Rapley, Michael J., Guildford.
Rosen, Elly, Brooklyn, N.Y., U.S.A.
Rumbold, Richard, St Leonards-on-Sea.
Samarajiwa, Eulalie, Reading.
Santiago-Gonzalez, Antonia, Tenerife, Canary Islands.
Sheffield, Martin, Don Mills, Ont., Canada.
Sideras, Triantafilio R., Nairobi, Kenya.
Silvant, John C.M., London.
Siroya, Bakhtawarmac B., Bombay, India.
Sivananthan, Chinniah A., Colombo, Sri Lanka.
Sjostrom, Bjarne J., Vallingby, Sweden.
Soni, Dinesh, Hounslow.
Sutton, Graham G., London.
Takahashi, Narifumi, Hiroshima City, Japan.
Tan, Carmela, Hong Kong.
Tarbuck, William B., Manchester.
Tateishi, Masateru, Tokyo, Japan.
Toughlouian, Gregoire, Chaville, France.
Verdiere, Jo, Kuurne, Belgium.
Wantanabe, Yoko, Hokkaido, Japan.
Win, Min Hla, Cupar.
Wong, Helen, Hong Kong.
Wu, Shun-Tien, Taipei, Taiwan.
Wyant, Harvey C., Lighthouse Point, Fla, U.S.A.
Yui Wai, Richard K., Hong Kong.

ANNUAL GENERAL MEETING

The Annual General Meeting of the Association will be held on Wednesday, 16th May, 1979, at 6.00 p.m. at Saint Dunstan's House, Carey Lane, London EC2V 8AB.

ETHYLENE DIBROMIDE—A WARNING

Ethylene dibromide (sometimes called ethylene bromide, dibromoethane, sym-dibromoethane, 1,2-dibromoethane, glycol dibromide or EDB) is commonly used by gemmologists as a heavy liquid (SG 2.188) or (owing to its low surface tension) in hydrostatic weighing. It is now listed by the National Institute for Occupational Safety and Health of the United States as a suspect carcinogen and rigorous precautions are suggested by the Institute for its use.

quantities are administered direct to the stomach, there is no evidence to date of any cases of cancer in man following exposure to it. Excessive acute or chronic exposure to EDB, however, can produce toxic effects in man, which can result from skin contact, inhalation of vapour, or, of course, swallowing. Care should therefore be taken in using ethylene dibromide (and also Clerici solution, and indeed any liquids other than clean water) to avoid skin contact or inhalation of vapour, and on no account should any of the liquids used by gemmologists for gem testing be swallowed.

In case of contact with the skin, it should be washed off: if in the eyes, they should be well flushed out with running water: if inhaled, move to fresh air: if swallowed, vomiting should be attempted and medical assistance obtained.

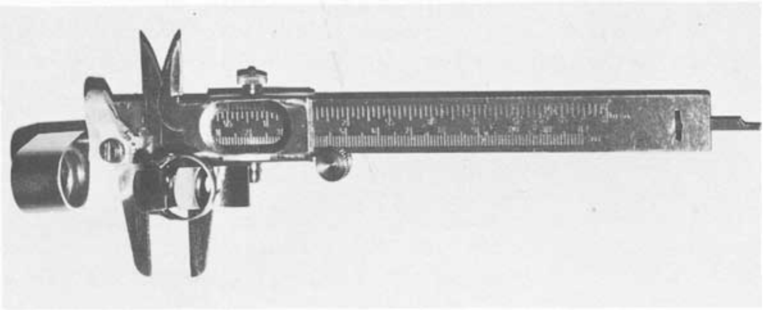
DEUTSCHE GEMMOLOGISCHE GESELLSCHAFT
2nd TECHNICAL CONFERENCE OF 1978

(Report received from Mr Peter G. Read, F.G.A.)

The Second 1978 Technical Conference of the German Gemmological Association was opened by the Association's President, Prof. Dr H. Bank, F.G.A., in the Diamond and Gemstone Bourse in Idar-Oberstein on Saturday, 30th September. This was followed by a talk on 'Methods of Geological Dating' given by Dr Klaus Hellmann, of the Nuclear Research Centre, Karlsruhe. In his talk, Dr Hellmann covered the various techniques of radio-active dating and discussed their relevance to the age determination of rocks and minerals.

This initial talk of the Conference was followed by a series of working and discussion meetings which were held in the well-equipped lecture rooms and laboratories of the new DGemG Gemmological Training Centre.

On Sunday, 1st October, Diplomas were presented to the successful graduates of the DGemG study courses by the President Prof. Dr H. Bank, and by Dr G. Lenzen. Dr Diehl then gave a talk on 'Djevalite, Phianite, Zirconia—what are they?' in which he described the Russian skull melting technique and the methods used to stabilize zirconium oxide in its cubic state. This was followed by talks on 'Automatic Weighing' by P. G. Read and on 'Gemstones of East Africa' by Dr K. Schmetzer.



After these three talks, H. Bartmann demonstrated a novel combination of vernier calliper gauge and hand lens which he had constructed to facilitate the measurement of refractive indices of both mounted and unmounted gemstones by the direct reading method. The illustration shows the device with a ring clipped in a spring holder. The apparent depth of the gemstone in the ring is measured by focusing the lens, via the calliper adjustment, first on the surface of the table facet, and then on the culet, and subtracting the two readings. The actual depth of the stone is measured directly, using, in the case of a mounted stone, an extension anvil fitted to the gauge head.

The final series of talks included short reports by W. Schneider on the 'Slocum Stone' and by D. Schwarz on 'Fluorescent properties of new diamond imitations'.

Among the faceted gem minerals on display were amethysts from Russia and Arizona and morganites from Brazil. Also shown were samples of cubic zirconium oxide crystals and several rock crystal specimens containing large pyrite inclusions.

ADDENDA

By way of clarification, Mr G. Bosshart would like to add three notes to his article 'Cubic Stabilized Zirconias' in J. Gemm., XVI, 4, 244-56, namely:

(1) The following to be added at the end of paragraph 3(c) on page 250 above, viz:

For obvious reasons a gemmological spectroscope, effective in the wavelength range of 400 to 700 nm, is of little aid in the differentiation between these nearly colourless solids. The yellow type of $(Zr,Ca)O_{2-x}$ absorbs totally below about 310 nm and the brownish-pink type below about 360 nm, which is roughly inverse to the behaviour of yellowish and faint pink $(Zr,Y)O_{2-x}$ as indicated in Table 1. For colourless $(Zr,Ca)O_{2-x}$, manufactured in Switzerland, total absorption starts near 260 nm as it does for $(Zr,Y)O_{2-x}$ of the Russian production, this minimum figure being valid for various hues of the faintest saturations (very weakly greenish, bluish, orangy, etc.).

(2) The label '$(Zr,Y)O_{2-x}$ colourless' in Fig. 1 on page 251 above to be replaced by '$(Zr,Y)O_{2-x}$ faint pink'.

(3) For the interested gemmological reader, the most comprehensive and latest article among modern papers on single crystals of cubic stabilized zirconia and hafnia may be mentioned, namely:

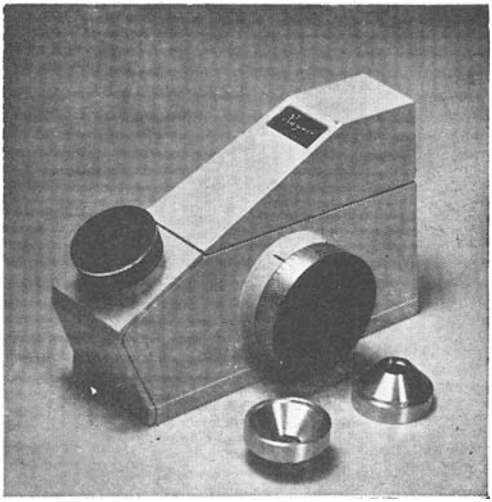
Alexandrov, V. I. *et al.* 1978. 'Synthesis and Crystal Growth of Refractory Materials by Radio-frequency Melting in a Cold Container', in *Current Topics in Materials Science,* vol. 1, pp.421-80. Amsterdam, New York, Oxford: North-Holland Publ. Co.

CORRIGENDA

On p.324 above, line 11, for 'The Rubyvale Sapphire Fields' (sub-heading) read 'The Rubyvale and Sapphire Fields'.

On p.331 above, lines 9 and 8 from foot of page, for 'back-how' read 'back-hoe'.

On p.349 above, second column, line 9, for '(Verduyn) Walter, Laetitia' read 'Verduyn-Walter, Laetitia'.



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