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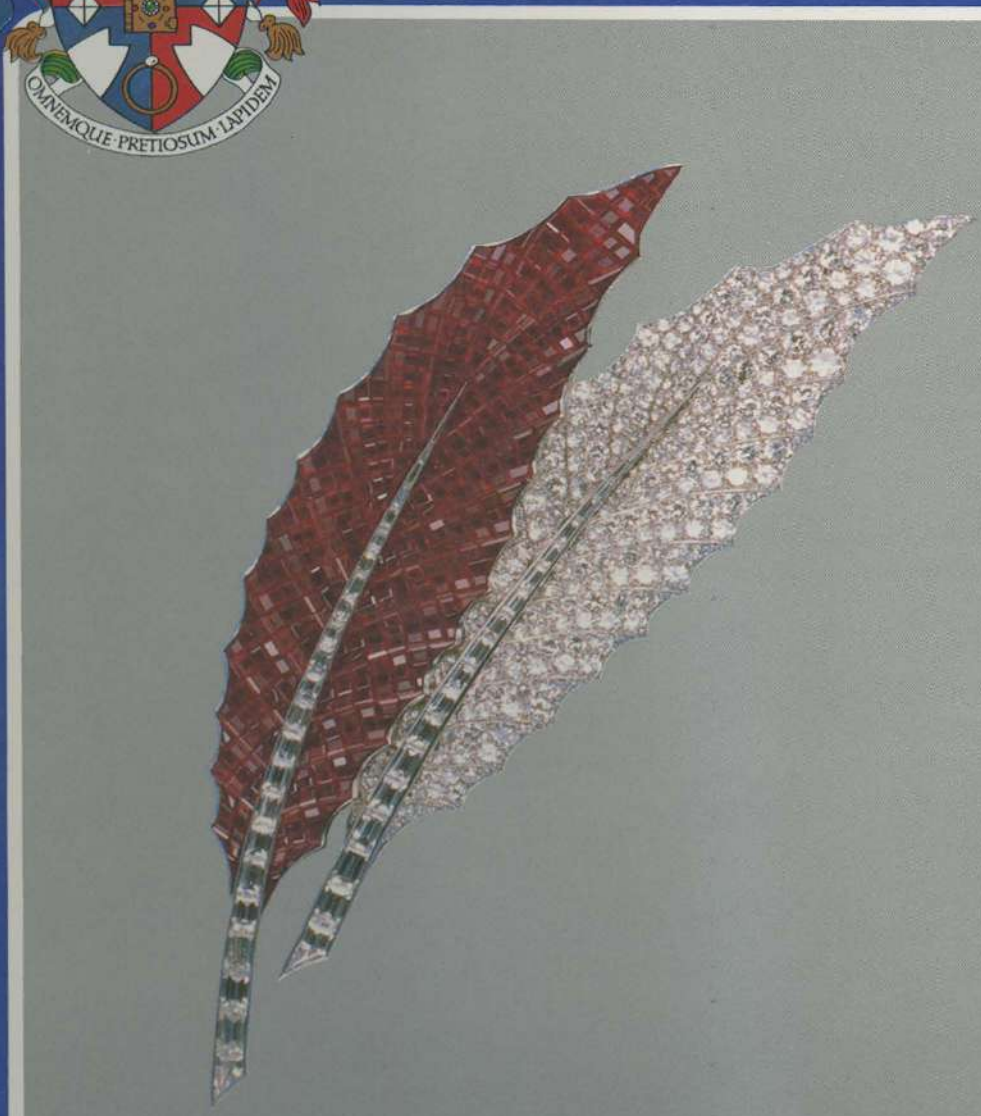

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Cover Picture

An 'invisibly set' ruby and diamond clip by Van Cleef and Arpels, Paris. Designed as two holly leaves, from the Duchess of Windsor's collection (see 'The sale of the Windsor jewels', pp. 423–426).
Photograph courtesy of Sotheby's.

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Editorial

This combined issue comprising numbers seven and eight concludes volume 20 of the redesigned *Journal of Gemmology*. The cover, with its colourful (and, we hope, educational) front and its readily informative back has earned more plaudits than brickbats. The papers (the 'meat' of the Journal) sometimes have a highly scientific content, but this is to be expected when we are tackling gemmological 'education' at the frontiers. However, we also try to include lighter material, and in this combined issue we hope we are approaching a balance between science (in the field and in the laboratory), commerce (in the auction rooms and in diamond grading), light biography (which includes the development of books and journals) and 'do-it-yourself' gemmology among other topics.

The production of the *Journal* poses many problems including late or non-arrival of copy, unsuitable submissions, and the complexities of modern printing technology. Material published depends upon material submitted, and the Editor looks back nostalgically at articles such as those written by Louis Kornitzer for *The Gemmologist* in the thirties. These anecdotal and narrative papers covered travel in the gem-producing areas prior to the advent of air travel, combined with accounts (often humorous) of his experiences, good and bad, in the Hatton Garden of yesteryear. There must be many merchants and retailers with like experiences over the years – the Editor would greatly welcome some articles from a few of them.

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Blue spinel from the Hunza valley, Pakistan

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Abstract

The spectral features of blue spinels from the Hunza valley, Pakistan, are described. Microprobe analyses indicate variable contents of Ti and Cr in the spinels and this, in addition to iron, probably gives rise to a range of colours from blue to pink.

Introduction

Parcels containing blue octahedral crystals of spinel mixed with rubies have recently arrived from the Hunza valley, Pakistan. Although small, the crystals are of gem quality and since the blue spinels described by Shigley and Stockton (1984) and Kane (1986) were thought to come from Sri Lanka, a description and chemical analysis were undertaken to characterize the Hunza crystals more precisely.

The crystals are single or twinned octahedra, black or dark blue in reflected light, but in strong transmitted light, a range of blue, lilac and pink colours. They are inert in both long- and short-wave ultraviolet radiation and show no fluorescence under crossed filters ($CuSO_4$ solution and Chelsea filter).

Colour zoning in the crystals appears diffuse and no sharp colour variations were seen. Feathers with liquid or gas in irregular patches are common inclusions but solid crystal inclusions are rare or absent. The spinel crystals occur in a matrix of white carbonates which also contain crystals of pink corundum, dark golden-yellow corundum, brassy pyrite and black opaque minerals. The identities of the corundums and pyrite were checked using X-ray diffraction analysis by S. Somogyi (film numbers: corundum 6400F, 6401F; pyrite 6399F).

Spectrum

The spectrum shown by each crystal through a Beck prism spectroscope is similar in pattern to those depicted by Shigley and Stockton (1984) for natural blue spinel. They show absorption at 650–630 nm, 600–590 nm, 580–565 nm, 555–540 nm, 470 nm tailing off to about 455 nm, and 440 nm tailing off to about 425 nm (Figure 1). In addition, the lilac and pink crystals show absorption at 680 nm with some fluorescence on the long-wave side of this band, indicating the presence of chromium. There is a qualitative correlation between the intensity of pink in the crystal and the strength of the chromium absorption.

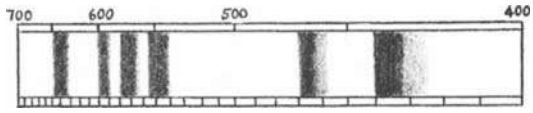

Fig. 1. Spectrum of blue spinel from Hunza valley through Beck prism spectroscope.

In Figure 2, trace 2 shows the absorption pattern of a Hunza spinel measured on a Pye-Unicam PU8800/03 UV-Visible spectrophotometer. The path length of light through the crystal measured 1.93 mm and wavelengths 380-750 nm were scanned at 1 nm/sec. The bandwidth was 0.5 nm and the recorder was set on a range of 2A (absorption units). For comparison a synthetic blue spinel was run under the same conditions except that the wavelength scan was extended into the ultraviolet (trace 3), and although the absorption pattern is similar in the 500–700 nm region, the natural spinel absorbs strongly in the ultraviolet below 400 nm. In contrast the synthetic spinel transmits radiation down to 290 nm. In comparison with the spectra shown by Shigley and Stockton (1984, p. 39) the pattern of absorption of the Hunza valley spinel most resembles that of the type I – natural although the centres of the absorptions between 500 and 700 nm are not identical.

Microprobe analysis

A flat octahedral surface of a spinel crystal measuring 8 mm across was chemically analysed using a Cambridge Instruments Microscan IX microprobe. Nine wavelength-dispersive spot

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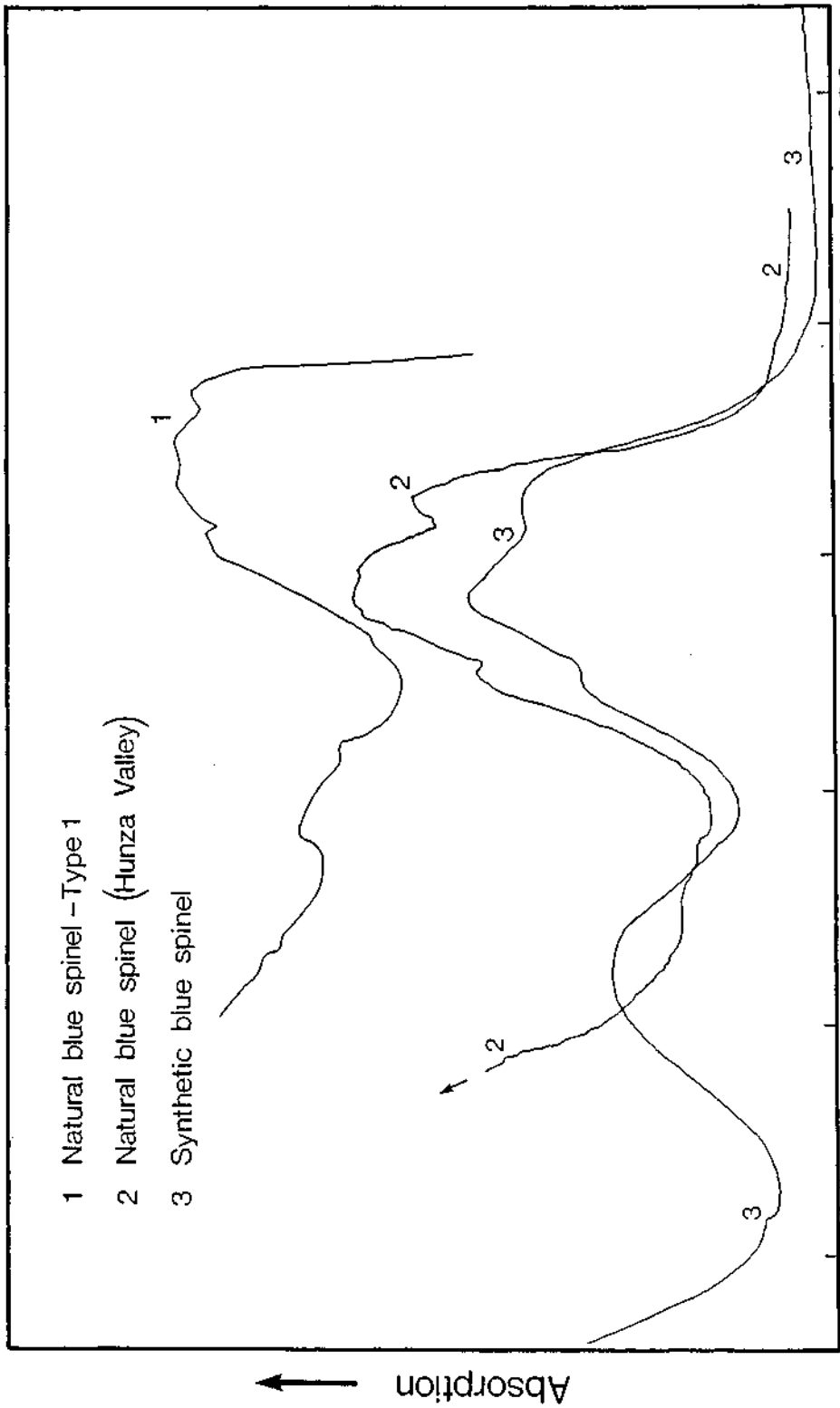

Fig. 2. Spectrophotometer traces of blue spinel from Hunza valley (2) compared with type I – Natural spinel (1) (converted from transmission trace of Shigley and Stockton, 1984, p. 39) and synthetic blue spinel (3).

analyses were carried out at 20 kV and 25 mA with a beam diameter of 1 μm, and the results are given in Table 1.

Table 1. Electron microprobe analyses of blue spinels.

Wt%	1		2
	Mean	S.D.	
MgO	24.6	0.32	25.45 – 27.88
Al_2O_3	69.3	0.26	70.20 – 71.61
SiO_2	0.05	0.01	n.r.
TiO_2	0.18	0.26	n.d. – < 0.04
V_2O_5	0.05		n.d. – 0.07
Cr_2O_3	0.73	0.14	n.d. – < 0.04
MnO	< 0.05		n.d. – 0.07
FeO	3.75	0.05	0.69 – 3.53
ZnO	0.35	0.04	< 0.04 – 0.44
CoO	< 0.05		n.d. – 0.05
NiO	< 0.05		n.d. – 0.14
Total	99.01		

Notes:
Total Fe as FeO; n.d. not detected; n.r. not reported. The standards used were: Eagle Station olivine (Mg, Fe), jadeite (Na, Al), manganese metal, chromium metal, zinc metal, vanadium metal, rutile (Ti), and wollastonite (Si,Ca).

1. Mean and standard deviation (S.D.) of nine analyses of different spots on octahedral face of blue spinel from Pakistan.
2. Range in composition of 18 natural blue spinels, Shigley and Stockton, 1984, Table 1.

The analyses show spinel with a consistent major element composition of Mg and Al, minor Fe, and small amounts of Cr, V, Mn, Si, Ti and Zn. The Ti distribution is heterogeneous and varies between 0.01 and 0.77% in different parts of the crystal. In one area a rounded patch measuring 200 × 100 μm shows a consistent content of 12.1% TiO_2. Material from this area was extracted and analysed by X-ray diffraction and a spinel pattern was obtained (film 6383F). However, the total analysis is not consistent with spinel proportions and further material must be sought.

Although the composition of the Hunza spinel compares closely with the spinels studied by Shigley and Stockton (1984) and reproduced in Table 1 column 2, it differs in two ways. Firstly there is significant Ti in the Hunza crystal while Shigley and Stockton (op. cit. pp. 38 and 41) state that there is considerably less than 0.04% TiO_2 in the stones they studied; and secondly there is significant Cr in the Hunza spinel. Cobalt was sought in the Hunza crystal but, if present, is below the detection limit for this analytical method of 0.05% CoO.

Conclusion

To summarize, spinels with spectral characteristics similar to those for blue spinels described previously are being extracted from rocks in the Hunza valley. They do, however, contain significant Ti and Cr, and these elements are probably responsible for the slightly different spectral features and wider colour range of the Hunza crystals. The range includes blues, lilacs and pinks comparable with those found in fine quality sapphires.

Acknowledgements

We would like to thank C. Cavey for the donation of Hunza spinel crystals to the museum; and we are grateful both to S. Somogyi for carrying out the X-ray diffraction analysis, and to K. Scarratt for results from the Anderson spectrophotometer at the Gem Testing Laboratory.

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Kane, R.E., 1986. Cobalt-blue spinel, an update. *Gems & Gemology*, **XXII**, 2, 111–13.

Shigley, J.E. and Stockton, C.M., 1984. Cobalt-blue gem spinels. *Gems & Gemology*, **XX**, 1, 34–41.

[*Manuscript received 24 July 1987.*]

Notes from the Laboratory – 11

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On 18 April 1985 Sumitomo Electric Industries Ltd issued a news release entitled: 'World's first mass production process for synthesizing large diamond monocrystals'. The news release starts with the following paragraph:

> 'Sumitomo Electric has succeeded, for the first time in the world, in mass-producing large synthetic diamond monocrystals. The company is beginning to market them for various industrial applications.'

The news release further stated that Sumitomo's synthetic diamond monocrystals are high-quality stones largely free of impurities and defects and range in size up to 1.2 ct (about 6 mm in diameter).

At the 20th International Gemmological Conference, which was held in Sydney, Australia, between 30 September and 4 October, 1985, I was able to obtain two specimens of the Sumitomo synthetic diamond (Figure 1) with the assistance of Ms Yunko Shida. Whilst both these specimens were interesting, little in terms of normal gemmological identifying characteristics could be obtained, and relied upon, from so few examples.

During 1986 the Laboratories of The Gemological Institute of America examined more than twenty examples of this new synthetic diamond and they subsequently published their findings in the form of an excellent paper in the winter 1986 issue of *Gems & Gemology* (Shigley *et al.*, 1986).

This report compares the results published by Shigley *et al.*, with observations made on our specimen crystals and one faceted Sumitomo synthetic diamond loaned to us by Mr J. Schlussel of The Diamond Registry, New York.

As with the GIA specimens, Mr Schlussel's specimen may be described as very deep, intense or pure yellow, its weight was 0.23 ct and its measurements were 3.95 – 3.95 × 1.62 mm. The stone was faceted as a shallow emerald-cut.

The colour of the faceted stone was such an intense yellow that this observation possibly plants the first seeds of suspicion in one's mind, i.e. if the possibility of a synthetic is not thought of, then an irradiated stone should be. When observed under magnification, particularly from the pavilion, whilst the intense yellow was found to be the dominant colour, areas of a lighter yellow and other areas which were colourless could be seen easily. These colourless and yellow patches formed a definite pattern which, when viewed through one of the four largest pavilion facets, might be described as either a 'bow tie' or 'hourglass' structure (Figure 2). Figure 3 shows this same structure under slightly different lighting conditions. As the stone was turned to examine the other three largest pavilion facets a similar structure was found to be present in each and it was seen that the 'bow ties' share a wedge-shaped light yellow area situated under the corner facets (Figure 4).

When bathed in long-wave ultraviolet radiation the faceted Sumitomo synthetic diamond was almost inert, but under the influence of short-wave the effect was markedly different. Short-wave ultraviolet produced a bright yellow fluorescence which when observed under magnification was sharply zoned. When viewed from the crown (Figure 5a) there was an octagonal area under the table facet which fluoresced a bright yellow and radiating from the edges of this were four lighter yellow fluorescing areas. The areas radiating from the corners of the bright yellow area were inert (see Figure 5). When viewed from the pavilion the fluorescence could be seen to be both zoned and layered (Figure 5b); close to the area of the culet was an almost square layered zone of bright yellow and below this was a layer of a lighter yellow. When placed in a beam of X-rays (Diffraction tube, Mo target, at 45kV/20mA) the Sumitomo synthetic diamond fluoresced a strong greenish-yellow and this was followed by a prolonged yellowish-blue phosphorescence.

The absorption spectrum of the faceted stone as seen with the hand spectroscope revealed no sharp changes in transmission, i.e. there were no absorption lines present. However, the blue and violet areas of the spectrum appeared to be increasingly

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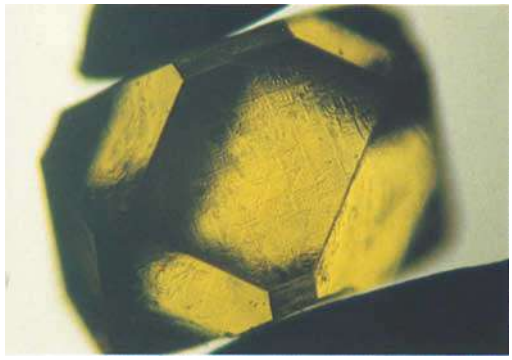

Fig. 1. Sumitomo synthetic diamond crystal obtained in late 1985 weighing 0.08 ct.

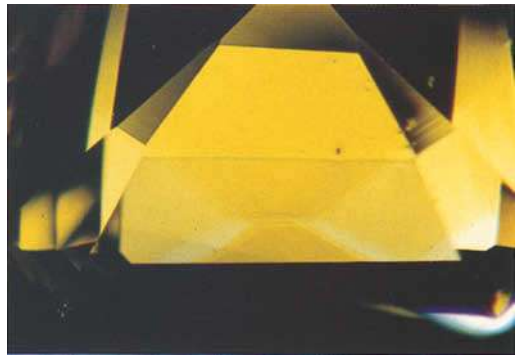

Fig. 2. 'Bow-tie' or 'hourglass' structure seen through a pavilion facet of the faceted Sumitomo synthetic diamond belonging to Mr Schlussel.

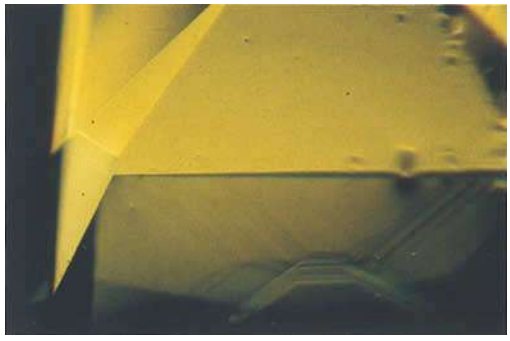

Fig. 3. 'Bow-tie' or 'hourglass' structure in the faceted Sumitomo synthetic diamond as in Figure 2, but in different lighting conditions.

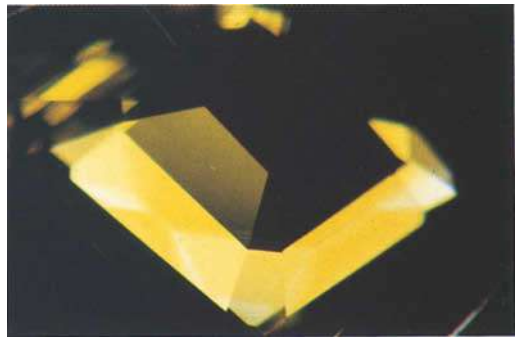

Fig. 4. Two 'bow-tie' structures in the Sumitomo synthetic diamond share a light yellow wedge-shaped area under a corner facet.

absorbed the shorter the wavelength (Figure 6b), and this was confirmed when the spectrum was examined between 750 and 390 nm on a spectrophotometer. Here, even at approximately 120 K, no absorption peaks were recorded, only a gradual increase in absorption from 560 nm.

Dr J. Milledge, of University College, London, carried out infrared measurements on the faceted Sumitomo synthetic diamond and these determined it to be type Ib.

The properties of the stone belonging to Mr Schlussel compare well with those of the twenty-three stones reported upon by Shigley *et al.*; both the visible and IR spectra reveal the same characteristics and the zoned short-wave ultraviolet fluorescence patterns show a remarkable similarity. The almost inert response to long-wave ultraviolet radiation is also similar to that reported by Shigley *et al.*, and both the colourless-yellow zones present in Mr Schlussel's stone, and those examined by the GIA appear to produce a similar regular ('bow-tie', 'hourglass') pattern.

The surface features of the Sumitomo synthetic diamond crystals described by Shigley *et al.*, are

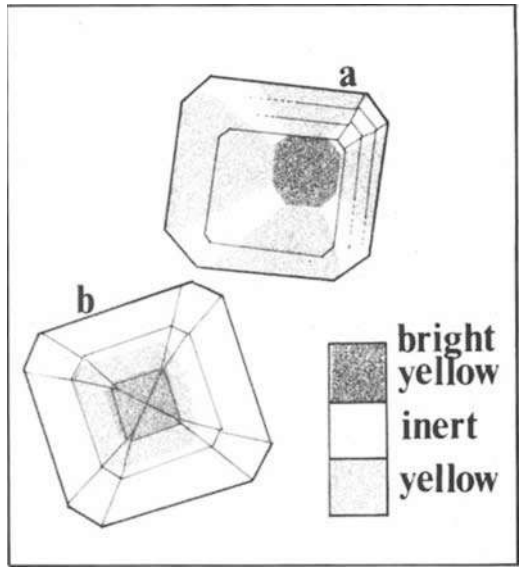

Fig. 5. The short-wave ultraviolet induced fluorescence of the Sumitomo synthetic diamond (a) as seen from the crown, and (b) as from the pavilion.

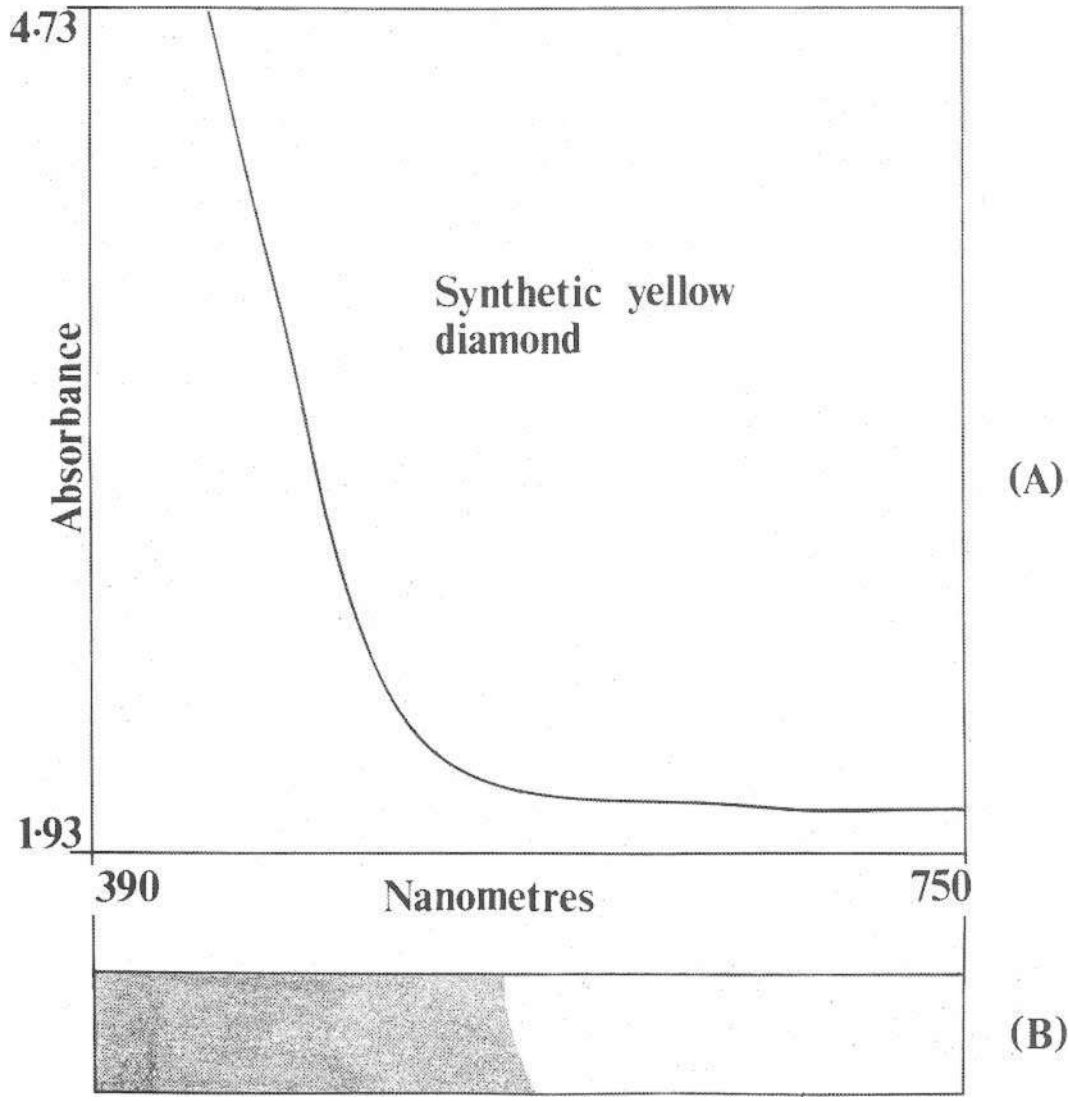

Fig. 6. The absorption spectrum of the Sumitomo synthetic diamond (A) as recorded at 120 K on a Pye Unicam PU 8800/03 UV/visible spectrophotometer (Basil Anderson model) with a speed of 1 nm/s, a bandwidth of 0.5 nm and a path length of approximately 1.6 mm, and (B) as seen with the hand spectroscope.

similar to those observed on the crystals obtained in late 1985 (Figure 1).

Richard T. Liddicoat, Jr., ended his editorial to the Winter 1986 edition of *Gems & Gemology* by stating that what is perhaps the 'last great barrier' in gemmology 'has been breached' and that the role of the gemmologist has never been more important. These few words cannot be ignored; we have indeed reached a very important point in the development of our science.

At the moment Sumitomo are only producing synthetic type Ib diamonds and these have a canary yellow body colour; it is also stated that they are only being produced for use as heat sinks in industry. However, even if Sumitomo's policy changed and large amounts of their presently produced material became available to the jewellery market, this should not create an insurmountable problem to jewellers.

All those who handle coloured diamonds must now be aware of this extra hazard, and when they become involved with an intense yellow diamond

they have not only to think of the possibility of an irradiated diamond but also of the Sumitomo synthetic. Identification of these stones, judging from the few samples so far examined, should not be too difficult.

The infrared (IR) spectrum of the Sumitomo synthetic is typical of this type of synthetic diamond in that it reveals pure type Ib characteristics, and this could assist in separating it from the natural type Ib diamond which may have Ia charactersitics also present. As the equipment needed to record IR spectra is not normally available to the 'average gemmologist' information in this area would at first seem surplus to the requirements of most gemmologists. There is a connection, however, for the visible spectra of Ib diamonds (natural or synthetic) is quite different from that of the majority of natural yellow diamonds. Most natural yellow diamonds are type Ia and these, at the very least, show an absorption band at 415 nm and possibly others in the violet and blue parts of the spectrum (Anderson 1985, 174), which are not seen in type Ib diamonds (the Sumitomo synthetic). The visible spectrum of a Ib diamond (natural or synthetic) is one of increasing and gradual absorption with shorter wavelengths from about 560 nm (Figure 6): therefore the observation of a 415 nm band is sufficient to identify the stone as natural. However, if the 415 nm band is not seen, this does not prove the diamond to be synthetic.

The response of the Sumitomo synthetic diamond to ultraviolet radiations is unusual and can serve as an aid to identification, particularly when the short-wave fluorescence is examined closely and its zoned nature is seen. We have never seen the 'bow tie' or 'hourglass' zoning (observed under magnification in normal lighting) in any natural yellow diamonds and this may prove in time to be a useful identifying feature.

* * *

Late in 1985 we received an enquiry from Sri Lanka for information about sapphirine $(Mg,Fe,Al)_8O_2[(Al,Si)_6O_{18}]$ as it was felt by the enquirer that gem quality material might be available in that country. Shortly after replying to that enquiry we received the Fall 1985 issue of *Gems & Gemology* in which there was a report of a purplish-pink faceted sapphirine (Fryer *et al.*, 1985). More recently sapphirine has been described as an inclusion in ruby (Koivula and Fryer, 1987).

Earlier this year we were sent an oval blue stone (Figure 7) measuring 5.86 – 7.40 × 2.74 mm and weighing 0.90 ct which had been bought as 'blue idocrase' in Sri Lanka. The stone was strongly pleochroic and had an SG of 3.45. The minimum and maximum refractive indices, as determined on the table facet in sodium light and with a Rayner Dialdex refractometer, were 1.704 and 1.710 with a variation for the lower reading up to 1.705 and for the higher reading down to 1.707, indicating a biaxial stone. Whilst 'biaxial' readings have been reported for idocrase (vesuvianite) (Larsen and Berman, 1964), as it is a tetragonal material uniaxial readings are usual and this anomaly along with the lack of any recognizable features in its absorption spectrum (Figure 8) raised some curiosity about the true identitiy of this stone.

Permission was sought to take a small scraping from the stone and an X-ray powder diffraction pattern was obtained. After comparison with standard JCPDS file 21-549, the stone was identified as sapphirine and this was further corroborated by comparison with the powder diffraction pattern produced from a specimen in the collection of the British Museum (Natural History) – BM 23304 – which comes from Friskernaes, Greenland, and was purchased by the museum in 1849.

* * *

Two interesting pearls both originating from the British Isles have been donated to the Laboratory collection recently. The first is from Scotland and weighs 13.36 grains and measures 8.06 mm in diameter and, as can be seen from Figure 9, only part of its surface is nacreous, the rest being a dull brown. Whilst much of the line where the nacreous coating and the brown surface meet is in the form of a 'step down' towards the latter, a large portion blends smoothly from one to the other with no visible demarcation line. The nacre has only an indistinct platelet structure at normal magnifications, whilst much of the brown area has a similar cross-section to that reported for another Scottish pearl in *Notes from the Laboratory – 9* (Scarratt, 1987). A radiograph of this latest pearl revealed the typical ring structure of a natural pearl (Figure 10).

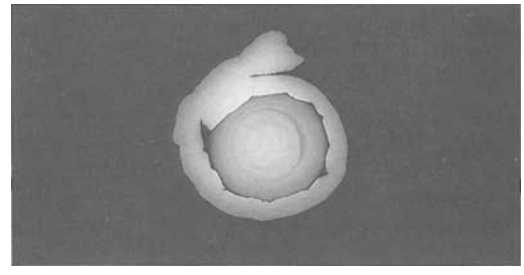

Fig. 10. A radiograph of the pearl in Figure 9 showing the typical ring structures. N.B. the opaque (white) area around the pearl is a lead mask.

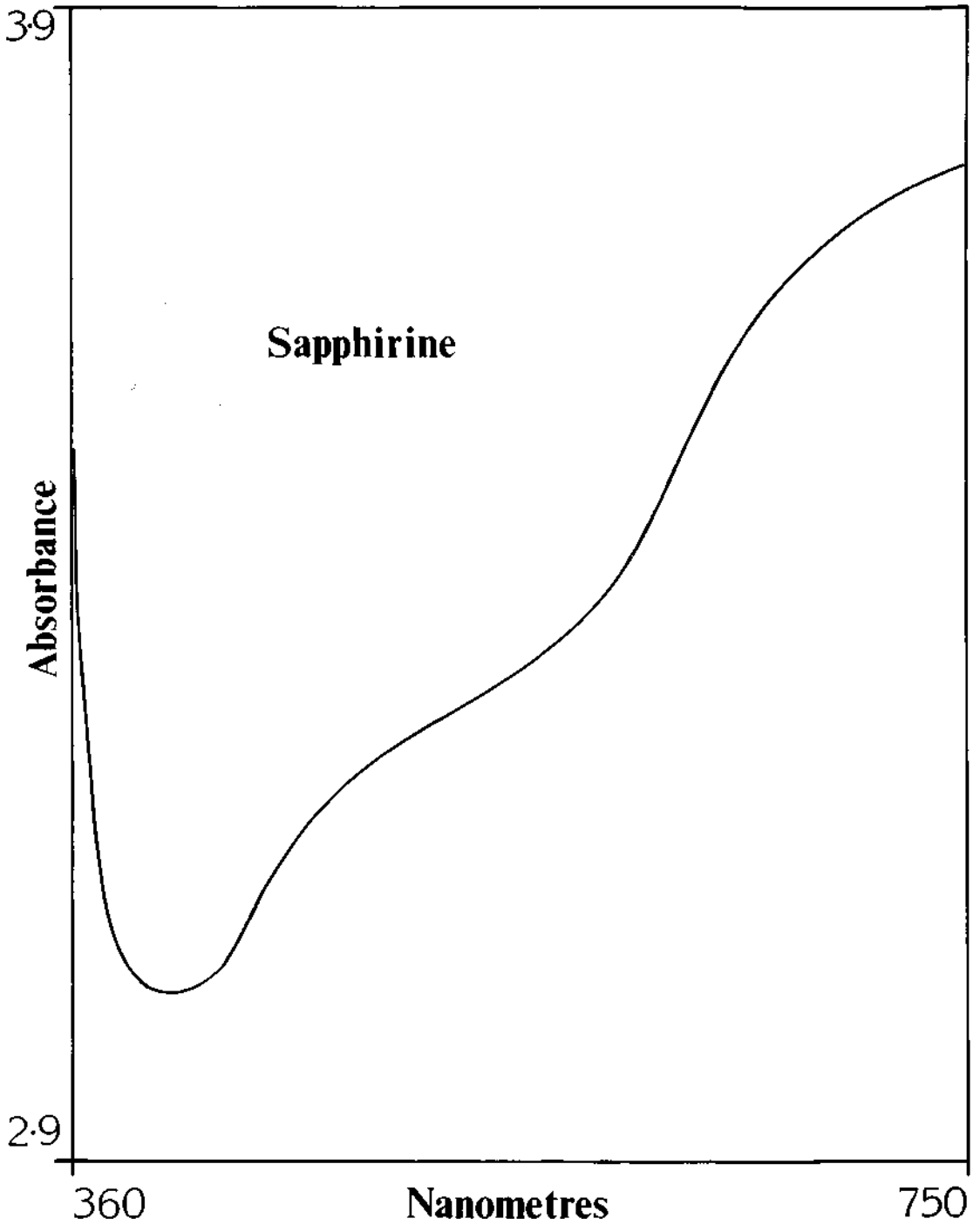

Fig. 8. The absorption spectrum of a 0.90 ct blue sapphirine. The curve was obtained using a Pye Unicam PU 8800/03 UV/visible spectrophotometer (Basil Anderson model) with a speed of 1 nm/s and a bandwidth of 1 nm at room temperature.

Fig. 7. An oval blue sapphirine weighing 0.90 ct.

Fig. 9. A 13.36 grain pearl with only a small surface area of nacre.

Fig. 11. A 8.20 grain salt-water mussel pearl found by a fisherman from Cromer, Norfolk.

Fig. 12. The network of cushion shaped 'holes' seen in a 10.56 ct opal. Transmitted light.

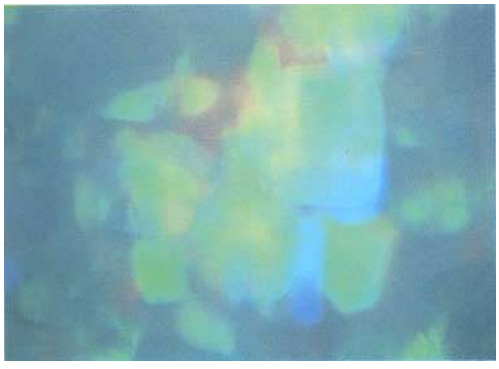

Fig. 13. The same structure in a 10.56 ct opal as seen in Figure 12 but in reflected light.

Fig. 14. Lapis-lazuli-like bead necklace.

The second is a slightly baroque button-shaped 8.20 grain 'salt-water mussel pearl' found by a Cromer fisherman, the colour of which varied from a dark to a bright blue (Figure 11). No overlapping platelet structure was seen on the surface and no internal structures were revealed by X-radiography although indications of a layered structure within could be seen on the surface. The surface has a high lustre, is uneven and dimpled, and in one of the larger dimples there is an area of brown organic-like matter. Using the X-ray powder diffraction technique the pearl proved to be composed of calcite.

* * *

As superbly illustrated by Gübelin and Koivula in their paper *Inclusions in Opal* (Gübelin and Koivula, 1986), the interior of opal can be as fascinating as any other gem material and there can be few more interesting than a 10.56 ct stone we examined towards the end of May this year.

The stone measured 19.21 – 15.06 × 6.72 mm, had a very fine play of colour and constants typical for opal (RI 1.44, SG 2.10). Internally a large number of worm-like needles were present, the cross-sections of some showing clear ring structures, but in addition to these and covering approximately two thirds of the stone, was a peculiar honeycomb-like structure. In transmitted light this structure appeared as many cushion-shaped 'holes' in a brownish network (Figure 12). Figure 13 shows this same structure but in reflected light.

* * *

Sometimes when we come across an item we have not encountered before, such as a new synthetic or imitation, we are allowed a reasonable amount of time to carry out a complete examination. Often though, the owner or his intermediary require the item to be returned by a specific time and when the period allowed is short and the item appears to be interesting a certain degree of frustration is experienced. Nevertheless an attempt is made to gain as much information as possible.

Such was the case when a single row of 43 blue lapis-lazuli-like beads was submitted for examination earlier this year. Each was similarly carved (Figure 14) and the colour, were it *lapis-lazuli*, was quite even (apart from a darkening on the high ridges of each of the beads that had been worn in contact with the skin) and fairly well matched. The structure, the like of which I have not seen in natural lapis-lazuli or the Gilson product, was fine grained although the surface was pitted and there was a profusion of pyrite-like inclusions of all shapes and sizes, including slivers. However, the colour of this pyrite was of a somewhat deeper yellow than one might expect to see in any natural material.

Under both long- and short-wave ultraviolet rays the beads weakly fluoresced a greenish cast which was quite unlike that produced by natural lapis-lazuli. The material was quite soft in that a cut was easily made into the area inside a drill hole with a steel blade but the powder produced by this cut was a very bright blue. In many cases when a 'hot point' was held close to the beads the surface appeared to either melt or sweat and in areas where this did not occur, when the hot point was brought into contact with the bead the surface appeared to be slightly 'sticky'. The application, on a small piece of cotton wool, of a small drop of dilute hydrochloric acid to the surface of one bead produced a strong smell of 'rotten eggs' and the colour of the bead (blue) was transferred to the cotton wool.

The necklace was compared with many known samples of natural lapis-lazuli, the Gilson produced material and many imitations, as well as reconstructed and stained material from the Laboratory collection. No match was found and unfortunately it then had to be returned to the owner without any further work being carried out.

* * *

Late in 1986 Alan Hodgkinson FGA, sent two 'new Russian hydrothermal synthetic emeralds' to the Laboratory for the examination of their absorption spectra. The first was a piece of partly polished rough weighing 1.43 ct and measuring 7.47 mm in length (Figures 15 and 16) and the second was an emerald-cut stone weighing 0.88 ct and measuring 5.49 – 4.96 × 4.63 mm (Figure 15).

The constants of the two pieces varied slightly in that the SG (determined hydrostatically in distilled water at room temperature) for the faceted stone was found to be 2.71, whilst that of the polished rough was 2.68. The RIs for the faceted stone (determined on the table facet and using a Rayner spinel model refractometer in sodium light) were 1.580–1.585, but those for the polished rough were found to vary significantly according to the face on which they were measured. Face 'A' (see Figure 16) gave RIs of 1.567 – 1.571, whilst face 'B' gave 1.580 – 1.587.

Under the influence of both long- and short-wave ultraviolet rays the stones produced virtually no response. There was also no response when the stones were viewed through the Chelsea colour filter.

The stones were examined under magnification, both dry as well as immersed in benzyl benzoate (RI 1.569 to 1.570). The growth features seen in the

faceted stone, in general over-view, had a distinctive *'water in whisky'* appearance (Figure 17) which in some directions was crossed with almost parallel growth banding (Figure 18). Upon closer examination very distinctive 'arrow-head' and 'quill' structures could be seen (Figures 19 and 20). Similar features were seen, if a little more graphically, in the polished rough sample (Figures 21 and 22) along with equivalent near-parallel growth banding (Figure 23). At one end of the polished rough sample there was a layer of reddish/brownish platelets (Figures 16 and 24), which was close to the surface and not of great depth (Figure 25). The reason for the differing RIs produced for face 'A' of the polished rough became apparent when the stone

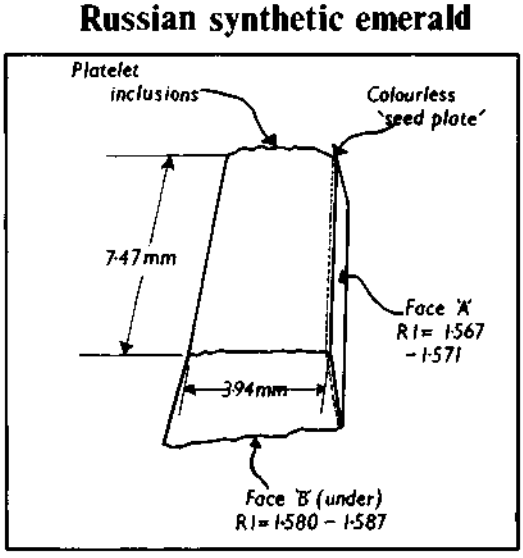

Fig. 16. Detail of the Russian synthetic emerald polished rough specimen seen in Figure 15.

was immersed in benzyl benzoate. Face 'A' was in fact a colourless seed plate (Figure 26) and the interface between this and the synthetic emerald had a cobbled appearance.

These features (Figures 17 to 26) help to identify these particular samples as being of synthetic origin and this goes some way to alleviating the problems created by the high RIs. However, some of the most interesting and indeed characteristic features of both stones were contained in their absorption spectra.

The two stones were, both for natural and synthetic emerald, unusually highly absorbing in the red portion of the spectrum (Figures 27, 28, 29 and 30). The 'normal' emerald absorption curves are presented in Figure 31 as examples '1' (Australian hydrothermal synthetic emerald) and '2' (Natural Colombian Emerald). These two curves clearly show the typical emerald chromium doublet in the red, with peaks at 679.9 and 682.4 nm in the case of the Australian synthetic and at 679.6 and 682.4 nm for the natural emerald from Colombia. Whilst the relative intensity and, to some degree, the wavelength of these peaks may vary according to the direction in which the curve is recorded, they commonly sit on the slope of a band to the short-wave side which allows some red to be transmitted (see also Sinkankas 1981).

Figure 27 shows the absorption curve for the polished rough specimen as recorded through face 'A' and this reveals a strong, sharp, chromium absorption peak at 683.6 nm. However, apart from a slight shoulder at 680.4 on the short-wave side and a more visible shoulder at 688 nm on the long-wave side of this main peak, there is no indication of the 'normal' emerald chromium doublet. Figure 29 reveals similar features in the curve recorded through the shorter, girdle to girdle, distance in the emerald-cut stone. In each case the peak is sitting on an area of absorbance that is gradually increasing from 500 nm through to the deep red, which is different from curves '1' and '2' in Figure 31.

Figures 27 (b) and 29 (b) indicate the direction in which those curves were recorded and the significant angle these were at to the optic axis of each stone. When further spectra were taken in a direction at approximately 90° to the first, no chromium peaks were recorded (Figures 28 and 30), but the general absorbance in the area where they might have occurred was particularly strong. In Figure 28 a shoulder occurs at 684 nm which may be related to the 683.6 nm chromium peak. However, if the spectrum of either of these stones were observed using a hand spectroscope, a strong chromium line would be observed amidst the general absorption of the red in one direction, and at 90° to this, most of the red will be strongly absorbed and no chromium lines will be visible.

Regardless of direction, a similar group of peaks was recorded for both polished rough and the emerald-cut stone, in the violet and ultraviolet. These are shown in Figure 29 as being a doublet at 368.6 and 372 nm and a strong peak at 425 nm with a shoulder on its long-wave side at 440 nm. This group compares well with those recorded in the spectrum of a greenish aquamarine from Pakistan and seen as example '3' in Figure 31, and also with those recorded in an emerald from Madagascar and seen as example '4' in Figure 31, as well as that reported for the Gilson 'N' series synthetic emerald (Anderson 1985, 134).

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Fig. 15. Two Russian synthetic emeralds, the polished rough weighing 1.43 ct (see also Figure 16) and the emerald-cut stone weighing 0.88 ct.

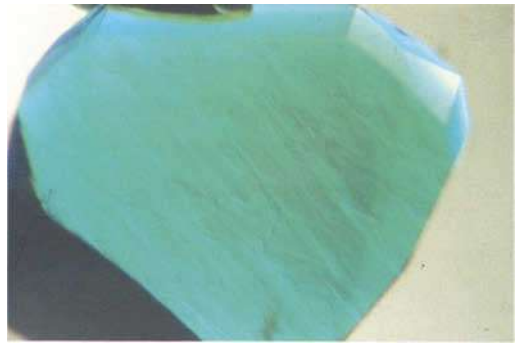

Fig. 17. 'Water in whisky' appearance seen in the emerald-cut Russian synthetic emerald of Figure 15.

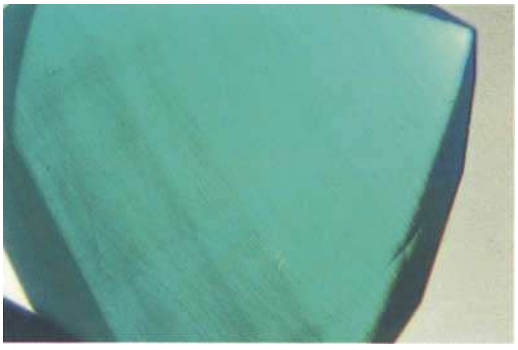

Fig. 18. 'Water in whisky' appearance seen in the emerald-cut Russian synthetic emerald of Figure 15, crossed by parallel growth banding.

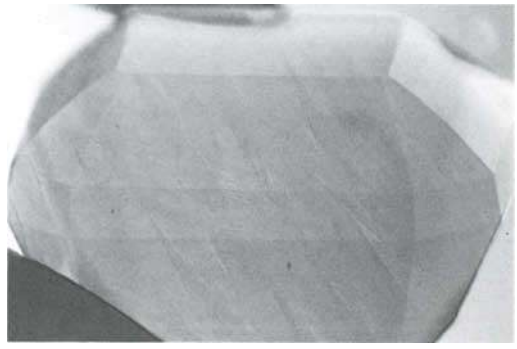

Fig. 19. 'Arrow-head' and 'quill' structures seen in the emerald-cut Russian synthetic emerald of Figure 15.

Fig. 20. A closer view of the 'arrow-head' and 'quill' structures seen in Figure 19.

Fig. 21. 'Water in whisky' appearance seen in the Russian synthetic emerald polished rough specimen of Figure 15.

Fig. 22. 'Arrow-head' and 'quill' structures seen in the Russian sysnthetic emerald polished rough specimen of Figure 15.

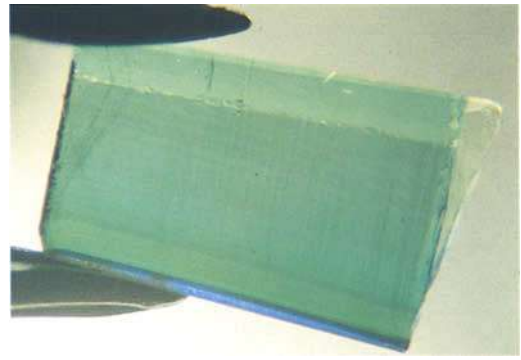

Fig. 23. The Russian synthetic emerald polished rough specimen of Figure 15 viewed through face 'B' (see Figure 16) showing parallel growth banding.

Fig. 24. Reddish/brownish platelets seen at one end of the Russian synthetic emerald polished rough specimen of Figure 15 (see also Figure 16).

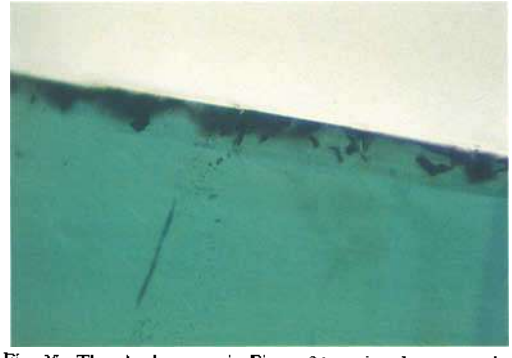

Fig. 25. The platelets seen in Figure 24 are in a layer near the surface which is not of great depth. The layer is seen here in side view.

Fig. 26. Colourless seed plate at the surface of the Russian synthetic emerald polished rough specimen of Figure 15.

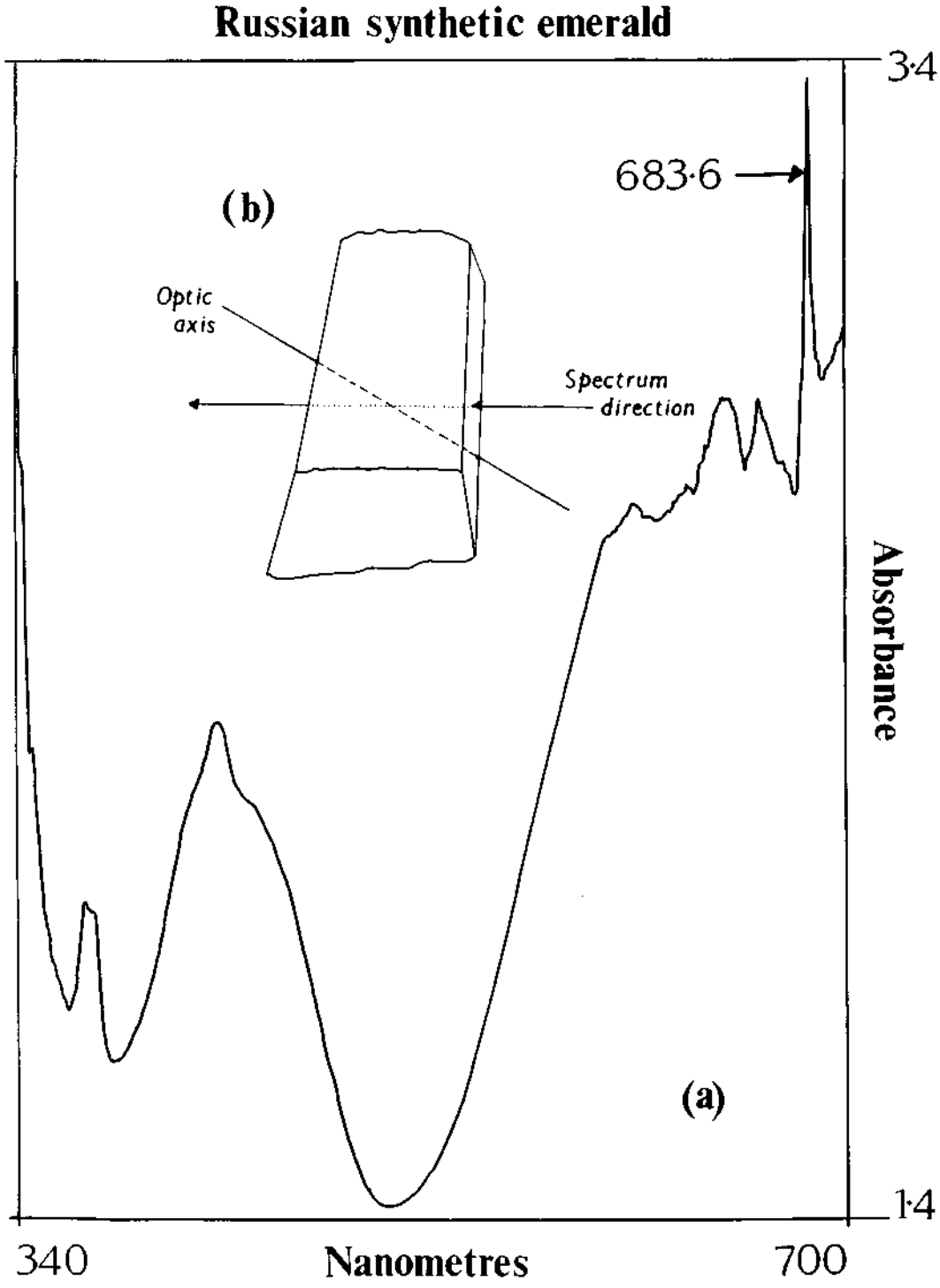

Fig. 27. The absorption curve of the Russsian synthetic emerald polished rough specimen of Figures 15 and 16 taken in the direction indicated by (b). The curve was obtained using a Pye Unicam PU 8800/03 UV/visible spectrophotometer (Basil Anderson model) with a speed of 1 nm/s and a bandwidth of 0.5 nm at room temperature. The path length was 4.3 mm.

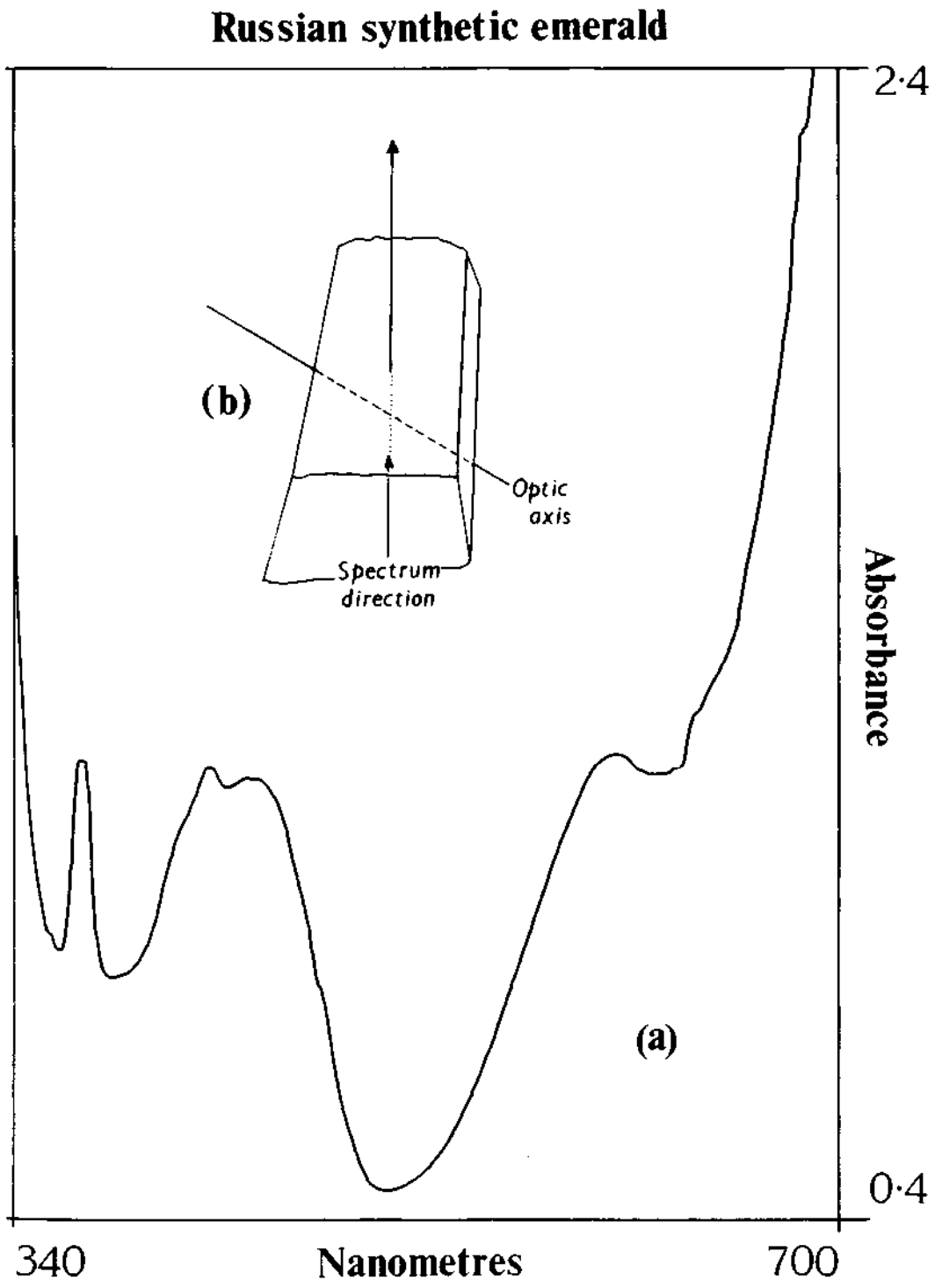

Fig. 28. The absorption curve of the Russian synthetic emerald polished rough specimen of Figures 15 and 16 taken in the direction indicated by (b). The curve was obtained using a Pye Unicam PU 8800/03 UV/visible spectrophotometer (Basil Anderson model) with a speed of 1 nm/s and a bandwidth of 0.5 nm at room temperature. The path length was 3.6 mm.

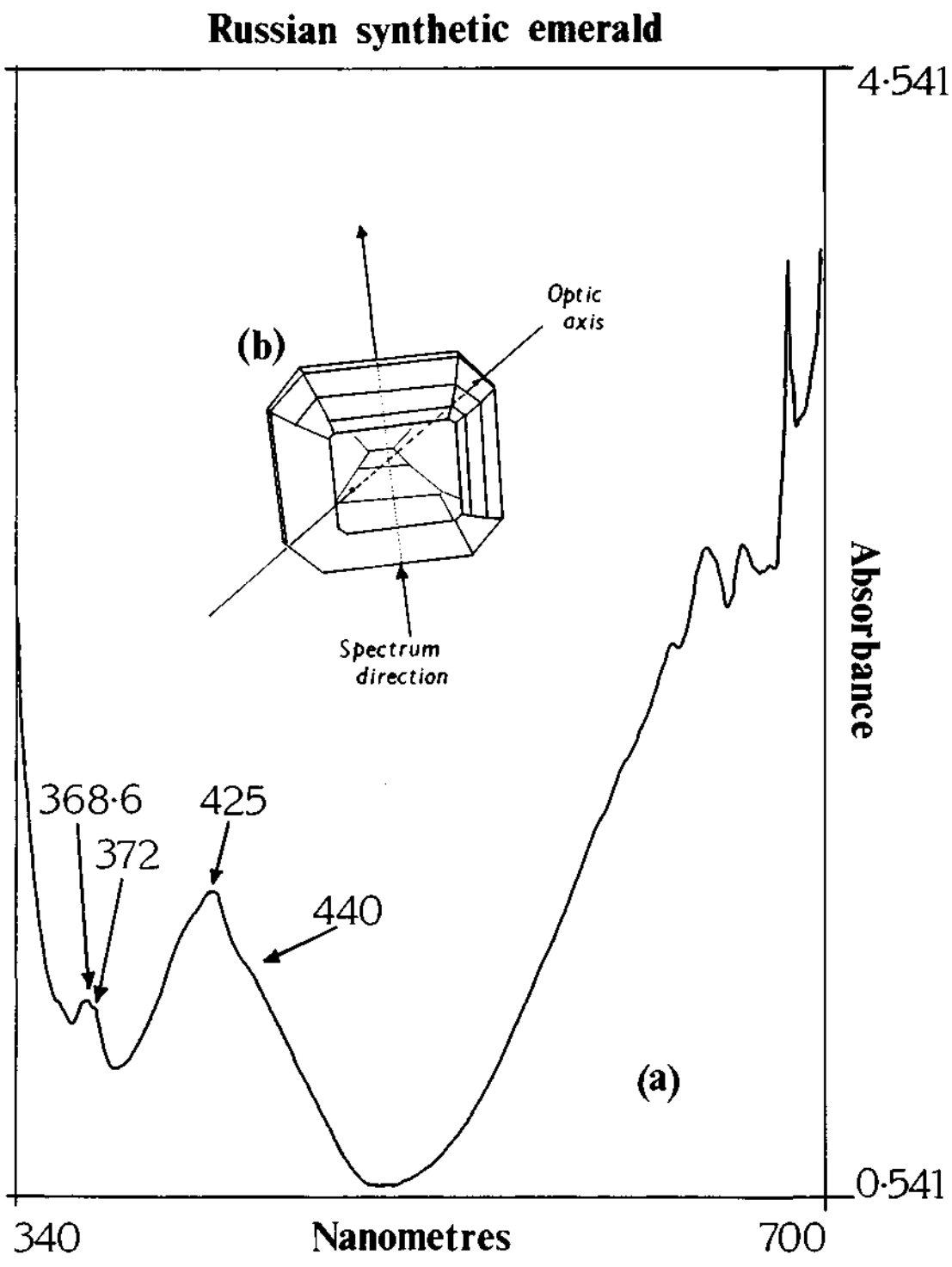

Fig. 29. The absorption curve of the emerald-cut Russian synthetic emerald of Figure 15 taken in the direction indicated by (b). The curve was obtained using a Pye Unicam PU 8800/03 UV/visible spectrophotometer (Basil Anderson model) with a speed of 1 nm/s and a bandwidth of 0.5 nm at room temperature. The path length was 4.96 mm.

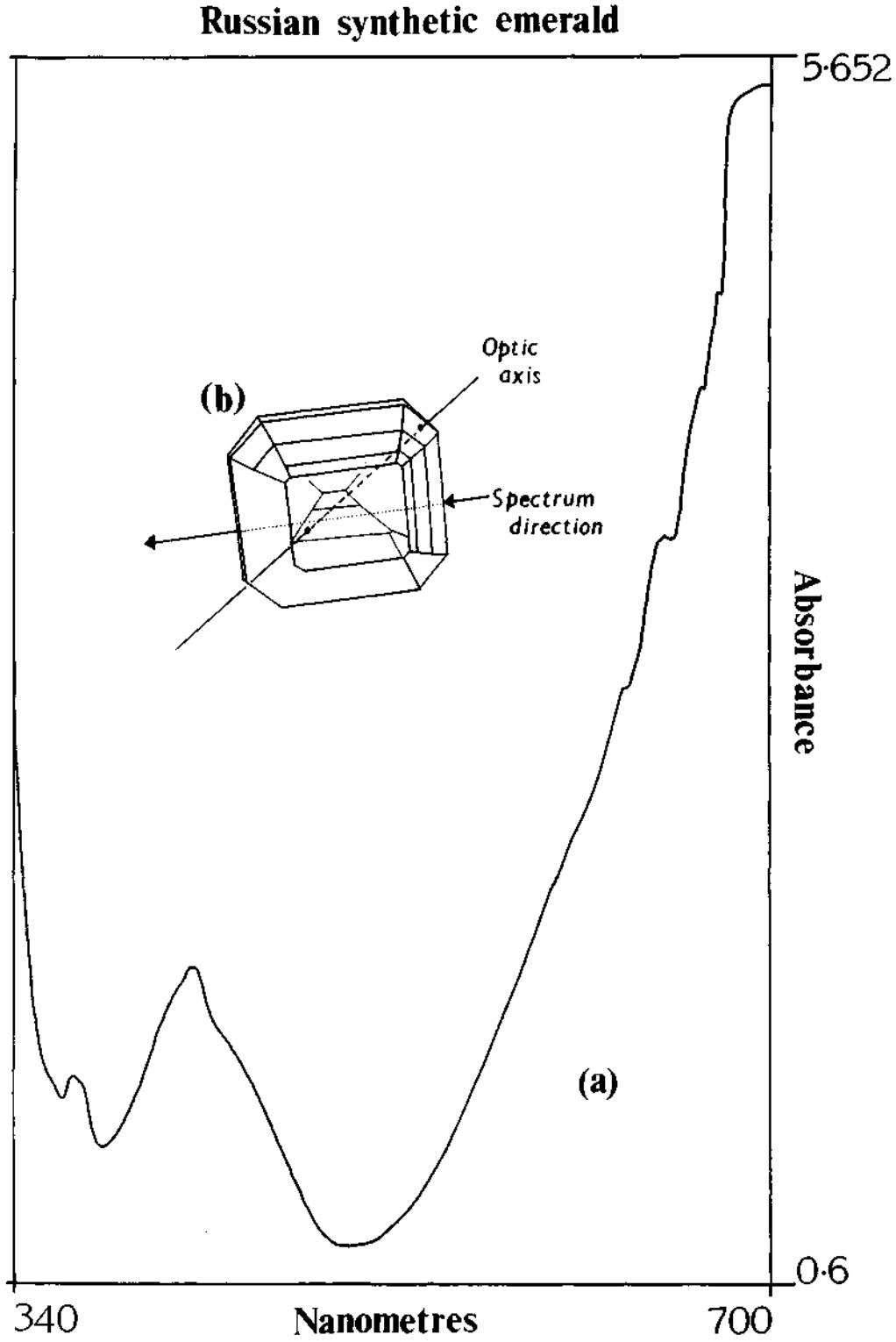

Fig. 30. The absorption curve of the emerald-cut Russian synthetic emerald of Figure 15 taken in the direction indicated by (b). The curve was obtained using a Pye Unicam PU 8800/03 UV/visible spectrophotometer (Basil Anderson model) with a speed of 1 nm/s and a bandwidth of 1 nm at room temperature. The path length was 5.49 mm.

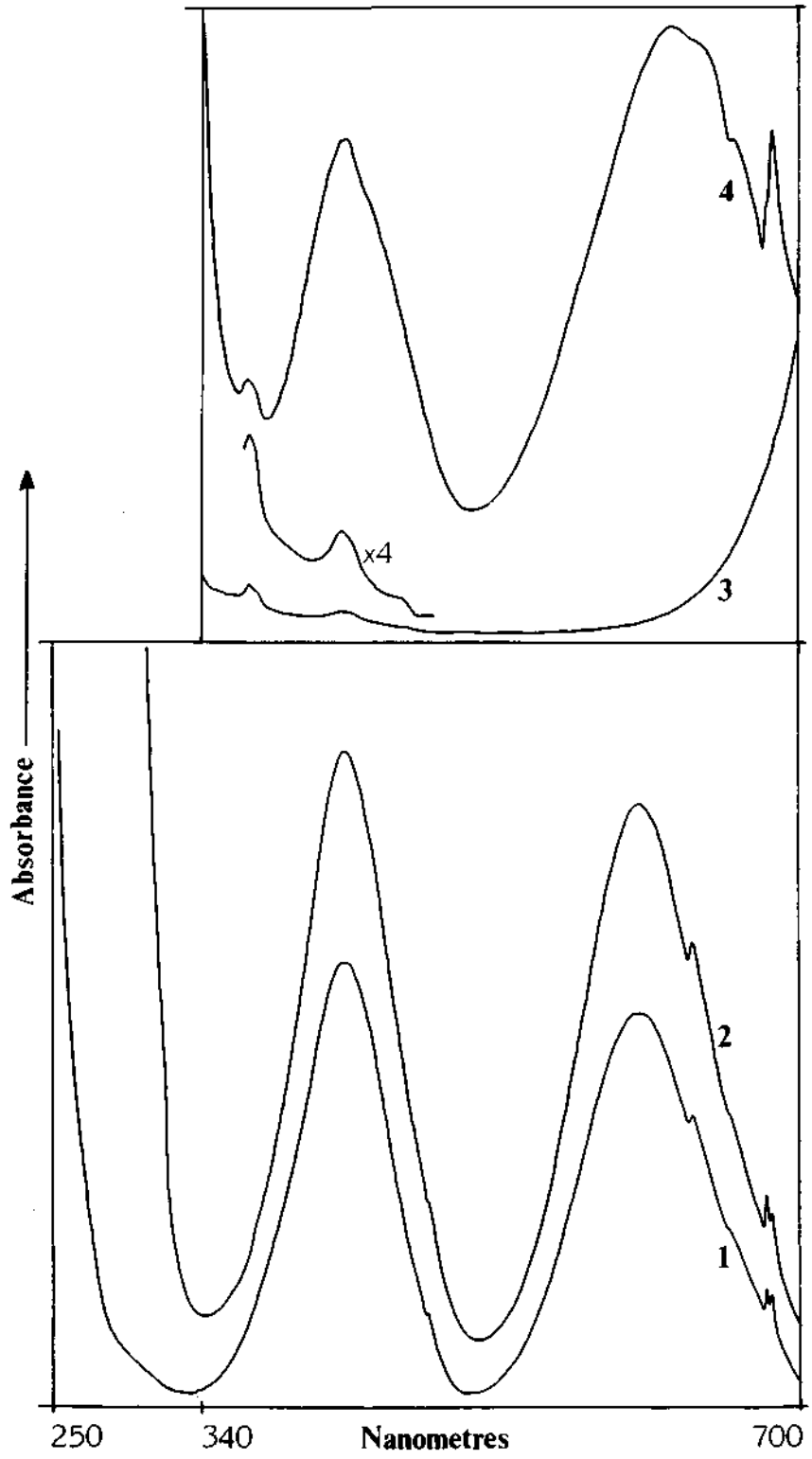

Fig. 31. Example absorption curves of (1) Australian hydrothermal synthetic emerald, (2) natural emerald from Colombia, (3) greenish aquamarine, (4) natural emerald from Madagascar.

Fig. 32. A 17.81 ct synthetic ruby with infilled cativies. The cavities are seen here looking through the crown to the bottom of the stone, positioned at the lower right corner and at the top edge of the table.

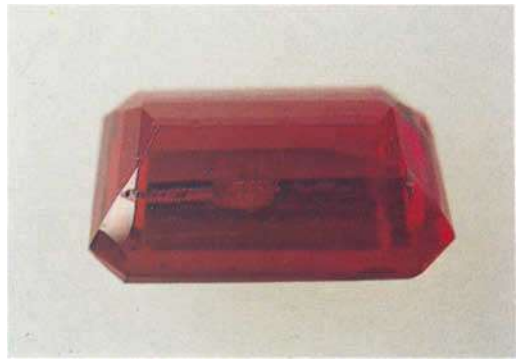

Fig. 33. An infilled cavity in the synthetic ruby of Figure 32 seen here from the bottom of the stone.

In recent times a number of papers have been published giving information on the glass infilling of cavities in ruby and sapphire (Scarratt and Harding, 1984; Kane, 1984; Scarratt, Harding and Din, 1986). In all instances the ruby or sapphire in question has, apart from the filling, been of natural origin.

A 17.81 ct red stone (Figure 32) sent for examination recently displayed the typical curved structures seen in stones produced by the Verneuil growth process and as a result was found to be a synthetic ruby. In addition to the curved growth structures though, there appeared to be a number of partially formed 'twin planes' which formed needle-like structures where their paths crossed, and a number of 'induced feathers', all of which might cause a little confusion to the uninitiated.

Somewhat amazingly though, on the bottom of the stone two holes appeared to have been manufactured, one on a side, and the other on a corner, and then filled with a colourless material (Figures 33 and 34) to imitate the cavity infillings of natural ruby. On the same corner as one of the infills two further cavities have been 'scooped out' and left in a similar manner to cavities that are left unfilled in natural rubies where infilling of other cavities has taken place.

The filling in this case is easily scratched by steel and against the brightly fluorescing background of the synthetic ruby it is inert to long-wave and green to short-wave ultraviolet rays. It also has a profusion of bubbles and, unlike the infilling seen in the natural material, the junction between the infill and the synthetic ruby at the surface is far from perfect.

The stone has now been placed on long-term loan in the Laboratory Collection.

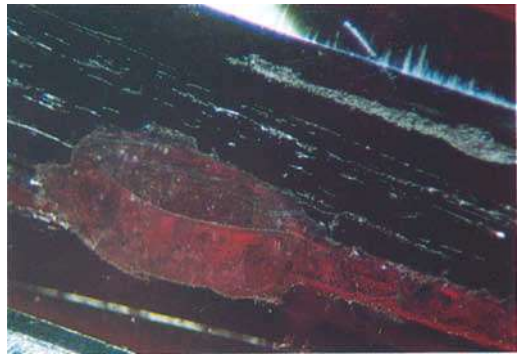

Fig. 34. A closer view of the infilled cavity seen in Figure 33.

Acknowledgements

It is with particular gratitude that the author acknowledges, on behalf of the Laboratory, firstly the good spirit of Mr Schlussel of The Diamond Registry, New York, in loaning to the Laboratory his faceted Sumitomo synthetic diamond and secondly, as always, the ready assistance of David Hargett for allowing the examination of the Sumitomo material that was in the New York Gem Trade Laboratory, in February of this year. Grateful thanks also go to Dr J. Milledge, of University College, London, for recording the infra-red spectrum of Mr Schlussel's stone.

Over the past few years Mr Mark L. Jones, FGA, has been a constant source of information to the Laboratory and he has made some very generous donations to the Collection, including the blue pearl described above. In this instance we are also indebted to him for sending the blue faceted sapphirine specimen for examination. We are

grateful also in this respect to J.G. Francis and S. Somogy of the British Museum (Natural History) for supplying the details of their sapphirine and providing a copy of its powder diffraction pattern for the Laboratory files.

The Laboratory is once again indebted to Alastair Cairncross, FGA, for his generosity, and on this occasion we thank him for the donation of the unusual brown (partly nacre-covered) pearl described above.

Finally we thank Alan Hodgkinson, FGA, for allowing us to examine his Russian synthetic emerald samples and Dr R.R. Harding and his colleagues at the British Museum (Natural History) for much discussion on the reasons for the peculiar absorption characteristics of these stones.

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The sale of the Windsor jewels

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Apart from creating international headlines, the April sale held in Geneva by Sotheby's of the Windsor jewels was a unique opportunity to see a collection of pieces of both gemmological interest and 'social' appeal. The Wallis and Edward romance attracted to the sale both the serious collector and the jet set.

Viewing the sale from the gemmological perspective it produced pieces of considerable interest, ranging from a matching pair of canary diamonds weighing 93 ct to a natural pearl necklace (Figure 1) graduating from 16.8 to 9.2 mm, and included many examples of fine craftsmanship by the well-known jewellers of the time.

The pear-shaped canary diamond lapel clips were exceptional due to the large size of the stones (40.81 ct and 52.13 ct), their good natural colour, and the fact that they were such a well-matched pair. They were very effective visually and Harry Winston put them into simple twisted wire diamond-set mounts. The Duchess had a pair of ear-rings to wear with the lapel clips; they each had two canary diamonds, one pear-shaped and one circular, in pavé-set mounts made by Cartier in 1968. These were of a deeper colour than the lapel clips.

The Duchess's most famous diamond was the 31.26 ct cushion-cut McLean diamond (Figure 2). This previously belonged to an American, Mrs Evalyn Walsh McLean, who had also owned the Hope diamond and the Star of the East, as well as many other pieces which were bought by Harry Winston after her death. He sold the McLean diamond to the Duke and Duchess in 1950. It was a beautifully proportioned stone and displayed considerable fire. A GIA report stated that it was 'D' colour, clarity VS2. The stone was claw-set with a single tapered baguette diamond on each shoulder; the ring sold for £1.8m. (before buyer's premium), the highest price in the sale, and was purchased by a Japanese diamond dealer.

On viewing the ruby pieces one was aware of their incredible vibrancy. The necklace (Figure 3) made by Van Cleef and Arpels for the Duchess's fortieth birthday, was in a design of twisted ribbons of cushion-shaped Burmese rubies and baguette diamonds with a tassel of rubies falling at the side of the neck. The whiteness of the diamonds provided a good contrast, making the rubies glow very intensely, creating a stunning effect overall. There were two large rubies weighing together 36.15 ct, in a Cartier bangle of 1938. These also appeared to be of Burmese origin; they were heavily included and had iron stains, patches of silk, and there was an interesting area of chatoyancy at the edge of one of the stones.

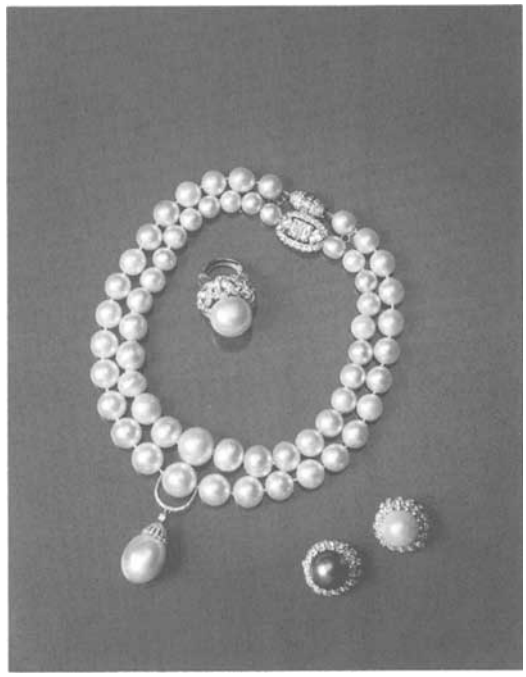

Fig. 1. Inner necklet: natural pearls graduated from 16.8 to 9.2 mm, diamond set clasp. Outer necklet: cultured pearls graduated from 15 to 11 mm, with detachable pearl drop. Ring set 18 mm natural pearl. Ear clips, set pearls (one black and one white) and diamonds.
Photo by courtesy of Sotheby's.

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Fig. 2. (Above) Flexible diamonds and sapphire set bracelet. 31.26 ct McLean diamond.
Photo by courtesy of Sotheby's.

Fig. 3. (Right) Ruby and diamond set necklet.
Photo by courtesy of Sotheby's.

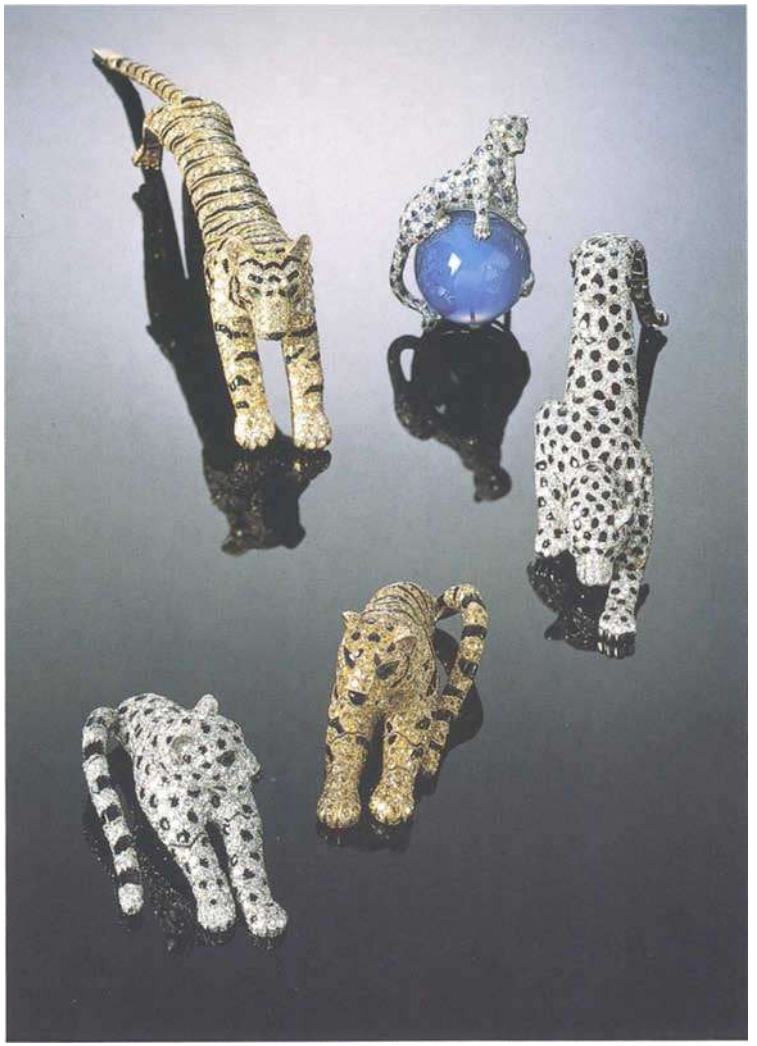
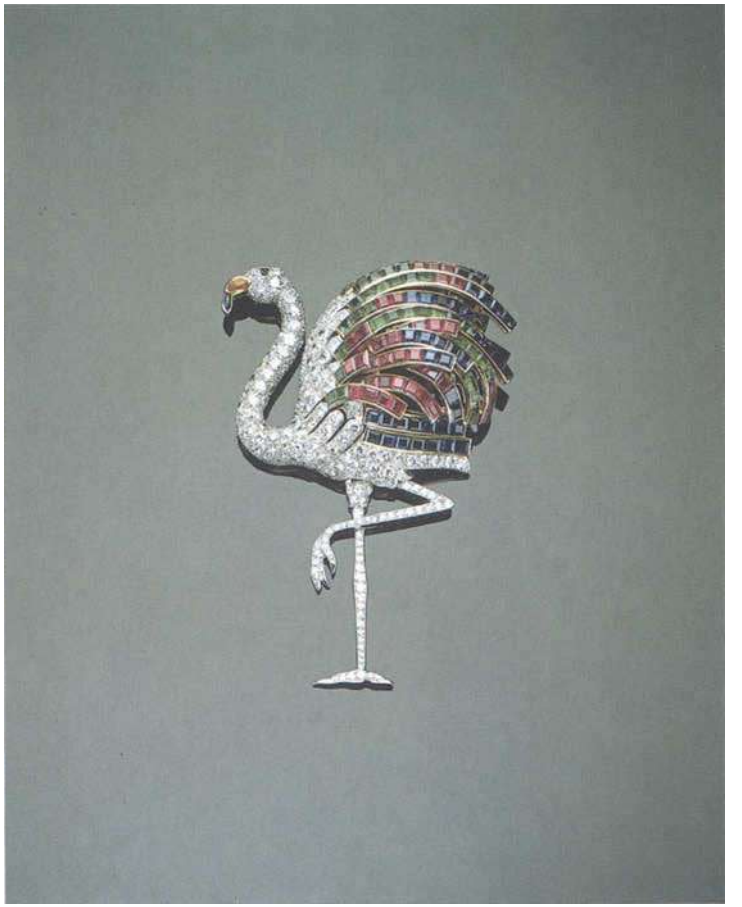


Fig. 4. (Left) Five of the famous cat jewels.
Photo by courtesy of Sotheby's.

Fig. 5. (Below) Gem-set flamingo brooch.
Photo by courtesy of Sotheby's.



One of the most interesting pieces of ruby-set jewellery from the design point of view was a double-leaf clip (cover picture) which was one of the first pieces in which Van Cleef and Arpels used the 'invisible setting'. The calibré rubies were cut with such precision that they slotted together and were held in place by channels of gold on the reverse of the piece so that no gold was visible at the front. The Duchess's wedding present from the Duke, a bracelet (Figure 2) in the form of a wide flexible band of diamonds, with an invisibly-set sapphire bow-shaped clasp, was also made by Van Cleef and Arpels. The cushion-shaped sapphires were of an incredibly intense blue. Her drop-shaped cabochon sapphire earrings were one of the most attractive pieces in the sale. The sapphires weighing 75 ct were suspended from diamond-set clips designed as Prince of Wales feathers. The sapphires had round dot-like inclusions and fine silk, and were probably of Burmese origin. The largest sapphire in the sale was a 206 ct cushion-shaped stone which was of an intense colour and simply mounted by Cartier in 1951 in a border of baguette and brilliant-cut diamonds with a detachable loop so that it could be worn as a pendant and also as a brooch. This was bought for £210,000 by Mr Marvin Mitchelson, purportedly on behalf of Miss Joan Collins. The Duchess often wore the pendant hanging from a diamond rivière which sold for eight times its estimated price.

There were various large emerald pieces in the Duchess's collection. The Duke is said to have swapped a couple of the Duchess's emerald and diamond necklaces for the 48.95 ct emerald and diamond pear-shaped pendant which once belonged to King Alphonso III of Spain. Although this was heavily included it must have looked very effective, particularly when worn suspended from the Cartier necklace which had five pear-shaped emeralds weighing 41.50 ct. Her engagement ring also had an interesting origin. It is said to have belonged to the Grand Mogul and was one half of a fantastic stone purchased by a member of Cartier on a stone-finding mission to Baghdad. He had wired home for a large sum of money which he spent on one enormous emerald. This stone was cut in half and repolished making two spectacular stones, one of which was bought by an American millionaire and the other by the Duke. The setting for the emerald was redesigned many times before the 1958 Cartier mount was settled on; the 19.77 ct stone is set in yellow gold with a diamond-set leaf border.

The Duchess owned some exceptionally large pearl pieces (Figure 1). She had a graduated natural pearl necklace with 28 pearls ranging from 16.8 mm to 9.2 mm, and a detachable pearl drop weighing 190 grains. Her pearl ring made by Cartier in 1964 was set with a single 18 mm natural pearl. She sometimes wore several pearl necklaces together; she also had a cultured pearl necklet by Van Cleef and Arpels of 29 pearls graduating from 15 to 11 mm, all of a fine lustre and well matched, compared with the natural pearl necklace which was of a greyish tinge and had small grain markings.

Among the highlights of the sale were the Cat jewels (Figure 4), inspired by Jeanne Toussain of Cartier. She had been a close companion of Louis Cartier and was made responsible for the Haute Joaillerie in 1934. She had a liking for panthers which resulted in the appearance of these jewels. The Duchess owned one of the first of these, made in 1948; it was an enamelled panther sitting on a 90 ct cabochon emerald. She also had another panther with a pavé-set diamond and calibre sapphire body with yellow diamond eyes, seated on a 152 ct cabochon sapphire. This sapphire was of a deep translucent cornflower-blue colour with some interesting inclusions; some small crystals with halos, other fine dots and a big patch of crystal inclusions on one side. This sapphire was originally purchased by the Duke for £5,000 and the finished piece sold for £576,000.

Jeanne Toussaint also designed the flamingo brooch (Figure 5) which the Duchess was often photographed wearing. It was made up by Cartier in 1940 using calibré-cut rubies, emeralds and sapphires in the plummage, a cabochon citrine and sapphire in the beak, a similarly cut sapphire in the eye, with a pavé-set body. The stones were of a fine colour; they were said to have come from other pieces of jewellery which had been broken up. It was exquisitely made and even had hinged legs.

As was widely publicized, the prices of these fantastic pieces far outreached all expectations. The estimate for the sale total had been £5m. but the final figure, including buyer's premium, was £31m. Pieces which incorporated the Prince of Wales feathers motif naturally fetched high prices. There was one particularly astonishing result – a dress suite comprising a pair of cufflinks, each link pavé-set with brilliant-cut diamonds, one with the letter 'W' and the other with the letter 'E', and three buttons and a stud with the letter 'E', estimated to sell for £4,800 to £6,400 realised £240,000! Elizabeth Taylor was said to have bid £350,000 'from her Los Angeles poolside' for the Prince of Wales feathers clip. These are just two indications of how the history outweighed the intrinsic value of the majority of pieces in this unique collection of jewellery.

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Blue and yellow sapphire from Kaduna Province, Nigeria

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Abstract

Blue and yellow sapphires from Kaduna province near Jos, Nigeria, were characterized by mineralogical and gemmological investigations and the diagnostic properties of the samples are given. The rough sapphire crystals with tabular, barrel-shaped or prismatic habit originate from a secondary weathering horizon. The mineral assemblage consists of quartz, kaolinite, goethite, hematite and gibbsite. The blue or yellow colour of the samples is caused by various amounts of Fe^{3+}, Fe^{2+}, Ti^{4+}, Ti^{3+} and Cr^{3+}. Microscopic investigations reveal characteristic properties such as growth structures associated with intense colour zoning, fissures on basal parting planes, mineral inclusions with or without primary liquid feathers (albite, uranpyrochlore, zircon), negative crystals, as well as pseudosecondary healing fissures and secondary inclusions in unhealed fractures.

Introduction

Dark blue sapphires from Nigeria have been known for about 15 years. They have been increasingly offered on the gem market since the beginning of the 80s and meanwhile have reached a certain economic significance. These sapphires are mostly dark blue, and although the majority are cut

Fig. 1. E. Petsch at a visit to the sapphire occurrence in Kaduna province, north-east of Jos, Nigeria.

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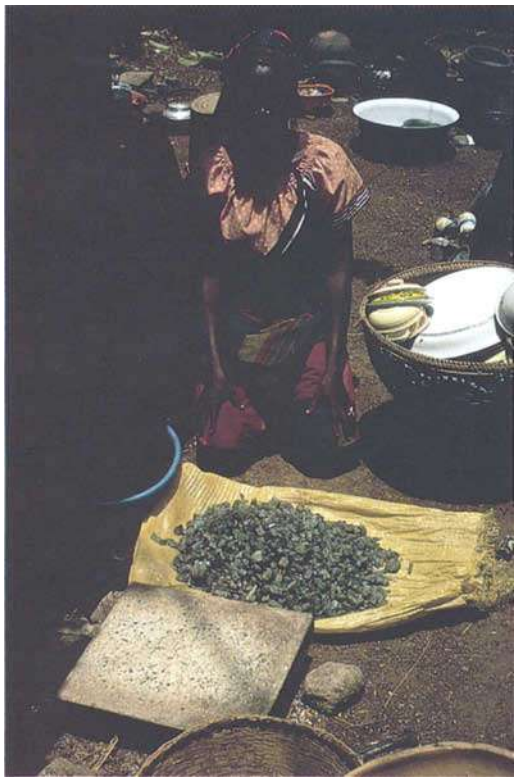

Fig. 2. Rough sapphire crystals from Kaduna province, north-east of Jos, Nigeria.

as cabochons, some are faceted. From time to time, yellow sapphires from Nigeria are offered as well.

Even though rough and cut sapphires from Nigeria have been available for a long time only one short contribution by Henn (1986) has been published until now with initial information about physical properties and inclusions.

38 rough crystals and 31 sapphires cut as cabochons from Nigeria have been at the authors' disposal in connection with systematic investigations of sapphires from different localities. Thus we had enough material to conduct detailed investigations of the diagnostic properties of the sapphires from this locality. Some interesting properties of these corundums caused the authors to publish a more detailed description of the Nigerian sapphires.

Occurrence and paragenesis

According to Petsch (1986, private communication), the sapphires described in this article originate from Kaduna province, about 45 km north-east of the city of Jos in Nigeria. The sapphires of the trade are derived, according to information given, from a secondary source. They are mined from an alluvial weathering rock, in holes and depressions up to a depth of about 0.5 to 1 m (Figures 1, 2). The sapphires show a dull, slightly corroded surface, which is a hint towards a magmatic rock as native host rock of the corundums, for the crystals were obviously in direct contact with a melt. There is only a slight rounding of the crystals, a sign for a relatively short transportation of the primary material to the secondary deposit.

In order to characterize the surrounding rock more exactly, the weathering minerals, which were existent on the faces of some rough samples, were determined by microprobe investigations and X-ray powder diffraction. In general, this very fine aggregate consists of quartz as well as the ferralitic weathering minerals goethite and kaolinite; subordinate minerals are gibbsite and hematite. These results reveal that this sapphire deposit in Nigeria is an occurrence in a secondary weathering horizon.

In literature Falconer (1911) describes a lateritic weathering horizon in the district where the investigated sapphire deposit occurs. Reyment (1965) mentions kaolinitic clays on the Jos plateau, and Turner (1977) characterizes lateritized Tertiary basalts from several localities in the whole area of the Jos plateau.

Scarratt *et al.* (1986) describe a weathered alkali basalt as primary mother rock of blue sapphires on the Jos plateau (cf. Figure 5 in Scarratt *et al.*, 1986). These authors also mention the slightly corroded surface of the crystals. Unfortunately, there is no information obtainable about the distance between the primary and the secondary occurrence. It is also unknown if the sapphire-bearing mother rock is exploited for gems commercially.

Morphology and appearance of the crystals

As mentioned above, the rough sapphires from Nigeria have dull, slightly corroded surfaces with slightly rounded edges. This appearance is typical for crystals which are brought up to the Earth's surface together with volcanic activity. The corroded crystal faces show a dull greasy lustre.

Furthermore, the crystals reveal smooth, highly lustrous faces parallel to the basal pinacoid c (0001) besides faces showing the typical conchoidal fracture of corundum. Those smooth faces are glide planes parallel to the basal plane c, a specific property of corundum, which causes basal parting of the crystals.

Due to the high number of crystals with well developed crystal faces, a typical morphology of the Nigerian sapphires was determined as follows: the majority of the crystals reveal tabular habit with the basal pinacoid c (0001) and the hexagonal dipyramid z (22$\bar{4}$1) or with the crystal faces c, z and the positive rhombohedron r (10$\bar{1}$1) (Figures 3a, b). Besides the

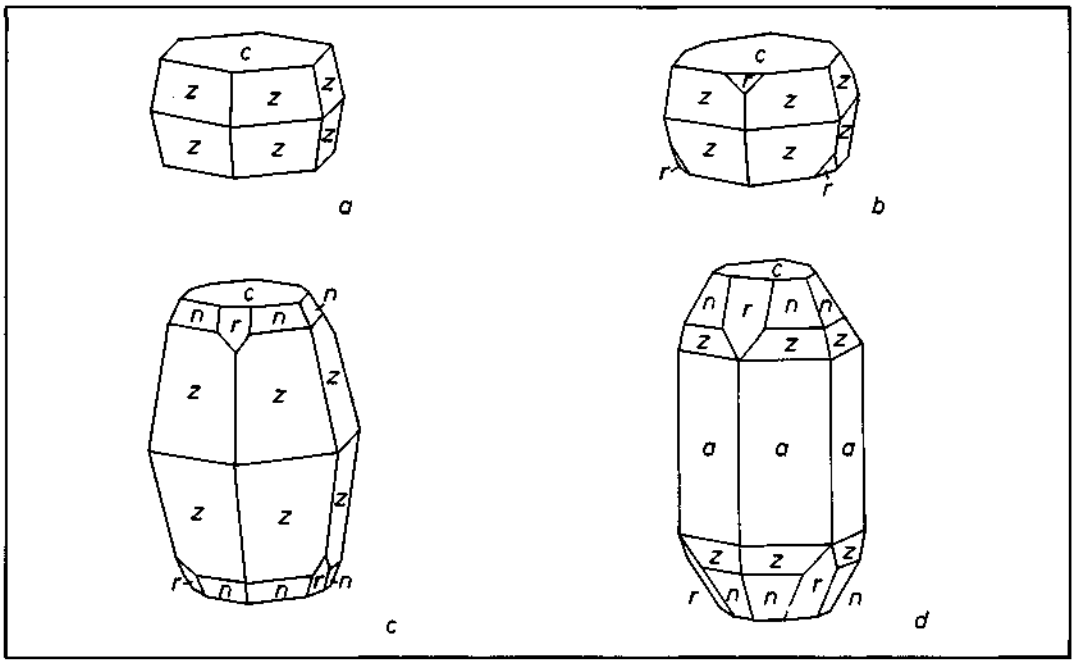

Fig. 3. Habit of blue sapphires from Nigeria, (a, b) tabular, (c) barrel-shaped, (d) prismatic; crystal faces are the basal pinacoid c (0001), the hexagonal prism a (11$\bar{2}$0), the positive rhombohedron r (10$\bar{1}$1), and the hexagonal dipyramids n (22$\bar{4}$3) and z (22$\bar{4}$1).

Fig. 4. Cut blue sapphires from Nigeria. *Photo by O. Medenbach, Bochum.*

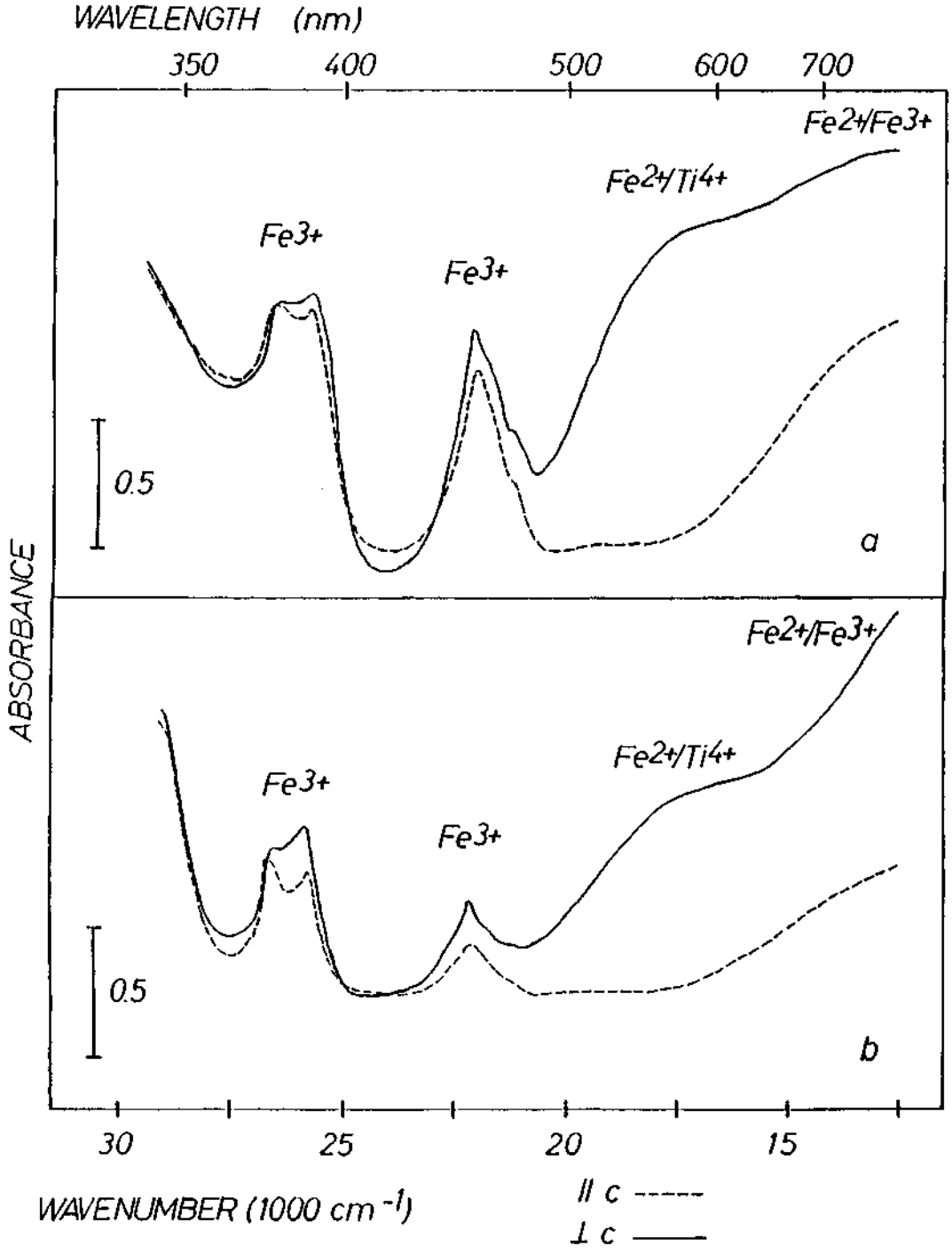

Fig. 5. Absorption spectra of blue sapphires from Nigeria without Cr^{3+}-component; pleochroism ∥ c yellowish-green, ⊥ c bluish-violet; hues in colour are caused by variable intensities of the Fe- and Fe-Ti-bands.

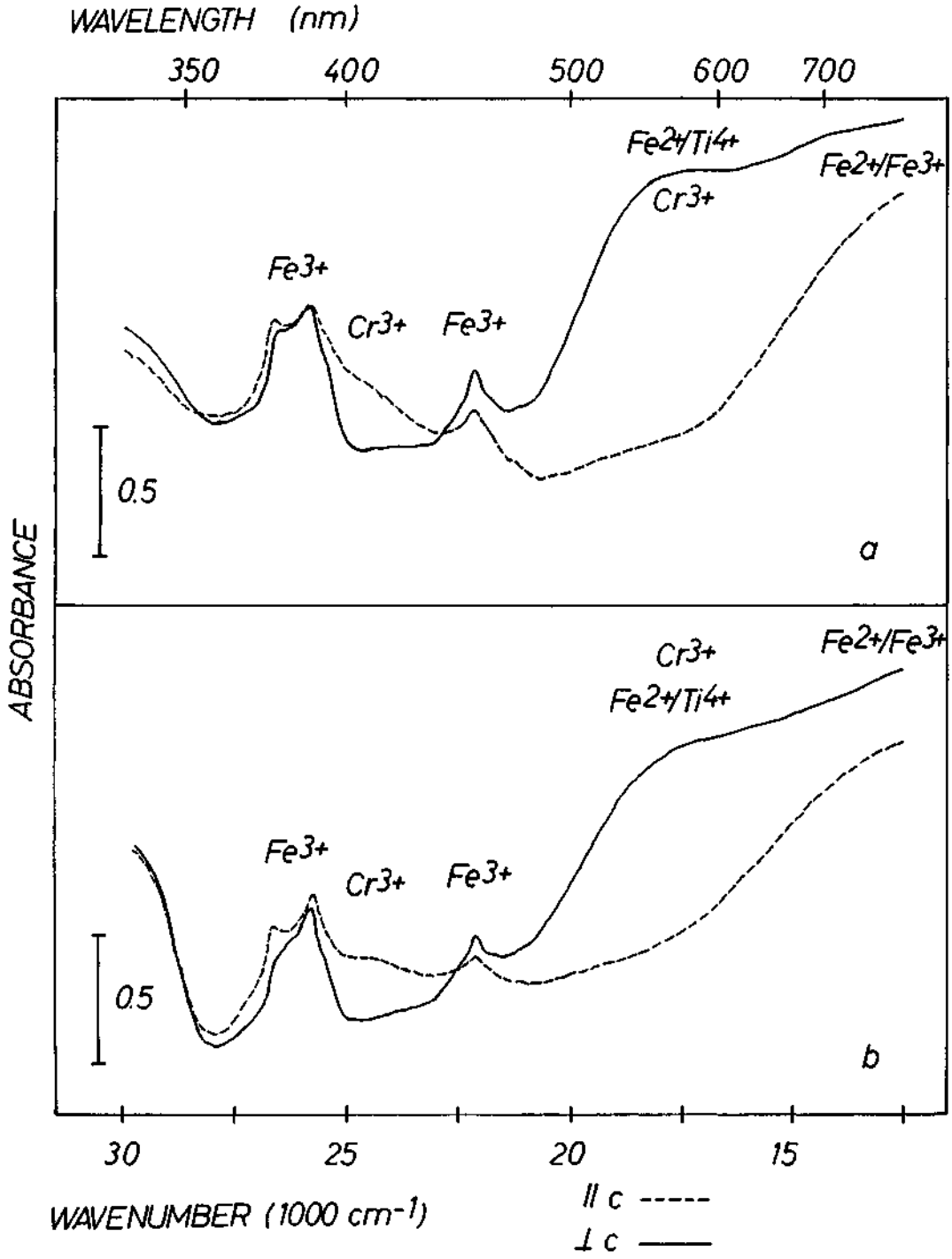

Fig. 6. Absorption spectra of blue sapphires from Nigeria with Cr^{3+}-component; pleochroism ∥ c bluish-green or green ⊥ c bluish-violet; hues in colour are caused by variable intensities of the Cr-, Fe- and Fe-Ti-bands.

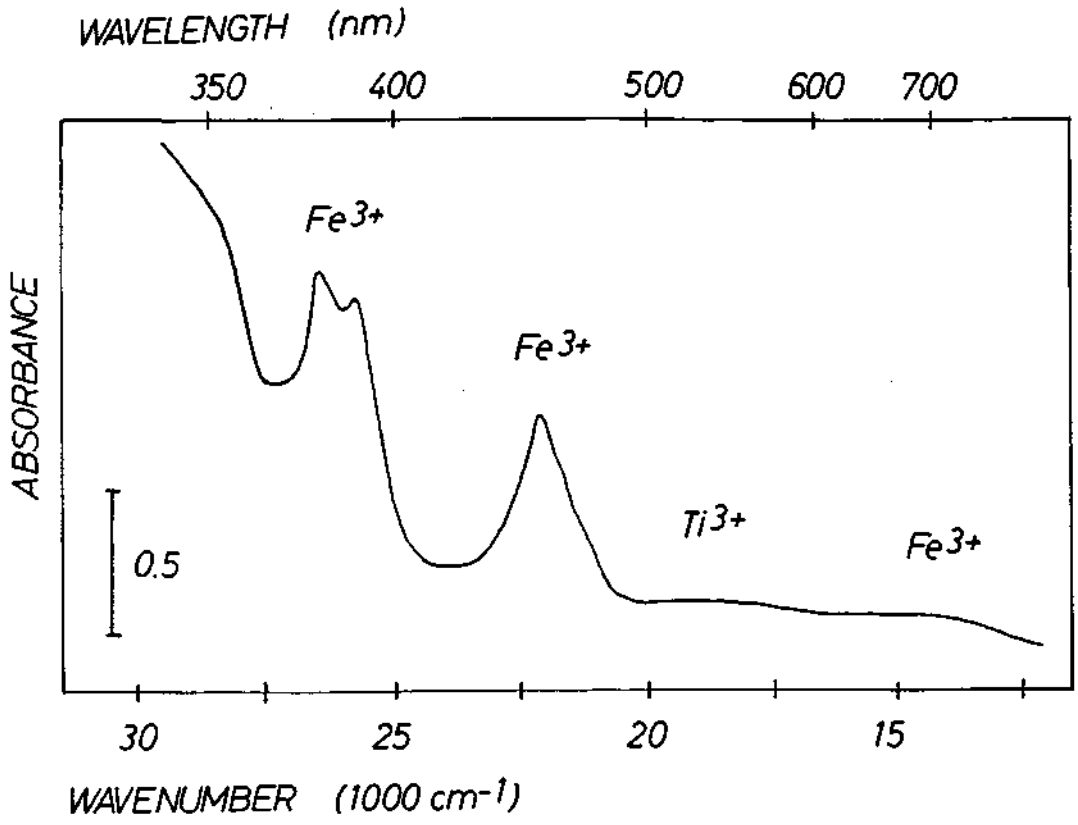

Fig. 7. Absorption spectra of a yellow sapphire from Nigeria without Fe^{2+}/Ti^{4+}- and Fe^{2+}/Fe^{3+}-component, weak pleochroism.

crystal faces as mentioned above, additionally sapphires with barrel-shaped habit reveal the hexagonal dipyramid *n* (22$\bar{4}$3) (Figure 3c). Crystals with prismatic habit display the hexagonal prism *a* (11$\bar{2}$0) in addition to the forms mentioned above (Figure 3d).

Physical properties

The density of some of the sapphires was determined to range from 3.99 to 4.01 g/cm^3. The refractive indices vary between 1.759 and 1.761 for n_e and between 1.768 and 1.770 for n_o; the double refraction equals 0.009. These data reveal the typical values for corundum (cf. also Henn, 1986).

Colour and spectroscopic data

Part of the sample of cut sapphires from Nigeria shows a very dark, inky blue, and part discloses a dark blue colour with a light greenish hue (Figure 4). Rough crystals reveal an especially distinct pleochroism. The Nigerian sapphires show bluish-violet colours perpendicular to the *c*-axis, and bluish-green, green or greenish-yellow colours parallel to the *c*-axis. Occasionally, the rough crystals show macroscopically a very distinct colour zoning parallel to the outer crystal faces.

In order to clarify the colour causes, absorption spectra of all available samples were recorded in the area of 11 500 to 30 000 cm^{-1} (870–333 nm) using a double-beam Leitz-Unicam SP.800 spectrophotometer. Some of the samples were measured in polarized light, i.e. the absorption spectra parallel and perpendicular to the *c*-axis could be measured separately.

The blue sapphires from Nigeria reveal a distinction into two main types of spectra (for the assignment of the absorption spectra of natural blue, bluish-green, green and yellow sapphires cf. the papers of Schmetzer and Bank, 1980, 1981, a, b; Burns and Burns, 1984; Schmetzer, 1987): samples that appear yellowish-green parallel to the *c*-axis and bluish-violet perpendicular to the *c*-axis show only the absorption bands of Fe^{3+} and the intervalence absorption bands of Fe^{2+}/Fe^{3+} and Fe^{2+}/Ti^{4+}. Perpendicular to the *c*-axis the band of Fe^{2+}/Ti^{4+} is much more intense in the yellow spectral range compared with the spectrum parallel to the *c*-axis, which causes the different pleochroism

of the crystals (Figures 5a, b).

Sapphires that show bluish-green to green colours parallel to the *c*-axis and bluish-violet colours perpendicular to the *c*-axis have, besides the already mentioned sapphire-spectra with Fe^{3+}, Fe^{2+}/Fe^{3+} and Fe^{2+}/Ti^{4+}, distinct Cr^{3+} bands in the yellow and bluish-violet ranges, respectively. This Cr^{3+}-component of the spectrum is more distinct in the direction parallel to the *c*-axis than perpendicular to *c*. It weakens the yellow and bluish-violet transmission parallel to *c* and leads to a strengthening of the green component (Figures 6a, b).

For both types of spectra, the presence of the Fe^{3+}, Fe^{2+}/Fe^{3+} and Fe^{2+}/Ti^{4+} bands is characteristic, but their relative intensities in different samples may, however, vary considerably. This wide range in variation is responsible for the different hues of blue Nigerian sapphires.

The spectrum of the less common yellow sapphires, which were available to the authors only as cut samples, is dominated by Fe^{3+}, and there is also a weak Ti^{3+} absorption band (Figure 7). The intervalence absorption bands of Fe^{2+}/Fe^{3+} and Fe^{2+}/Ti^{4+} were not observed in yellow samples.

Microscopic properties

Corundum samples from Nigeria which are described in this paper commonly reveal small lamellae of corundum in twin position, which are intercalated parallel to the positive rhombohedron r $(10\bar{1}1)$ of the dominant corundum crystal in one, two or three directions intersecting at angles of 93.9° (Figures 8, 9, 10). The distances between different twin lamellae vary widely; occasionally they end irregularly in the dominant corundum crystal. Frequently, the intersecting lines between two sets of intercalated corundum lamellae reveal lath-like structures consisting of polycrystalline material (most probably boehmite) (Figures 10, 11; cf. Schmetzer, 1986b).

As a characteristic feature, the crystals disclose families of straight parallel growth planes; repeatedly two or more sets of straight parallel growth planes that form an angle are observable. Nearly always there is a strong colour zoning between darker and lighter, almost colourless areas connected with growth structures. This colour zoning is due to different growth conditions, i.e. due to a different incorporation of the colour-causing elements Fe and/or Ti in concentration and/or valence. The determination of growth structures according to the method of Schmetzer (1985, 1986a) reveals that the planes are, according to the morphology of the rough crystals, mainly parallel to dominant crystal faces like the hexagonal dipyramid z $(22\bar{4}1)$, parallel to the positive rhombohedron r $(10\bar{1}1)$ and parallel to the basal pinacoid c (0001). In addition, crystal faces parallel to the hexagonal dipyramid n $(22\bar{4}3)$ and parallel to the hexagonal prism a $(11\bar{2}0)$ may occur (Figures 12–17). In connection with growth structures and colour zoning the sapphires from Nigeria may contain zones with different concentrations of extremely small particles ('mineral dust') (Figure 18) or, rarely, with tiny needle-like mineral inclusions.

There is a strikingly high number of samples with unhealed plane fissures orientated parallel to the basal pinacoid *c*. These fissures are arranged so that they are intersecting right-angled with the prism faces a $(11\bar{2}0)$ and under an angle of 79.6° with the dominant pyramid faces z $(22\bar{4}1)$. They appear transparent in a view parallel to the *c*-axis, but expose total internal reflection under distinct angles in the microscope (Figure 19). This proves that these are fissures on glide planes parallel to the basal pinacoid *c*, which are due to a plastic deformation of the corundum crystals (cf. Schmetzer and Kiefert, 1986). As indicated in laboratory experiments, glide planes, or partings, respectively, parallel to the basal pinacoid *c* may be generated already at low temperatures, i.e. at about 900°C (Kronberg, 1957; Scheuplein and Gibbs, 1960). Glide planes and partings parallel to *c* are common in natural corundum from different localities.

Mineral inclusions are not present in all sapphires from Nigeria. However, part of the investigated samples reveal characteristic solid inclusions like hexagonal platelets, crystals with tension cracks, crystals with rosette-like fluid inclusions parallel to the basal pinacoid *c* as well as grains surrounded by irregularly orientated rosette-like fluid inclusions. These orientated and not orientated fluid inclusion rosettes are, as well as the mineral inclusions, of primary origin. They were included in the host crystal together with the mineral grains during the formation of the corundum host.

In one sample, opaque, hexagonal-shaped platelets, that are partly corroded, were observed (Figure 20). These platelets, which could not yet be determined exactly, reveal a certain similarity to hexagonal Pt-particles in flux-grown Chatham synthetic rubies and sapphires (cf. Kane, 1982; Schmetzer, 1986b). Furthermore, short-prismatic to columnar mineral inclusions with small stress cracks were observed and identified by electron microprobe as zircons (Figure 24). Red to reddish-brown, slightly rounded grains with irregularly orientated stress cracks and rosette-shaped fluid inclusions are frequently observed (Figures 21, 22, 23). These inclusions were exposed at the surface of two cut samples. They were determined by microprobe investigations as uranpyrochlore (cf. also Hogarth, 1977). Furthermore, occasionally

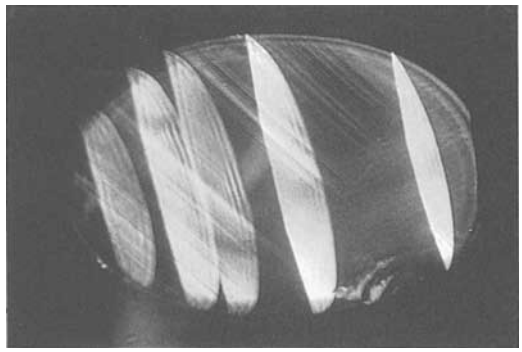

Fig. 8. Blue sapphire from Nigeria; intercalated lamellae of corundum in twin position parallel to one rhombohedral face r $(10\bar{1}1)$. Crossed polarizers. 20x.

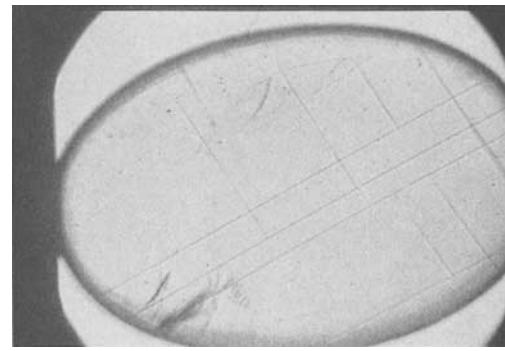

Fig. 9. Blue sapphire from Nigeria; intercalated lamellae of corundum in twin position parallel to two rhombohedral faces r and r' $\{10\bar{1}1\}$ intersecting at angles of 93.9°. 30x.

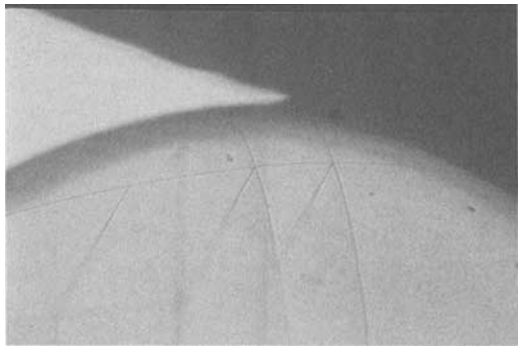

Fig. 10. Blue sapphire from Nigeria; intercalated lamellae of corundum in twin position parallel to two rhombohedral faces r and r' $\{10\bar{1}1\}$; polycrystalline material, most probably boehmite, at the intersecting lines of both lamellar systems. 65x.

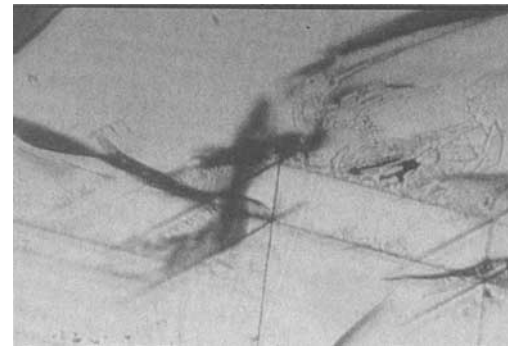

Fig. 11. Blue sapphire from Nigeria; rectangular three-dimensional lattice of polycrystalline material, most probably boehmite, at the intersecting lines of twin lamellae intercalated parallel to the three rhombohedral faces r, r' and r'' $\{10\bar{1}1\}$. 85x.

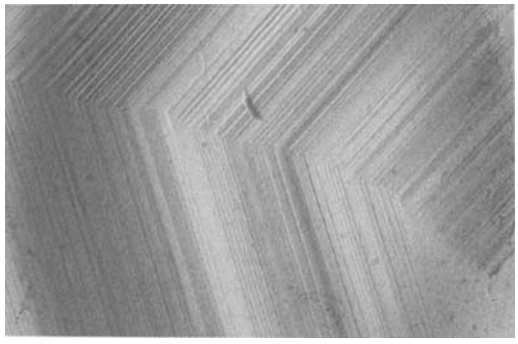

Fig. 12. Blue sapphire from Nigeria, view 10.4° inclined to the c-axis; angled growth structure, the faces z and z' $\{22\bar{4}1\}$ are forming an angle of 121.1°. Crossed polarizers. 30x.

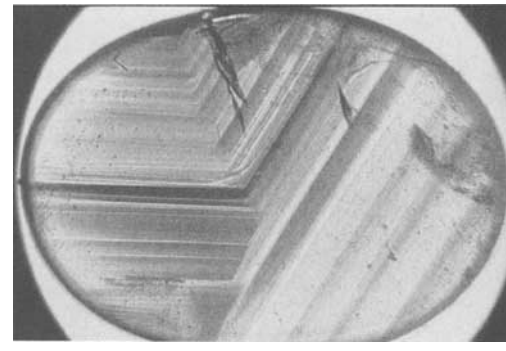

Fig. 13. Blue sapphire from Nigeria, view ‖ to the c-axis; angled growth structure, the faces a and a' $\{11\bar{2}0\}$ are forming an angle of 120°. 30x.

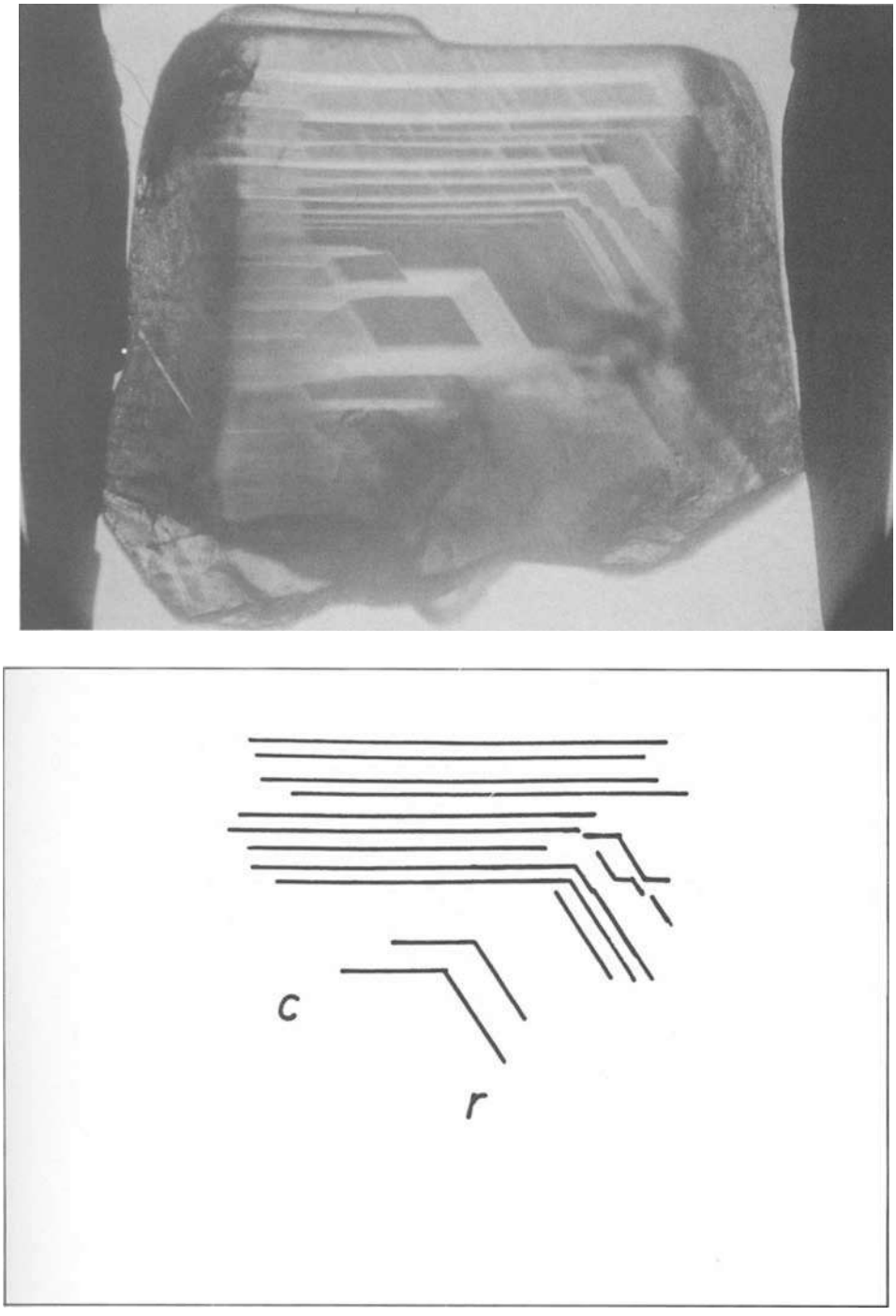

Fig. 14. Blue sapphire from Nigeria, view ⊥ to the *c*-axis; growth- and colour zoning parallel to the basal pinacoid c (0001) as well as parallel to the positive rhombohedron r ($10\bar{1}1$). Above: microphotograph, 16x; below: drawing of growth planes.

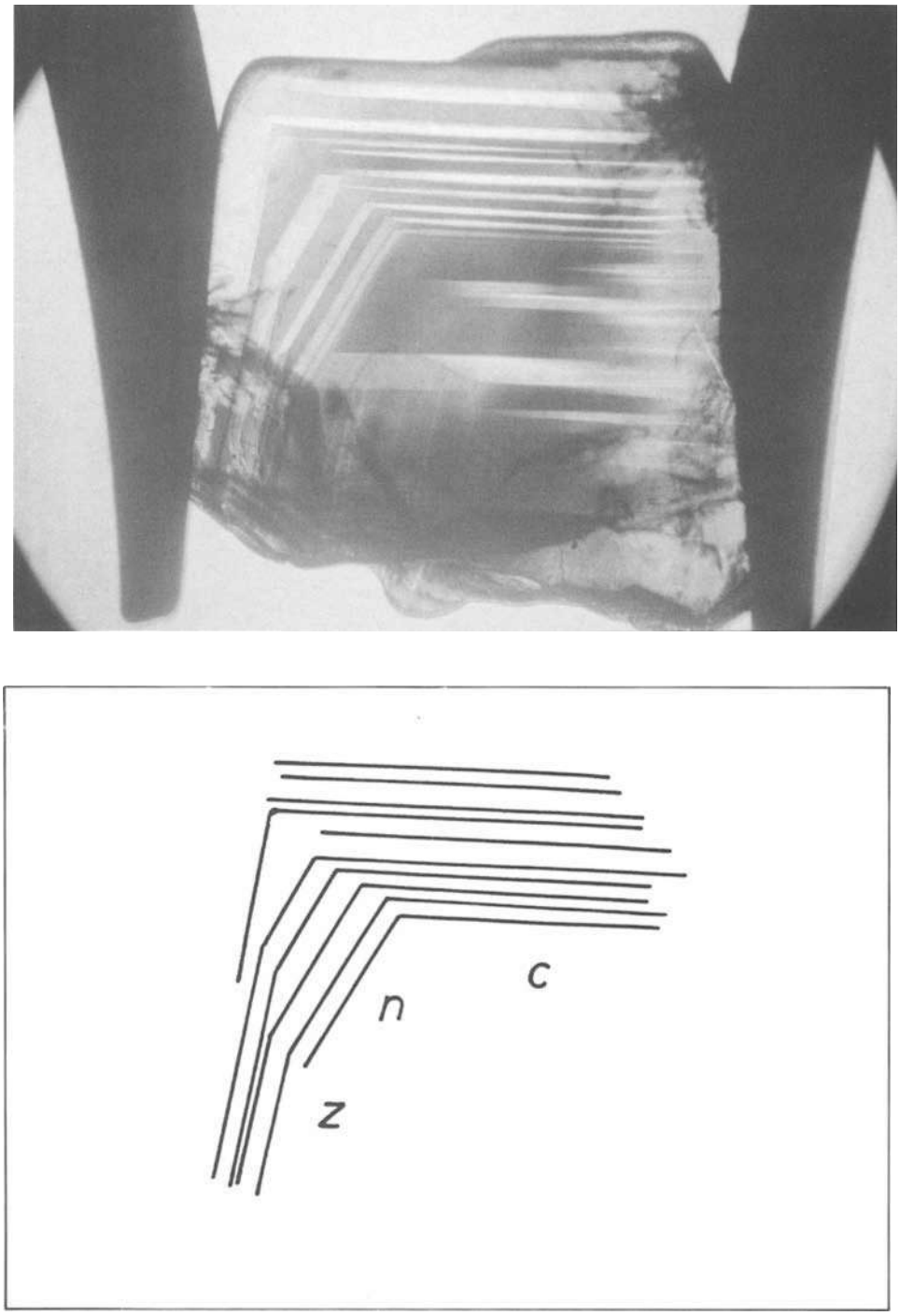

Fig. 15. Blue sapphire from Nigeria, view ⊥ to the c-axis; growth- and colour-zoning parallel to the basal pinacoid c (0001) as well as parallel to the hexagonal dipyramids n $(22\bar{4}3)$ and z $(22\bar{4}1)$. Above: microphotograph, 16x; below: drawing of growth structures.

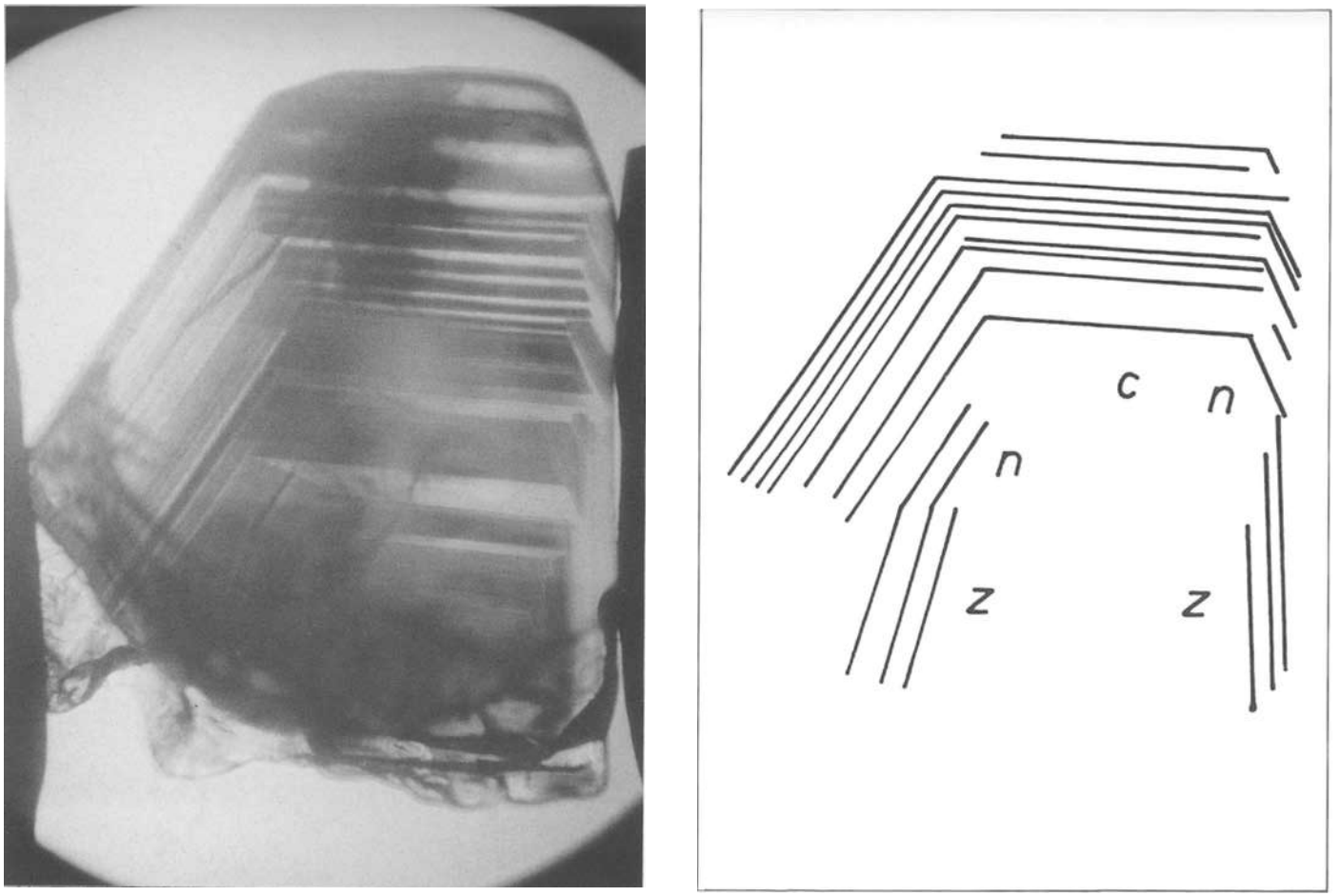

Fig. 16. Blue sapphire from Nigeria, view ⊥ to the *c*-axis; growth- and colour-zoning parallel to the basal pinacoid *c* (0001) as well as parallel to the hexagonal dipyramids *n* $\{22\bar{4}3\}$ and *z* $\{22\bar{4}1\}$. Left: microphotograph, 18x; right: drawing of growth structures.

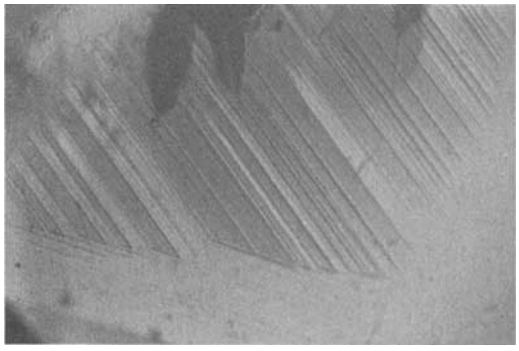

Fig. 17. Blue sapphire from Nigeria, view 32.4° inclined to the c-axis; growth structure parallel to the positive rhombohedron r $(10\bar{1}1)$. 30x.

Fig. 18. Blue sapphire from Nigeria, view ⊥ to the c-axis; growth structure parallel to the basal pinacoid *c* (0001), connected with areas of different concentrations of extremely fine mineral inclusions. 45x.

Fig. 19. Blue sapphire from Nigeria; fissures showing internal reflection due to glide planes parallel to the basal pinacoid *c* (0001). 50x.

Fig. 20. Blue sapphire from Nigeria; corroded, hexagonal-shaped mineral platelet. 100x.

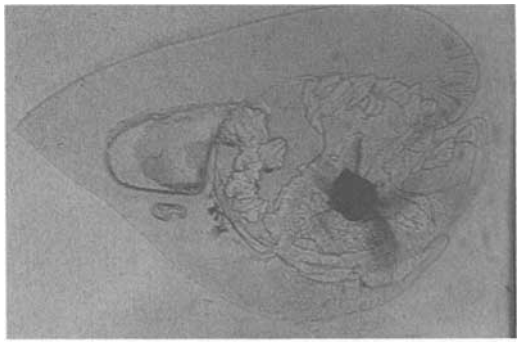

Fig. 21. Blue sapphire from Nigeria; uranpyrochlore with stress cracks and irregularly orientated primary rosette-like fluid inclusions. 45x.

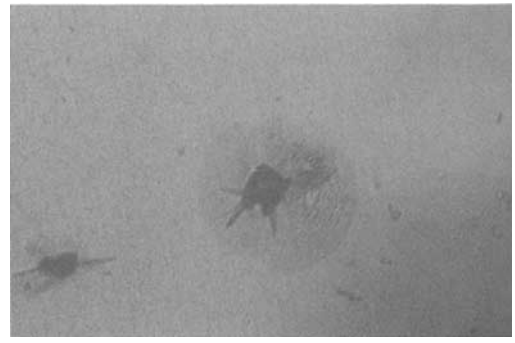

Fig. 22. Blue sapphire from Nigeria, uranpyrochlore with stress cracks and irregularly orientated primary rosette-like fluid inclusions. 100x.

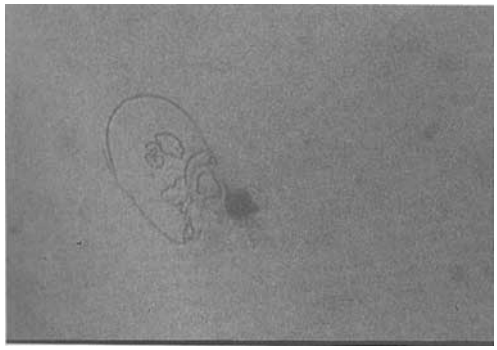

Fig. 23. Blue sapphire from Nigeria; uranpyrochlore with stress cracks and irregularly orientated primary rosette-like fluid inclusions. 85x.

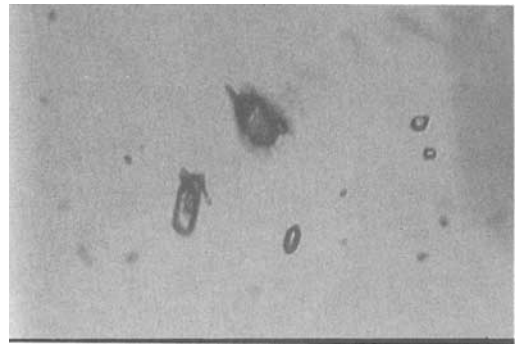

Fig. 24. Blue sapphire from Nigeria; rounded uranpyrochlore with stress cracks (above), prismatic albite (right), zircons (below and left). 100x.

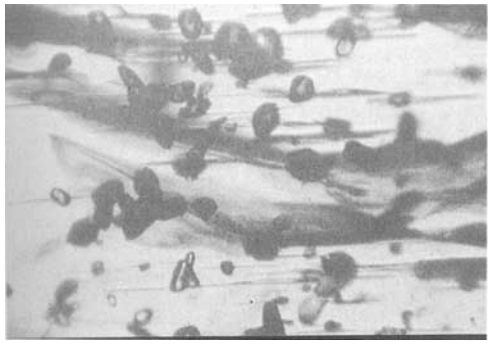

Fig. 25. Blue sapphire from Nigeria; prismatic to rounded albite crystals with rosette-like fluid inclusions parallel to the basal pinacoid c (0001). 65x.

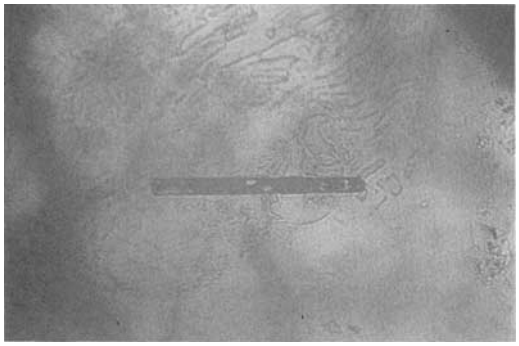

Fig. 26. Blue sapphire from Nigeria, view $\perp$ to the c-axis; prismatic to rounded albite crystals with rosette-like fluid inclusions parallel to the basal pinacoid c (0001). 75x.

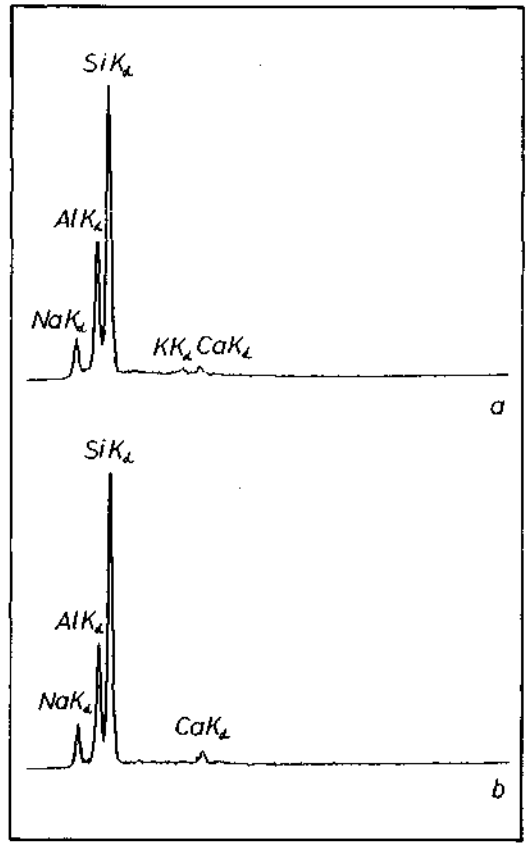

Fig. 27. Energy dispersive X-ray spectra of an albite crystal in a blue sapphire from Nigeria (a) as well as of an albite-standard of the Institute of Mineralogy and Petrography, University of Heidelberg (b).

slightly rounded, double-refracting prisms were observed with rosette-like fluid inclusions, which are orientated parallel to the basal pinacoid *c* (Figure 24). Similar fluid inclusion rosettes around grains or negative crystals with an identical orientation on faces parallel to the basal pinacoid are frequently observable in rubies from Thailand and should be known to all gemmologists.

In one specimen of the available investigation material, a greater number of such slightly rounded, prismatic mineral inclusions with rosette-like fluid inclusions parallel to the basal pinacoid was observed (Figures 25, 26). This sample was cut and polished several times and the inclusions exposed at the surface were investigated by microprobe. These investigations revealed partly irregularly formed cavities and negative crystals, but also five crystals of identical chemical composition. They were identified as a Na-Al-silicate. By comparison with the energy dispersive X-ray spectra of an albite-standard, the inclusions in the blue sapphire from Nigeria could be determined as albite (Figures 27a, b).

Besides the different mineral inclusions (zircon, albite, uranpyrochlore) and the above-mentioned irregularly formed cavities and negative crystals, the sapphires from Nigeria frequently show cavities partly filled with microcrystalline substances or two-phase inclusions, which are also surrounded by healing fissures (Figures 28, 29, 30).

Whereas the orientated and non-orientated rosette-like fluid inclusions around mineral grains are certainly of primary origin, the corundums from Nigeria frequently reveal pseudosecondary healing fissures (Figures 31, 32) and not healed fissures. Furthermore, the investigated sapphires show occasionally fissures secondarily filled with brown mineral substances (Figure 33). Presumably, these brown fillings consist of Fe-oxides or -hydroxides, that were deposited in the fissures during the weathering process of the rock. Probably they are the same weathering minerals, which build the surrounding weathering rock, i.e. goethite or hematite.

Healing fissures of one kind are worth mentioning in particular because they are so far observed in this form in corundum from Nigeria only: these healing fissures show an initial pseudo-secondary healing at the rims of the cracks. Later on, no subsequent formation of corundum took place until the fissure was completely healed. However, the crack desiccated, because obviously no adequate growth conditions, e.g. no adequate nutritive solutions, were available for the formation of corundum. Substances which were contained in the residual or later newly infiltrated solution were precipitated in dendritical form during the desiccation of the fissure (Figures 34, 35). The designation for this type of healing fissure is proposed to be pseudo-secondary – secondary according to its formation in two subsequent parts.

Discussion

The blue and yellow sapphires from Kaduna province, Nigeria, are characterized by a considerable number of diagnostic properties which are suitable for the recognition of samples from this occurrence in contrast to blue sapphires from different localities, as well as to distinguish Nigerian sapphires from synthetic blue and yellow sapphires. Macroscopically, in addition to the characteristic morphology of the samples, which is frequently connected with colour zoning parallel to the crystal faces, the corroded surfaces of the crystals and the parting planes parallel to the basal pinacoid are worth mentioning. The density and optical data of

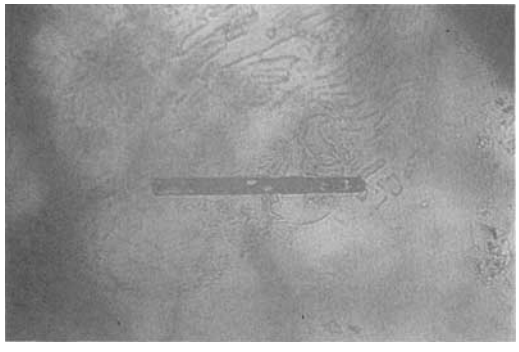

Fig. 28. Blue sapphire from Nigeria; elongated negative crystal with two-phase inclusion, healing fissure. 100x.

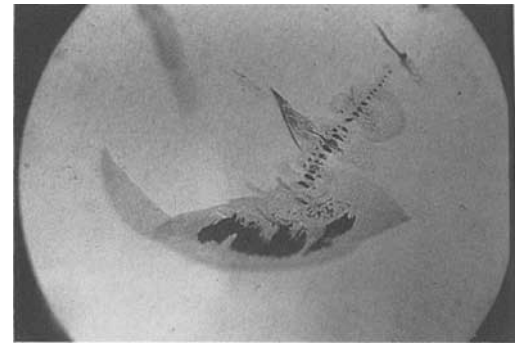

Fig. 29. Blue sapphire from Nigeria, primary negative crystals surrounded by primary or pseudosecondary healing fissures. 40x.

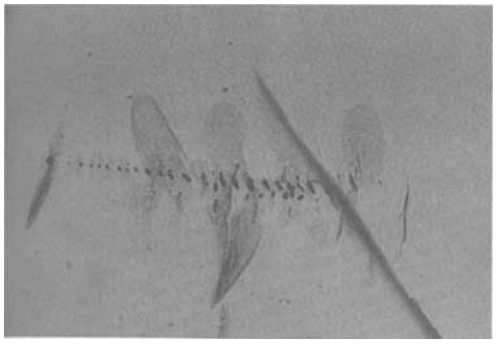

Fig. 30. Blue sapphire from Nigeria, primary negative crystals surrounded by primary or pseudosecondary healing fissures. 40x.

Fig. 31. Blue sapphire from Nigeria; healing fissure. 40x.

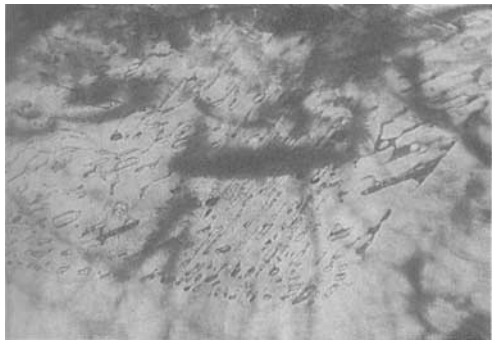

Fig. 32. Blue sapphire from Nigeria; healing fissures with two-phase inclusions. Crossed polarizers. 30x.

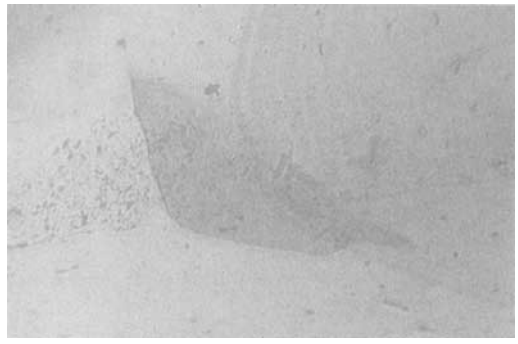

Fig. 33. Blue sapphire from Nigeria; fissure with secondary filling of a brownish substance, most probably Feoxides or hydroxides. 70x.

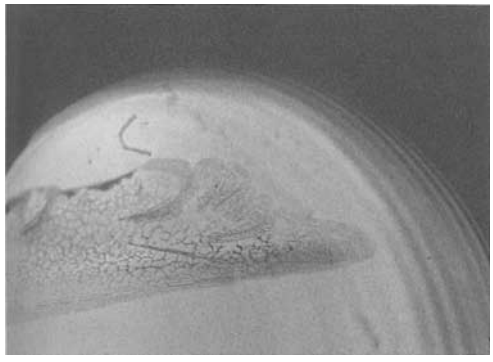

Fig. 34. Blue sapphire from Nigeria; fissure, partly healed pseudosecondarily at the rims of the cracks, partly filled secondarily with a dendritical substance. 16x.

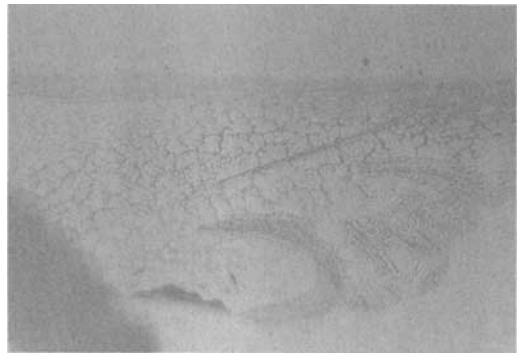

Fig. 35. Blue sapphire from Nigeria; fissure, partly healed pseudosecondarily at the rims of the cracks, partly filled secondarily with a dendritical substance. 80x.

the sapphires as well as colour, pleochroism and absorption spectra are less suitable for a determination of the locality, because similar properties are observable in samples from other localities, e.g. Australia and Thailand.

Some important microscopic properties that are especially worth mentioning are the intense growth- and colour-zoning correlated with the morphology of the crystals. The frequently observable parting planes parallel to the basal pinacoid are reflected by unhealed fissures that reveal total internal reflection under distinct angles in the microscope. Inclusions of zircon, uranpyrochlore and albite crystals are frequently surrounded by stress cracks (zircon, uranpyrochlore) or primary unorientated rosette-like fluid inclusions (uranpyrochlore) as well as by rosette-like fluid inclusions orientated preferably parallel to the basal pinacoid (albite). These mineral inclusions frequently appear together with primary cavities and negative crystals. Opaque lamellar mineral inclusions could not yet be determined exactly. Besides the healing fissures and the unhealed fissures secondarily filled with Fe-oxides and -hydroxides, which are observable also in sapphires from other occurrences, Nigerian sapphires reveal a mixed type of partly pseudosecondary healed fissures with dendritical secondary relicts in the unhealed areas.

The determination of uranpyrochlore crystals as primary mineral inclusions besides albite and zircon supports the indication of Scarratt *et al.* (1986), who mentioned alkali basalt as mother rock of blue Nigerian sapphires. Uranpyrochlore was first determined by Gübelin (1969) in blue sapphires and was reputed to be a typical characteristic property of blue sapphires from Pailin, Cambodia (Gübelin, 1974). Recent investigations identified their mother rocks as Tertiary to Quarternary alkali basalts (Jobbins and Berrangé, 1981). However, inclusions of uranpyrochlore were also determined in Australian sapphires (Coldham, 1986; Moon and Phillips, 1986), whose mother rocks are alkali basalts, too. Obviously, the distribution of sapphires with inclusions of uranpyrochlore is more abundant than supposed previously. This inclusion is not, therefore, any longer characteristic for sapphires from Pailin, but it seems to occur frequently in sapphires from alkali basalts.

Acknowledgements

The authors are grateful to the firms of Gebr. Leyser and Julius Petsch Jr., both from Idar-Oberstein, FRG, who supplied the samples for investigation. Financial support was given by grants of the Wirtschaftsministerium des Landes Rheinland-Pfalz, FRG.

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In the witness box

Eric Bruton, FGA

Great Bentley, Essex, CO7 8QG

Eric Bruton, FBHI, FGA, when President of the National Association of Goldsmiths in 1983–85.

How did you become involved in gemmology?

The simple answer is 'By chance.' I was offered a job as group training officer in the then new Pakistani Air Force, but instead started up a farm machinery business with a friend in the UK. Our RAF gratuities ran out, so I applied for a job with a small firm, NAG Press in Hammersmith, and was interviewed on a Thursday by the owner, Arthur Tremayne, who to my surprise said I could have it if I started on Monday. I did, to find AT in hospital after a heart attack. Another young man wandering through the office, a converted shop, said 'If you're Eric Bruton, I'm your new assistant, Malcolm Henderson'.

There were four monthly publications, *The Gemmologist*, *Goldsmiths Journal*, *Horological Journal*, and *Industrial Diamond Review*, all running at least a month late. Worse was to come AT: had sacked the printers as well as his editorial staff. We were in very deep water. That was in 1947.

Did you know anything at all about gemmology?

Nothing. I knew how a clock worked and something about the use of industrial diamonds, but I'd not even heard the word gemmology. We'd got the four journals settled at a new printer and coming out regularly by the time AT returned. His first instruction was, 'Get to know Gordon Andrews of the GA and Major Cowen of the Horological Institute'. I did and fortunately quickly became friends with both. Not much later I was able to count Robert Webster and then Basil Anderson as friends. Robert gave me private lessons to supplement the teaching of Thorold Jones at the Chelsea Polytechnic gemmology classes; just as well, since my diploma exam coincided with getting married to Anne and finding somewhere to live in 1950. Courting inhibits swatting constants, but at least Anne got to know some basic gemmology.

Later, a course in silversmithing at the Central School of Arts and Crafts and studying more advanced horology at home with the help of a correspondence course helped with the other subjects. AT was a partly spent force by then and I took over much of his work as Editor, even to ghosting his vituperative trade gossip page, not a particularly pleasant job.

Did NAG Press publish books as well at that time?

Oh yes, nearly all of them textbooks, but a few odd ones, like one on film stars! AT asked Basil Anderson, Robert Webster and C.J. Payne if they would co-operate in writing the definitive book on gemmology, but I might have left by then. About this time I intended to leave to avoid getting too specialized, but AT promised me a share in the business.

When he died in 1954 he left everything to the company secretary, Miss Edith Palmer. After much heart searching, I stayed on, taking over AT's office. In the meantime, Robert Webster finished

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his section of *Gems*, while neither of the others had started. Eventually they agreed to let Robert finish the book himself. After I'd subbed it and sorted out the pictures, format, paper, binding, etc. I asked Edith for £1000 to set it in motion. That was in 1961. 'We haven't got the money,' she said. So I had to help Robert find another publisher. Butterworths took it and are now our main rivals (my own company acquired NAG Press Ltd in 1986) in publishing gemmological books.

Was that when the Thomson Organization took you over?

Yes. Robert's book was the crunch. We offered ourselves to Thomson in 1961. It's a fascinating story, but out of place here. They gobbled up so many small firms there were more of us directors than there were staff. In less than two years our overheads had been doubled and we were losing money. I was asked what I was going to do about it. The outcome was the fortnightly quality newspaper, *Retail Jeweller*, a concept I'd had for some years without the finance to launch it. Fortunately it was a winner from the start. *The Gemmologist*, which had ceased publication, was incorporated in it, and while I was *RJ* publisher and editor we kept up a good gemmology content with the help of Basil Anderson, Alec Farn, and later Alan Hodgkinson.

One objective was to encourage the jeweller to promote himself more effectively as a specialist, and it struck me one day that the best way would be to take a group of jewellers and gemmologists to visit the Kimberley diamond mines for first-hand experience. No party had done it before. I rang Lionel Burke of De Beers, who enthusiastically promised plenty of help. 'How many?' Ten, I thought.

A page one paragraph in RJ brought 96 enquiries, but we had to limit numbers to 45. In SA it was red carpet treatment all the way with access to everything. Many of the group gave series of slide or cine lectures afterwards which helped their images and businesses. The study tours soon became established yearly, and I have taken groups to mines and trading centres in Australia, Brazil, Colombia, Ceylon, Hong Kong, India, Israel, Namibia, Pakistan, South Africa, Thailand and elsewhere, several times to some countries. But they were not for a month each time like the first one!

Weren't you in the trade at one time?

Yes. One day Northampton jeweller, Michael Jones, declared, 'Eric, in *RJ* you're always advising us, but seriously, what do you know about retailing? Have you ever sold a ring over the counter or locked up the safe for the night?' He was right. I went home and asked Anne, 'What do you think about starting a jewellers' shop?'

To her credit, she didn't even blink. So we did, with Diamond Boutique in Maidenhead in 1967, selling only gold and natural gemstones. That worked too, thanks largely to Anne's drive. Soon she was elected to the council of the National Association of Goldsmiths. I sold the business, regretfully, about eighteen months after she died aged 46 in 1976. Starting such a business from scratch is like walking along the parapet of the Empire State Building in a high wind!

A lot of things were happening about this time. Norman Harper had started a diamond grading course in Birmingham, and I kept nagging him to get one started in London, as I wanted to learn. Eventually he told me he'd say something at the next GA meeting. He gave me one of the worst frights ever by announcing that *I* was to run it. It was useless trying to protest. The next day Fate took a hand, when a stranger arrived in the office. He was D.C.B. Jones, who graded diamonds for Monnickendam and wanted to help. Edward Gübelin was exceptionally supportive with encouragement and arranging for me to be an observer at a Frankfurt course in which he was the key figure.

Someone said Sir John Cass College might have space for us, so I went to see the head, Mr Greenman, who liked the idea. Asked if he had a safe for our valuable diamonds, he took me to see a large Victorian contraption in which he kept bottles of sherry safe for governors' meetings. When he tried to open it, the handle came off in his hand! This also resulted in the silversmithing and other jewellery departments going to Cass when squeezed out of the Central School, followed later by gemmology when Chelsea wanted them out.

The first grading courses in 1967 attracted a lot of the 'top brass' from gemmology and the diamond trade, and we never failed to have a waiting list from retailers thereafter for many years. One day Professor Font-Altaba and Dr Bosch-Figueroa from Barcelona University suggested we set up a course there, so Andy Taylor (who graded for Tanzania and succeeded David Jones) and I prepared for a week of instruction to a class of top jewellers as well as the Spanish teachers-to-be.

We could only manage tiny stones for grading, and when one day we asked the students to bring some of their own stones, the open parcels presented a staggering sight. One paper alone held over a million pounds' worth of three and four carat stones. Almost every cut and colour was there. Perhaps the jewellers felt safe because the students were on strike and the campus was full of riot police.

Professor S. Tolansky, whom I got to know through editing his book, *Microstructures of Diamond*

Surfaces, agreed to becoming our first examiner. There was no suitable course book, one covering the whole field of diamonds, so I was forced to write one. De Beers were immensely generous, giving me flights and access to mines in various parts of Africa as well as introductions to key people and I went to mines in other countries under my own steam. Having a background in mechanical engineering was a great help. Fate again got the timing right because the book *Diamonds* (somewhat shorter than its original 130000 words in manuscript) still sells well all over the world.

That's about it, except that a powerful team of specialists, of which I'm fortunate to be chairman, is in the later stages of preparing the first GA home study course in gem diamonds, including grading, that we confidently expect to broaden membership into the diamond trade.

You haven't mentioned how you started writing.

It's something I've done as long as I can remember, articles then books, fact and fiction. May I add an odd footnote? De Beers gave me a very friendly send-off party when I retired recently from being publisher of *RJ*, and *Diamond Trading Company* director, Michael Grantham, presented me with a silver half-octahedron surmounted by an octahedral diamond crystal, designed by Gerald Benney. Sometimes an unguarded comment slips out before I can stop it. 'Some of the trigons are wrongly orientated!' To my relief, it caused a laugh. Later I was looking up something in Tolansky's book and to my horror I spotted an incorrect drawing which was obviously the reference source. I'd been the culprit in the first place!

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The emeralds of the Belmont Mine, Minas Gerais, Brazil

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1. Introduction

Although Brazil was for many years renowned for its agate, tourmaline and aquamarine, emerald can be considered today to be its most important gemstone.

The search for the 'Serra das Esmeraldas', a mythical country in the north-east of present-day Minas Gerais, significantly helped the development of the interior of the country by the Bandeirantes in the sixteenth and seventeenth centuries. The first large discoveries of emerald, however, were not made until 1963, in Bahia. The discovery of further occurrences in the states of Bahia, Goiás and Minas Gerais, has resulted in Brazil becoming one of the leading producers of emerald.

At the present time, emerald mines in production are Carnaíba and Socotó (both in Bahia state), Santa Terezhina (Goiás) and Itabira (Minas Gerais). In addition, there are a number of other occurrences whose yields were never, or only temporarily, of economic significance (Figure 1).

The Belmont mine lies near Oliveira Castro (Itabira district, MG), about 13km south-east of the town of Itabira and 120km north-east of Belo Horizonte, the state capital of Minas Gerais.

The first emeralds were discovered in 1978 at Itabira, near the railway line joining Belo Horizonte with Vitoria. Using primitive tools, garimpeiros set about exploiting an area of about 60 by 120 metres to a depth of 6 metres. From this initial stage of mining, about 40 kg of emeralds were extracted from about 20 000 cubic metres of rock, and marketed.

Since 1981, the workings have been extended using modern machinery. A few hundred metres from the workings is the plant, and within this a water cannon is used to wash away the finer components. Coarser pebbles of waste material are then removed before the remaining material is transported to a large hall by conveyor belt. In this hall the emerald is removed and sorted manually.

The average emerald-content of the biotite schist is 165 s/ton. The Belmont mine is probably the richest emerald occurrence in Brazil so far as emerald-content of the parent rock in relation to the average quality of the emeralds is concerned.

2. Geology

The following remarks concerning the regional and local geology are based on the works of Schorscher (1973), Schorscher and Guimarães (1976) and Schorscher *et al.* (1982) – see Figure 2.

2.1. Regional Geology

The stratigraphy of the Itabira region is characterized by two rock series of Precambrian age: the crystalline basement (after Pfulg, 1968: 'Série pré-Minas'), underlying meta-sediments ('Supergrupo Minas').

The (crystalline) basement is mainly composed of paragneiss and poly-metamorphic migmatites. The rocks, which show a mainly granitic character, are subdivided according to their origin into 'primary' and 'secondary' components (Schorscher *et al.*, 1982).

The 'primary' components comprise mainly meta-tectic gneisses and anatectic migmatites. Granitic intrusions are rare. Amphibolites occur within these and, depending on their origin, are designated either 'basic' or 'ultramafic'. The 'ultramafic' amphibolites are made up of over 95% (vol.) of a green clino-amphibole as well as accessory chromite (further minerals: tremolite, talc, clinozoisite, epidote and magnetite). Two samples analysed by Schorscher *et al.* (1982) exhibit a peridotitic composition with high Cr- and Ni-contents (ca. 2000 ppm Cr and 1500 ppm Ni).

The 'secondary' components mainly comprise metasomatic crystalline rocks, low-grade meta-sediments (serpentinites to chloritites and talc schists) and non-metamorphic rocks. Granitic intrusions are common. Pegmatoids, meta-ultramafites as well as meta-basic and basaltic rocks are

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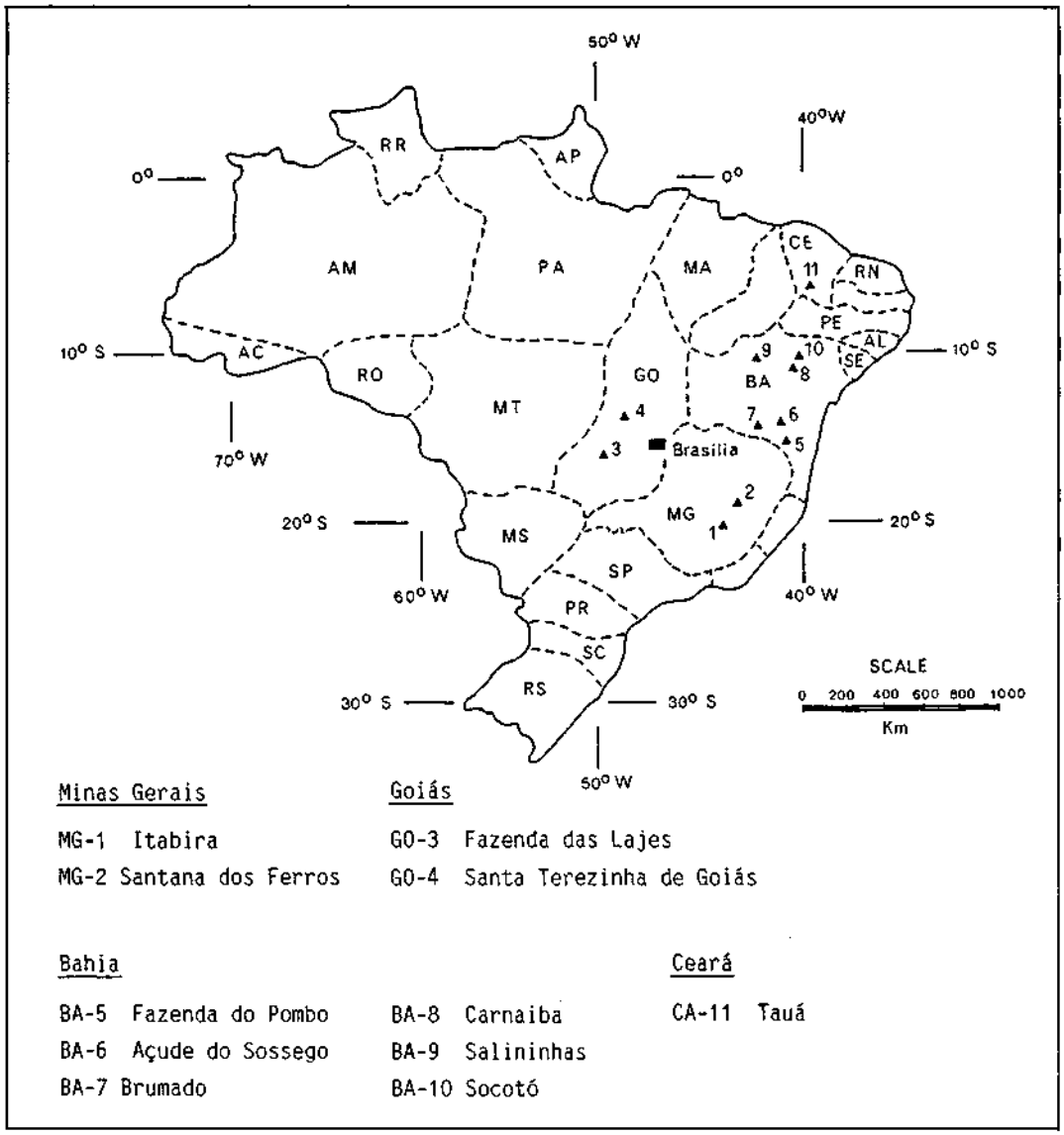


Fig. 1. The emerald occurrences in Brazil.

also present, albeit to a lesser degree.

The meta-ultramafites contain high Cr and Ni values (>1000 ppm) and are younger than the 'primary' rocks.

2.2. Local Geology

In the Itabira region (MG), the 'Supergrupo Minas' is made up of the following sub-groups, from the lowest to the uppermost: paragneisses, greenschists, the Caraca group, the Itabira group and the Piracicaba group. The three last-named groups are separated from the basement ('Série pré-Minas') by a structural and metamorphic discontinuity.

The paragneisses were formed through the metamorphism of greywackes and other sandstones. The Caraca group is composed of micaceous quartzites and, to a lesser extent, phyllites. The Itabira group is economically the most important unit of the Minas Series, due to its itabirite- and hematite-iron ore contents. Quartzites, sericites and phyllites dominate the Piracicaba group.

The 'Supergrupo Minas' sequence is structurally characterized by folds with horizontal or nearly

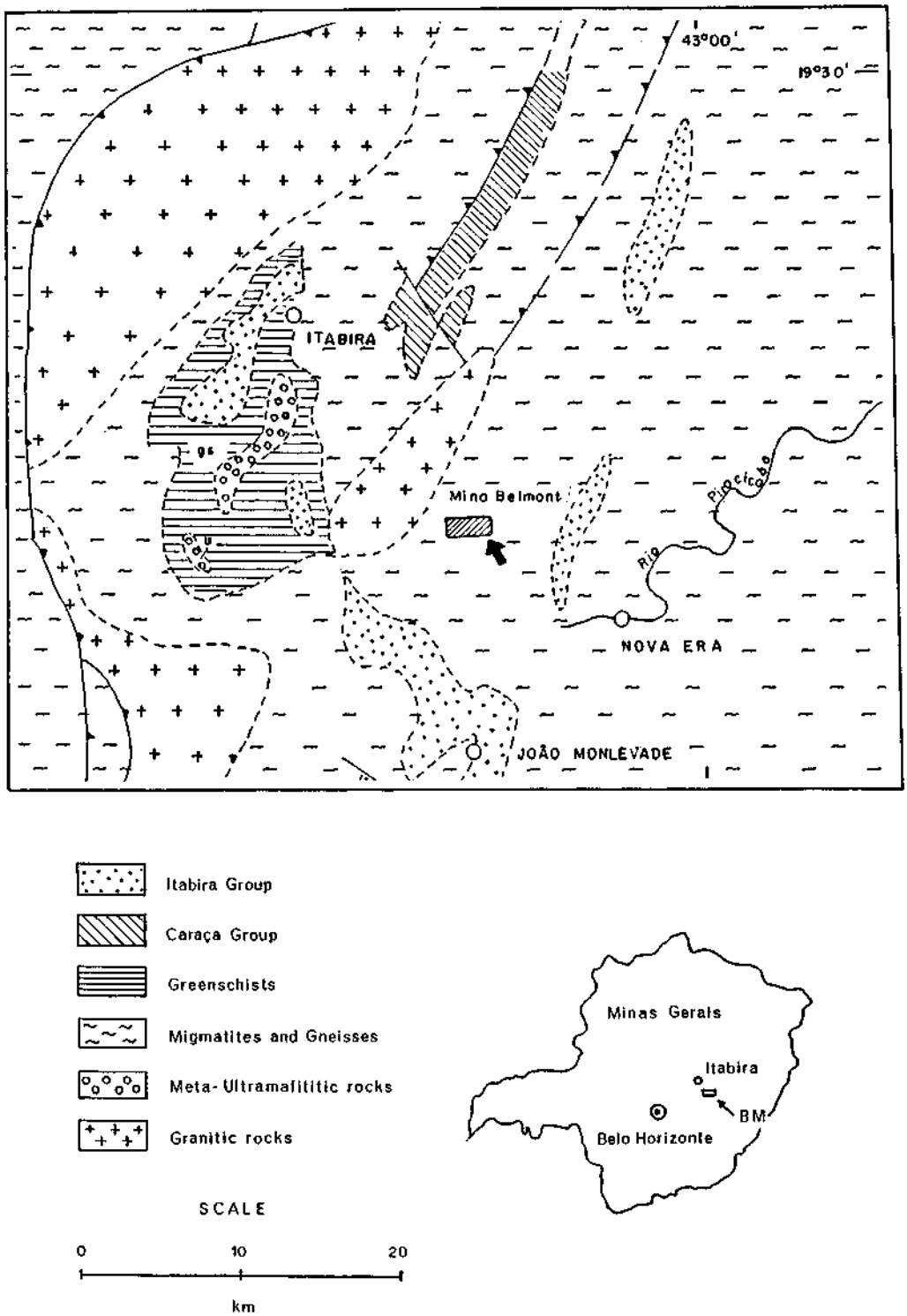


Fig. 2. Regional geology of the emerald occurrences at Belmont Mine, Itabira, Minas Gerais, Brazil.

Fig. 3. The present workings of the Belmont Mine in the emerald occurrence near Itabira.

horizontal axes. The whole sequence was subjected to a regional metamorphism.

In the area of the emerald occurrence, a belt of schists dominates, stretching in a north to north-easterly direction. The width of the belt varies between 750 and 1200 metres. Leucogneisses occur symmetrically on both sides of this belt. The schist belt, together with the mafic rocks, is stongly folded, with axes generally trending north to north-east.

The gneisses and the schists are riddled with small pegmatite bodies in the form of pockets of quartz and kaolin. These are concentrated between the gneisses and the schist belt. The largest pegmatite body is a vein (ca 10 metres wide) which cross-cuts the gneiss and schist structures at right-angles.

No emeralds are found in the gneisses, although these occasionally contain pegmatites with beryl and/or aquamarine.

Emeralds mined from the present workings (Figure 3) occur in black biotite/phlogopite schists, in green chlorite schists or in kaolin masses (altered pegmatite). They are occasionally accompanied by chrysoberyl or alexandrite. Crystals of lower quality are also found in quartz masses.

3. Optical and chemical properties of Itabira emerald

Optical data of Itabira emerald determined by different authors are presented in Table 1. The measured density values range between 2.72 and 2.74 g/cm^3.

Table 1. Refractive indices and birefringences of Itabira emeralds.

n_e	n_o	Δ_n	References
1.580	1.589	−0.009	Muller-Bastos (1981)
1.580±0.01	1.589±0.01	−0.009	Sauer (1982)
1.574−1.578	1.580−1.583	−0.004−0.006	Schwarz (1986)a
1.581−1.582	1.589−1.590	−0.007−0.008	Schwarz (1986)b

Table 2. Microprobe analyses of Itabira emeralds. Total iron as FeO. CaO-content <0.01 Wt%.

Sample number:	1	2	3	4	5	6	7	8	9
SiO_2	64.00	67.58	65.46	66.00	65.59	66.99	66.48	66.35	68.05
Al_2O_3	15.83	17.79	18.25	18.25	18.42	16.66	16.21	16.09	18.92
Cr_2O_3	0.39	0.20	0.00	0.05	0.18	0.91	0.07	0.08	0.06
V_2O_3	0.00	0.11	0.00	0.02	0.00	0.07	0.02	0.00	0.00
FeO	0.98	0.33	0.40	0.32	0.19	0.76	0.64	0.62	0.43
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.08
MgO	1.86	0.56	0.66	0.62	0.52	1.69	1.84	1.79	0.97
Na_2O	1.29	0.29	0.40	0.34	0.26	0.99	1.18	1.18	0.37
Total	84.35	86.86	85.17	85.60	85.16	88.07	86.47	86.18	88.88
Chemical formula (normalized: Si = 6)									
Si	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Al	1.749	1.862	1.972	1.956	1.986	1.759	1.724	1.715	1.966
Cr	0.029	0.014	0.000	0.004	0.013	0.064	0.005	0.006	0.004
V+	0.000	0.008	0.000	0.001	0.000	0.005	0.001	0.000	0.000
Fe++	0.077	0.024	0.031	0.024	0.015	0.057	0.048	0.047	0.032
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.006
Mg	0.260	0.074	0.090	0.084	0.071	0.226	0.248	0.241	0.127
Na	0.234	0.050	0.071	0.060	0.046	0.172	0.206	0.207	0.063
Total	8.349	8.032	8.164	8.129	8.124	8.283	8.234	8.221	8.198

The microprobe analyses (Table 2) were carried out using an ARL-SEMQ instrument, with wavelength dispersive (WD) spectrometers and an energy dispersive system (EDS, TN 2000) (Schwander and Gloor, 1980). Beam diameter was 2 microns, accelerating voltage 15 kV and specimen current 30 mA. Standards used for the analyses comprised synthetic oxides and some simple silicate minerals.

Franz *et al.* (1986), in their work on beryl in regionally metamorphosed rocks, discussed in detail the problems which may arise during the calculation of the beryl formula. For this reason, the emerald analyses given in Table 2 were normalized both cationically (Si = 6) and anionically (O = 15); as the lighter elements such as Be or Li cannot be analysed with the microprobe, 3BeO was not taken into consideration during the anionical normalization.

Both methods of normalization resulted in virtually identical chemical formulae.

Structural and chemical considerations indicate that the following substitutions in the Itabira emeralds could be applicable:

(a) Al^{3+} (octahedral) = $(Mg,Fe)^{2+}$ + Na^+ (channel site).

(b) Al^{3+} (octahedral) = $(Cr,Fe,V)^{3+}$.

The mineral formulae calculations (Table 2) indicate substitution type (a) is mainly present. Through this substitution, channel positions are also occupied and the difference in charge between Mg^{2+} and Fe^{2+} versus Al^{3+} is compensated for by Na^+.

Figure 4, showing a gradient of less than 1, demonstrates a slight excess of (Mg+Fe) over Na. This can be explained by a small amount of Fe^{3+}, which is not compensated charge-wise by Na^+.

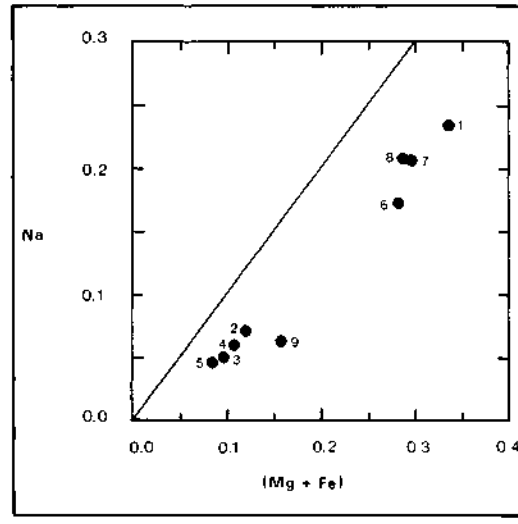


Fig. 4. Plot of (Mg + Fe) v. Na for the Itabira emeralds showing the slight excess of (Mg + Fe) over Na. Numbers refer to analysis numbers in Table 2.

According to (b), Cr^{3+} is accommodated into the lattice at the same time (the analyses show Cr_2O_3-values from 0.00 to 0.91).

The emerald analyses show relatively low values for FeO, MgO and Na_2O when compared with similar material from biotite schists (Hänni 1982, Hänni and Klein, 1982, Hänni and Kerez, 1983).

4. Inclusions

In general, emeralds from the Belmont mine at Itabira, Minas Gerais, can be easily distinguished from those from Santa Terezinha, Goiás, Carnaiba, Bahia, and Socoto, Bahia, on the basis of inclusion studies.

Under the optical microscope Itabira emeralds are found to contain relatively few inclusions. By far the most common inclusions are of mica, which occurs in a diversity of form and colour.

Not only does the colour of the mica inclusions vary from emerald to emerald, but also within the same gemstone itself. The colour is mainly various shades of brown, from a yellowish brown through grey-brown to nearly black. Greenish shades also occur, albeit seldom.

The mica flakes are usually strongly rounded or irregular (Figures 5, 6), although elongated forms or nearly ideal pseudo-hexagonal crystals (Figure 7) can be observed. Two generations can be seen, the first indicating formation before that of the emerald (protogenetic), and the second indicating formation at the same time as that of the host crystal (syngenetic). The protogenetic micas exhibit irregular, or strongly rounded forms, and usually possess a deep brown colour. This colour can be so deep that platelets thick enough may appear opaque. These inclusions are irregularly distributed within the emeralds and show no preferred orientation (Figure 5). The syngenetic micas on the other hand, are thin, transparent flakes which either are elongated or partly exhibit a distorted pseudo-hexagonal shape (Figure 7). These flakes usually show a preferred orientation within the emerald: the elongated crystals lie sub-parallel to the *c*-axis, and the pseudo-hexagonal sections lie parallel to the basal plane.

Microprobe analyses have shown that these micas are members of the biotite-phlogopite series. The fluorine-contents of these micas are about 2–3 wt% (Table 3). This indicates that complex fluorine phases played a role during the formation of the emeralds, especially during the formation of ion complexes capable of migration.

Apart from intergrowth of mica crystals with other mineral inclusions (Figure 8), interesting phenomena can be observed, apparently related to dissolution and re-crystallization processes. Figure 9 shows a mica crystal whose narrower end has been either partly dissolved or altered to another mineral species. At the other end, apart from signs of resolution, the 'birth' of a (new?) mineral can be observed in the form of dendrites.

Table 3. Microprobe analyses of some mineral inclusions in Itabira emeralds.

	Andesine	Biotite/ Phlogopite	Fe-Dolomite
SiO_2	59.95	38.15	0.12
TiO_2	0.00	0.86	0.00
Al_2O_3	25.64	15.01	0.00
Cr_2O_3	0.00	0.35	0.00
FeO	0.06	9.26	6.32
MnO	0.00	0.11	0.69
MgO	0.20	16.65	16.62
CaO	7.99	0.10	33.40
Na_2O	7.35	0.35	0.00
K_2O	0.14	9.15	0.01
F	0.00	3.09	0.00
Total	101.33	93.08	57.16
	An 37.2% Ab 62.0% Or 0.8% Andesine		

As mentioned above, inclusions other than mica in the Itabira emeralds are much less abundant. Apart from an opaque mineral (hematite or molybdenite), the following minerals have been identified using either X-ray diffraction or micro-X-ray spectroscopy techniques: quartz, tremolite, dolomite, andesine and apatite.

Andesine (see chemical analyses in Table 3) occurs as colourless, transparent, tabular crystals (Figure 10). Quartz occurs colourless to brownish, mainly as crystals rounded by corrosion. Similarly corroded forms are also normally exhibited by the beryl and carbonate inclusions (Fe-dolomite: Table 3). The latter occur in groups of colourless crystals. Tremolite generally forms transparent needle-like crystals, and apatite occurs as rounded hexagonal forms. The opaque (?pseudo-) hexagonal crystal inclusions shown in Figure 8 intergrown with a mica flake have not been positively identified. These could be molybdenite or hematite.

The claim of Gübelin and Koivula (1986) that 'biotite, chromite and pyrite preferably determine the inner paragenesis of the emeralds from Itabira' could not be confirmed by our investigations, although we studied about 300 emeralds from this location, also using the gemmological microscope.

The very commonly-occurring growth tubes in the Itabira emeralds are of greater diagnostic value than the mineral inclusions. These tubes are tiny

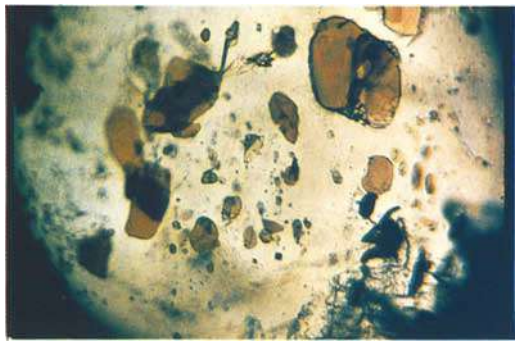


Fig. 5. Protogenetic mica inclusions (biotite/phlogopite) with irregular/rounded outlines. These crystals possess no preferred orientation to the host crystal. 20x. (Note: all photographs were taken using immersion liquids).

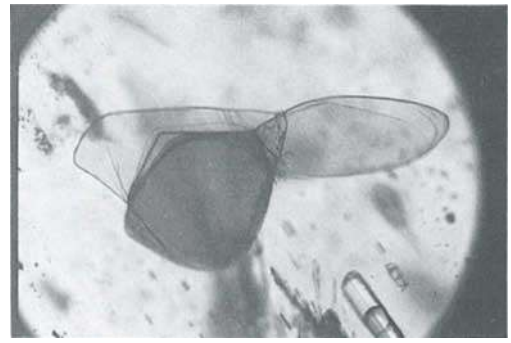


Fig. 6. Biotite/phlogopite inclusions with a protogenetic origin. The crystals exhibit rounded forms and their colour varies from light to dark brown. 100x.

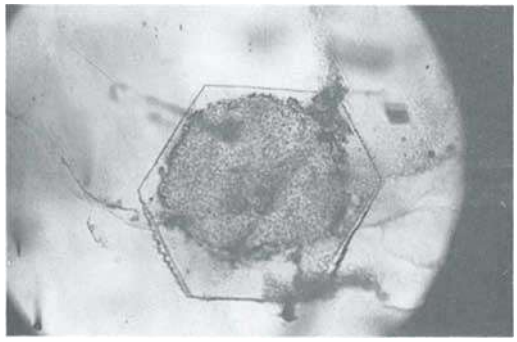


Fig. 7. Mica flakes with a syngenetic origin showing nearly ideally-formed pseudo-hexagonal shapes. Orientation parallel to the basal plane of the emerald host crystal. Partly corroded surface. 100x.

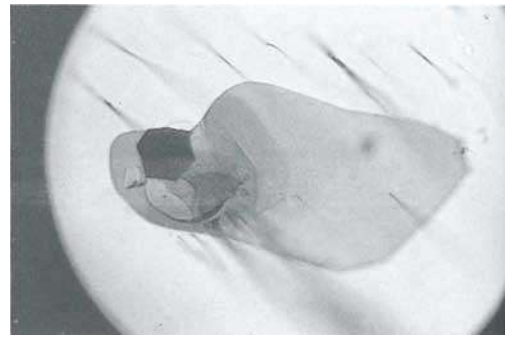


Fig. 8. Intergrowth of a mica crystal with an opaque mineral platelet, which possesses a (pseudo-) hexagonal form (probably hematite or molybdenite). 70x.

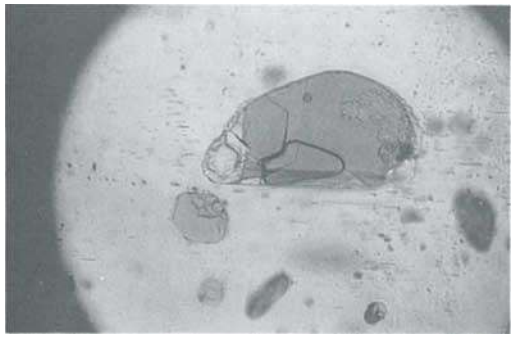


Fig. 9. Mica flake exhibiting solution and recrystallization phenomena. 100x.

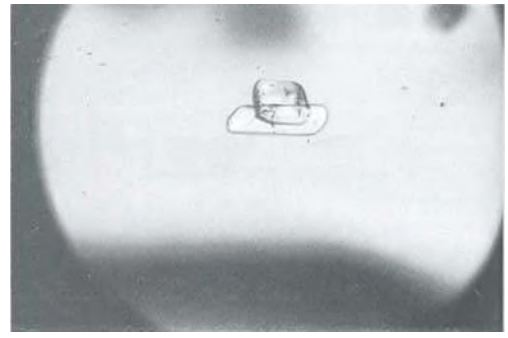


Fig. 10. Colourless, transparent, tabular crystal inclusion (andesine). The other inclusions could not be identified due to their loss during preparation. 70x.

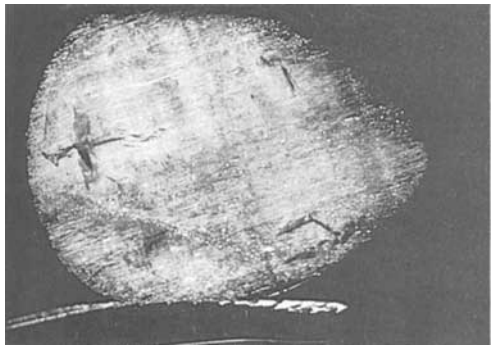


Fig. 11. Itabira emeralds containing numerous fine growth tubes, and exhibiting a slightly turbid, silken appearance. 20x.

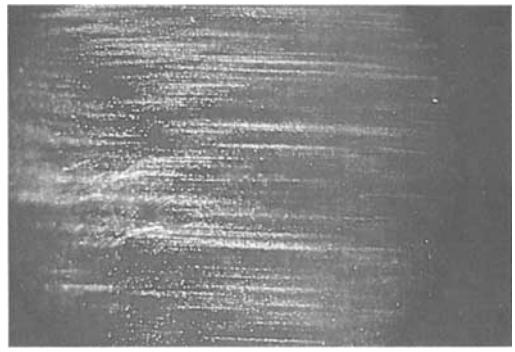


Fig. 12. Growth tubes are often arranged in parallel strings which produces the so-called 'Rain Effect' leading to chatoyancy. 35x.

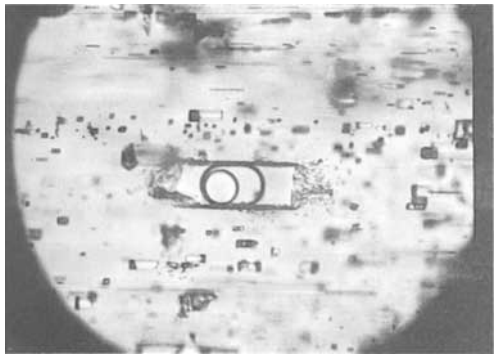


Fig. 13. Rectangular cavity oriented in the direction of the *c*-axis, with a fluid three-phase filling of the type liquid/liquid/gas ('l-l-g'). 70x.

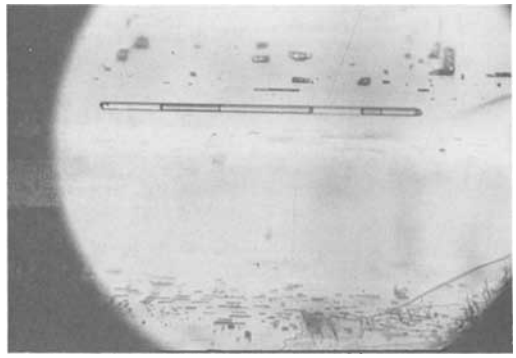
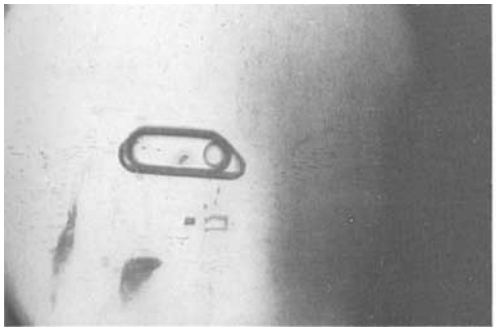


Fig. 15. Elongated cavity oriented parallel to the *c*-axis, with an interesting filling: the phase sequence from left to right is: l_1-g-l_2-l_1-g-l_2. 70x.



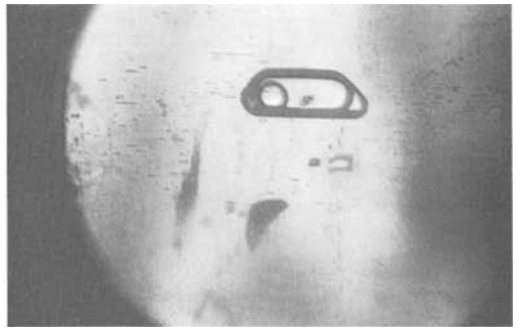


Fig. 14. Negative crystal with an 'l-l-g' three-phase filling. Note the mobile gas bubble seen once on the right-hand side of the cavity. 70x.

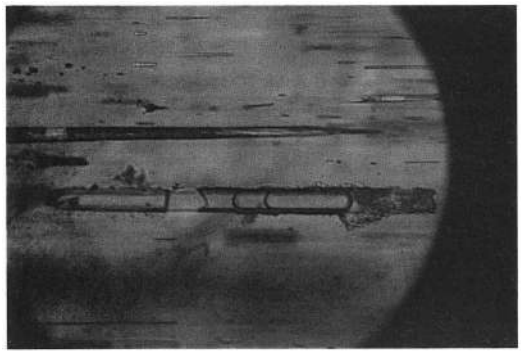


Fig. 16. Elongated multiphase inclusion, oriented parallel to the c-axis of the emerald. 100x.

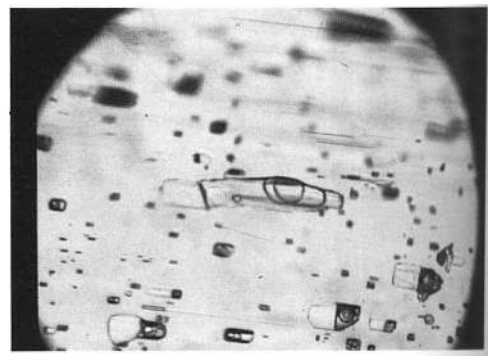


Fig. 17. Common and characteristic inclusion type in the Itabira emerald: birefringent crystals accompanied by cavities containing a variety of fillings (i.e. various fluid inclusions). 100x.

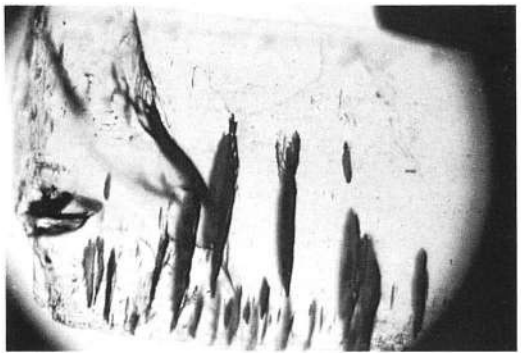


Fig. 18. Cluster of unhealed fissures, parallel to the basal plane. 20x.

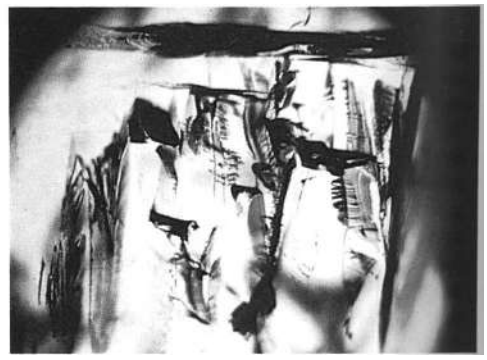


Fig. 19. Unoriented unhealed fissures. 20x.

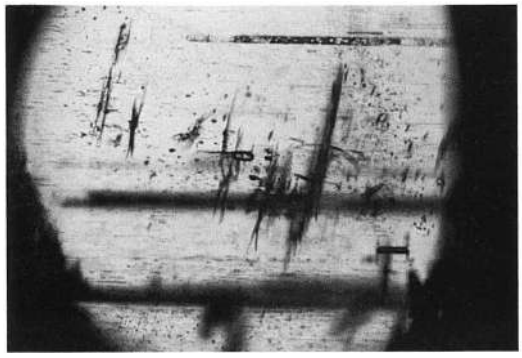


Fig. 20. Disc-like fissures are characteristic of the Itabira emeralds. Their centres usually possess a cavity containing a variety of fillings (Fig. 19). 70x.

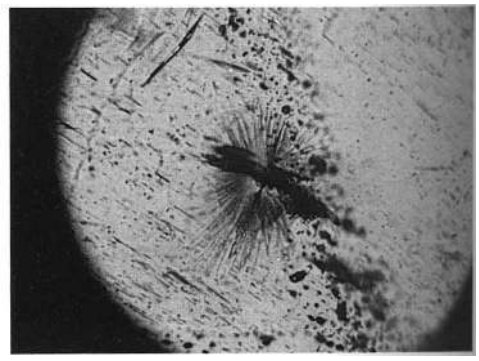


Fig. 21. The fissures shown in Figure 19 often form swarms more or less parallel to the basal plane. 35x.

channels oriented parallel to the *c*-axis of the emerald and are filled with a variety of material. These tiny tubes are sometimes so abundant that they impart a turbid appearance to the emerald or a nearly silken lustre (Figure 10). Their arrangement in parallel strings gives rise to the so-called 'Rain Effect', which has also been observed in many Brazilian aquamarines (Figure 12).

The tiny growth tubes are often concentrated in planes or layers which run parallel to the basal plane of the emerald. These growth tubes could have formed in the crystallization 'shadow' of extremely fine particles of other minerals on the basal plane. These growth tubes are often accompanied by a large number of much larger tubes or channels which can contain various fillings: one or two liquids, possibly combined with a gas bubble and/or a solid phase (see below). When an abundance of fine growth tubes is present, the gemstones, when cut as cabochons, will display the cat's-eye effect termed chatoyancy.

The most abundant group of inclusions in the Itabira emeralds are those with two-, three- and multi-phase inclusions, and these exhibit an extraordinarily large variety of forms (Figures 13–17). This indicates a complex and multiphase formation history of the emeralds. Apart from their occurrence in the various-sized growth tubes, these inclusions can be observed in irregular or regular/rectangular-bordered cavities (Figure 13), as well as in more or less perfectly-formed negative crystals (Figure 14). Analogous to the 'classical' solid/liquid/gas (s-l-g) three-phase inclusions in the Colombian emeralds, they can be sub-divided by virtue of their formation history into primary and secondary inclusions, originations as residues from the mother liquid. The 's-l-g' three-phase inclusions can be observed occasionally, while liquid-gas inclusions (i.e. l-g two-phase inclusions at room temeprature) also occur widely distributed. Other phase combinations, however, are more interesting and of greater diagnostic value.

1. Cavities containing two immiscible liquids (fluid 'l-l two-phase inclusions).
2. Cavities containing two immiscible liquids and a gas bubble (fluid 'l-l-g' three-phase inclusions; Figure 13)
3. Cavities containing two immiscible liquids, a gas bubble and a crystal (fluid 's-l-l-g' four-phase or multi-phase inclusions)

Typical inclusions in the Itabira emeralds are composed of white, birefringent crystals usually associated with a rectangular cavity (Figure 17). The cavity filling can be variable (mainly 'l-g' or 'l-l-g' type). The crystal inclusions could not be positively identified. They normally have short- to long-prismatic forms and seem to show a hexagonal symmetry (apatite?). These inclusions are often abundant, normally oriented parallel to the *c*-axis of the emerald (with primary cavities), but also in healed fractures.

The final types of inclusion to be described from the Itabira emeralds are the various fissure types. Of special note is the relatively large number of unhealed fissure planes (Figures 18, 19). This indicates that these fissures have an epigenetic origin and were only formed after the emerald crystal had finished growing, when it was no longer in contact with any mother liquid. For this reason, the fissures and cracks were often filled with other solutions (mainly water containing Fe or Mn). The relatively fast rate of crystallization resulted in the formation of skeletal or dendritic crystals. In contrast, the 'healing' of a fissure takes place through the crystallization within it of material similar to that of the host crystal. The mother solution generally possesses a complex chemical composition and it contains additional components which are not needed for the formation of further host crystal. These remaining components normally concentrate in small cavities. They seldom form single-phase fluid inclusions, and two-, three- or multi-phase inclusions are more common. The healed fissures so formed have a characteristic appearance and play an important role in the discrimination between natural and synthetic gemstones.

Another type of inclusion, which has not yet been observed in other Brazilian occurrences and which is thus specific to Itabira emeralds, occurs in disc-like stress fissures. Generally, these contain a cavity in the centre with a variable filling (Figures 20, 21). These small fissures mostly occur in swarms, are parallel to each other and also run parallel to the basal cleavage face of the emerald.

5. Formation Conditions

Genetically, the emerald occurrence at Itabira is linked to the association between mafic-ultamafic rocks (or their metamorphic derivatives) and pegmatites. The pegmatites provide the beryllium, and the (ultra-) mafites the Cr and Fe necessary for the green colour of the emerald. Vanadium (stemming from the metasediments) could also contribute to this colour. On the basis of the inclusion-type specific to the Itabira emeralds, this deposit may be regarded as a specific sub-type when considering the occurrence of emerald systematically (Schwarz, 1986).

On the basis of microthermometric determinations on a chosen sample containing 25 four-phase inclusions, a minimum formation temperature of 380°C and a minimum formation pressure of 1400 bars has been calculated (Mullis, 1979). The

pressure was calculated on the basis of the temperature of homogenization, with the aid of the PVT data relating to the system H_2O-CO_2-NaCl, after Bowers and Helgeson (1983).

The Itabira deposit is unique in the apparently low conditions of formation (P,T) when compared with other emerald occurrences associated with metamorphic schists. These low conditions are probably responsible for the inclusion and chemical characteristics of the emeralds.

The formation of the Itabira emeralds cannot be directly connected to the intrusion of the pergmatite masses. The emeralds are more likely to have been formed as a result of a later metamorphic or retrograde episode.

The occurrence of various types of gas-liquid inclusion within the same crystal indicates a complex formation history involving more than one event.

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The separation of natural from synthetic diamonds using the Barkhausen effect

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According to various sources in current gemmological literature (Koivula and Fryer, 1984; Rossman and Kirschvink 1984; Shigley *et al.*, 1986), synthetic diamonds currently produced by both the General Electric and Sumitomo processes are affected by externally induced magnetic fields. This is due mainly to the presence of ferromagnetic particles or inclusions in the stones which are artefacts of the current synthesis methods.

In order to understand the effect produced when a ferromagnetic material is subjected to an external magnetic field, the theory of magnetic domains has been postulated (Graf, 1978). Figure 1 illustrates the separate magnetic domains in an unmagnetized polycrystalline ferromagnetic sample. The domains are orientated at random, so no external magnetic field is observed, but within each domain there exist completely aligned atomic or molecular dipoles (magnets). The arrows in the diagram indicate the random orientation of these dipoles in the crystals that make up the solid. (There are methods of observing these domains directly but they fall outside the scope of this article.) When a non-magnetized ferromagnetic sample is moved through a strong magnetic field, the non-aligned dipoles try to align themselves with the field. This alignment occurs as a series of small abrupt steps (known as Barkhausen jumps). They are caused by the discontinuous movements of mobile magnetic boundaries between magnetic domains. When this happens we can detect the electrical 'noise' produced by the sudden irregular motion of the domain boundaries as the favoured domains grow at the expense of their neighbours. This noise is known as Barkhausen noise after the person who first observed the phenomenon.

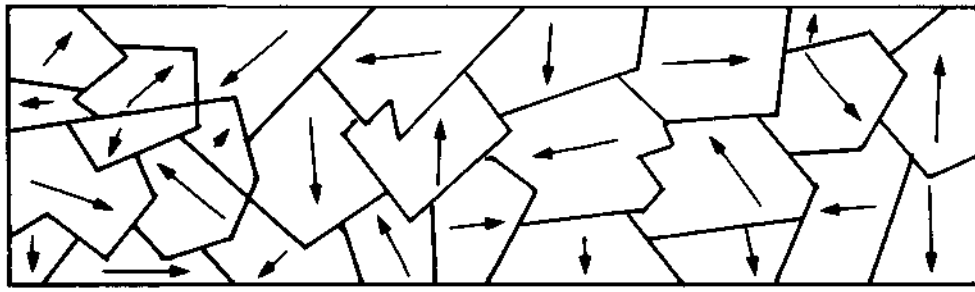

Fig. 1. Diagrammatic representations of magnetic domains in an unmagnetized polycrystalline ferromagnetic sample.

Practical application

A very strong, small magnet is placed opposite a sensitive pick-up coil (Figure 2). The coil in turn is connected to a very high-gain low-noise amplifier, the output of which is connected to a pair of headphones. The gap between the coil and magnet should be 1 cm. If a diamond containing ferromagnetic particles is swung to and fro between the magnet and coil a 'swishing' sound will be heard in the headphones, which is due to the changing of the magnetic domains in the ferromagnetic inclusions in the diamond. Until now synthetic diamonds have shown much higher levels of magnetism (due to ferromagnetic particles) but near-colourless, inclusion-free synthetics do occasionally display less magnetism than some natural stones (Rossman and Kirschvink, 1984).

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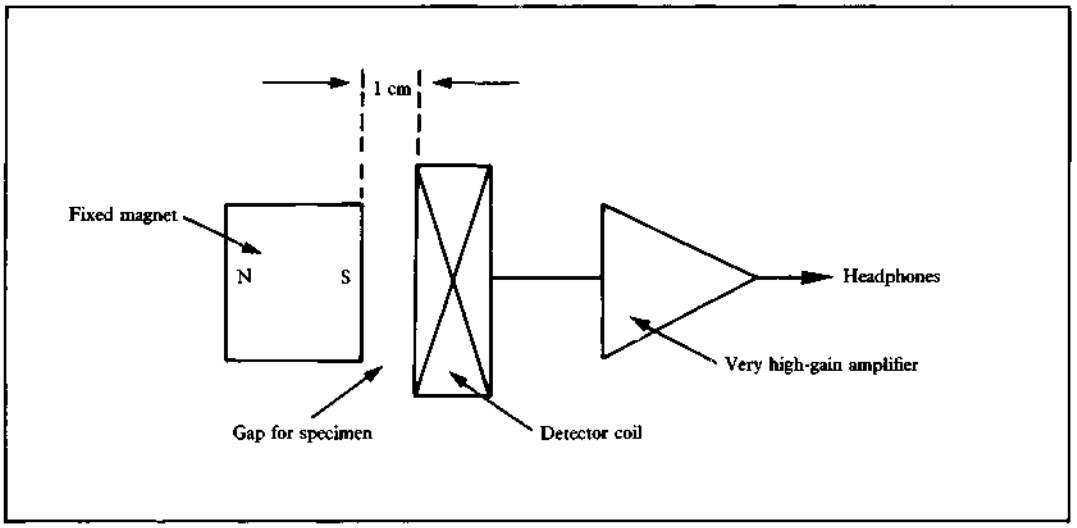

Fig. 2. Diagram illustrating a possible circuit for detecting the Barkhausen effect when synthetic diamonds are placed in a magnetic field.

NB. The stone *must* be in motion for the effect to be observed. The longer the arc of the swing, the more pronounced the effect is.

Precautions

Obviously the effect is less pronounced in stones that contain fewer ferromagnetic particles. Also, for more accurate results, the stones should be boiled in acid beforehand to clean off any external ferromagnetic particles. The stones to be tested can be enclosed in a clean stone-paper and this can be held in the hand and waved through the detector taking care not to touch either the magnet or the coil in the process, otherwise false results can be produced due to the noise caused by the paper striking the detector apparatus. Do not use metal tweezers to hold the stone!

In keeping with standard gemmological practices, other tests should be conducted, i.e. microscope examination of inclusions, etc. before a final conclusion is reached.

Note: Excellent results have been achieved with the tests that I have conducted. These have, however, only been carried out on synthetic industiral diamonds, since gem quality synthetics are unavailable to me in this remote locale, but I see no reason why this method of testing should not work on the latter, provided they contain ferromagnetic particles.

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The body colour of gemstones

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Abstract

This article is a response to a previous article by Dr K. Nassau who discussed the relation of gemstone 'body colour' to gemstone colour appearance.

It affirms that the author (J.B.N.) has made no claim to link 'FMIR body colour' with Nassau's 'overall colour impression produced by the gemstone under ordinary viewing conditions'.

Reasons are given why it is both practically and theoretically unlikely that *gemstone colour appearance* will ever be capable of being expressed in numerical terms. On the other hand, *gemstone body colour* can be so expressed and the three numbers measured represent an intrinsic property of a particular polished gemstone.

Discussion

In the last issue of the *Journal*,[1] Dr Kurt Nassau raised doubts about one specific aspect of my article 'The colour bar in the gemstone industry'.[2] He stated that . . . 'this aspect comprises at least three separate problems, any one of which is fatal to the validity of this model'. He concludes by advising me . . . 'not to permit myself to be taken in by the deceptively simple gemstone which poses problems far more complex than do any of these other systems' (non-gem applications which the author touched upon).

I dearly wish that Nassau could speak with many of these other colour scientists who think that their own successful industrial application of colour measurement, process control and their customers' colour perception of their product was initially anything other than an ulcer-producing activity.

His doubts hinge upon the term 'gemstone body colour' and its connection with the visual colour appearance of a gemstone. He expresses fears about the possible survival of my 'idealized model'. In these notes I hope to persuade him that his fears may not be so firmly based as he first imagined. In any event I am most grateful to him for giving me the opportunity of a further discussion of this most fascinating subject.

Firstly, it seems to me that he does little service to the scientific approach to gemmological problems by suggesting that 'we scientists unfortunately are rather prone to build a 'model' which is usually an interpretation of what one feels are the most important aspects of the problem without demonstrating that the model does indeed correspond to the reality it was intended to represent'.

This kind of utterance will bring much comfort to those gemmologists who already believe that physicists are very odd people indeed and certainly these modern bogeymen should not be allowed to frighten gemstone traders. Compared with other professionals, I have found scientists to be so much concerned with their need to unite theory with experiment that they often shrink from advancing quite sensible explanatory models. The reason for their timidity lies in the fact that most scientists are harsh and unforgiving judges of their own and their colleagues' work if they feel that proposed models do not exactly fit the observed facts. It is this simple process which keeps science cleansed of much theoretical litter.

Dr Nassau claims that I have fallen into his own imaginative invention, the *'irrelevant model trap'*. I feel that I am a little too sure-footed to have stumbled blindly into such a hole. Indeed, I fear that it is he who has slipped into another kind of trap and this of his own making.

If he will re-read the relevant parts of my article, together with an earlier one,[3] he might be surprised to discover that in neither article have I claimed that the methods and measurements which I describe provide the observer with a description of the *colour appearance* of a gemstone. The claims made relate only to establishing that my visual tristimulus colorimeter yields CIE co-ordinate measurements of a particular kind of volume body-colour, a kind automatically defined by the description of the FMIR technique. The reason for attempting to measure body colour of this kind is that it serves to characterize the colouring properties

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of any faceted† stone. Up to the present time such measurements do not and cannot convey the *colour appearance* of a stone, either in isolation, or in the company of neighbouring stones or metal mountings. Therefore I have no need of any kind of 'model'.

Unlike Dr Nassau, a diamond merchant does not confuse 'body colour' with 'total colour appearance.' Nassau describes the latter as 'the overall colour impression produced by the gemstone under ordinary viewing conditions'. When a merchant is assessing the 'show of colour' of a faceted stone, he takes steps to avoid those colour disturbances arising from differences in 'fire', lustre-orientation, size, shape and imperfections.

When very small body-colour differences between stones first became recognized as an important value factor* in trading, it soon became a common practice among merchants to produce a fine condensed mist over their standards and test stones by breathing upon them.[6] This matt water-droplet coating 'quenched the fire' by frustrating the multiple total internal reflections and allowed the body colours alone to be isolated and compared. The other components contributing to the total colour appearance could then be separately assessed. These are the size, perfection of cut, shape (defining brilliance and dispersion) and external and internal scattering discontinuities. So far as is known, traders have not yet attempted to describe the 'total colour appearance' of a diamond or give it a number or 'figure-of-merit'. This may be because the only way open to them to assess the body colour is by viewing the stone across the girdle (or effectively, the light path illustrated in Figure 15 of Reference 2). The most desirable viewing aspect would be approximately normal to the table, but the disturbing spectral fire precludes this choice.

It might be mentioned here that the writer has already measured the FMIR-type body colour on a number of Cape Yellow Series diamonds. The stones were the seven colour master stones of the Diamond Trading (Propriety) Ltd, and were measured using the Nelson-Lovibond Gemstone Colorimeter at the London Laboratory of the De Beers Central Selling Organisation, with the kind cooperation of the Head of the Laboratory, Dr G.S. Woods. The CIE Illuminant used was the 'A' Source and the measurements placed the stones in the correct order of yellow-saturation (all with λ_d = 587nm ± 1). However, as the master set of stones was calibrated against CIE Illuminant 'C' no direct comparison with the colorimeter's performance could be made.

Nassau has curiously and wrongly assumed that I am attempting to link body colour with total colour appearance. I have never dreamed of entering that awesome minefield. The aims are much more modest. It might be helpful here to describe the bones of the method again and its sole purpose.

By means of a microscope, a narrow, well-defined beam of incandescent white light, mains-stabilized and calibrated to attain the colour temperature of a CIE 'A' Source, is directed through the table to a spot near the culet of the specially-mounted test stone. The focused spot of now semi-coloured light is diffused by a pure white elastomer adhering optically to the stone's pavilion. The diffuse patch of light then retraces the same optical pathway as it entered. On leaving the stone, this trans-reflected (remitted) light is collected by the microscope's objective lens and delivered to the colour sensor. The sensor may be an eye or a suitable electronic photosensor, preferably the latter. For the purpose of comparison, visual colour matching or electronic colour measuring, an identical parallel system of optics is employed, using a colourless faceted stone as the primary calibrant. With the help of a calculator or a microcomputer, the measured light intensities are converted into CIE colour co-ordinates for the CIE Illuminant used.

These three co-ordinates represent the body colour of the test stone only, *and nothing more*. To quote from my article[2] (page 231) 'The stones are also shown in Figure 12, positioned within this colour space and occupying the point positions representing their body colours.'

Like the diamond merchant's body-colour assessment, colour appearance effects such as specular reflection, spectral dispersion and multiple internal reflections are eliminated. In the case of birefringent stones exhibiting pleochroism, an effective mixing of the two polarized coloured beams is accomplished without effort by the sensor, whether it be eye or photodetector. Even the curious dichroic phenomenon seen in certain tourmalines, which the author would like to propose to be known as the 'Mitchell effect', after its discoverer,[6] would yield the correct perceived body colour.

†Nassau refers to the measurement of FMIR-mounted windowed rough as being 'not particularly useful'.

The author (J.B.N.) has assumed that the sensible faceter usually chooses his window so that it will yield the best hue and that it will lie parallel to the same plane as the table of his finished stone. The measurement will be useful because it will allow the faceter to measure the metric luminance (L*) of the darker kinds of valuable rough. This provides him with precise information about the optimum depth to aim at for his finished stone, thus bringing it into a favourable L* range for displaying the maximum liveliness.

*The commercial importance of diamond body colour becomes clear when considering the current wholesale cost of a round, brilliant-cut, one-carat, flawless, well-proportioned stone.

A 'D-colour' stone is valued at $10,000, and an 'E-colour' stone at $5,500.[4] The excitation purity (p_e) of the 'A' stone is 0.35% and that of the 'E' stone is 0.79%.[5] The p_e difference (0.44) at this chromaticity value lies almost at the threshold level of visual colour discrimination!

An important feature of the FMIR mount is that the ray-paths are chosen by microscopical viewing. In this manner, gross light-absorbing or light-scattering centres can be easily avoided by a sliding or rotational movement of the stone on its stage. Small scattering centres and those similar to the colloid-size liquid inclusions present in Kashmir sapphires or in 'sleepy' stones will contribute, as they must, to the final observed body colour coordinates. Again, by successive angular positionings of the stone on its stage between individual measurements, colour discontinuities can be assessed. Such controlled and recorded variations serve as a further useful characterization of a valuable stone's body colour. The variations can be of the diffuse patchiness variety or of the sharp-zoned kind. It will be argued that zoning will distort the instrument's assessment of body colour. It depends entirely on the nature of the colour discontinuity.

The author recalls seeing a huge, stunning, clean, round, brilliant-cut blue sapphire on a Sri Lankan dealer's finger ring. The dealer was most reluctant to allow a closer inspection, but finally consented. It turned out that all of the crown and most of the pavilion were quite colourless. A thin, flat, 'sandwich-filling' of deep blue colour lay just below the girdle and was parallel to it. The measured body colour of such a stone would not conflict with its perceived body colour if measured by the FMIR method.

A word of explanation is necessary here with respect to Nassau's puzzlement about the use of the word 'multiple' in the FMIR acronym.

The optical coupling of the stone with the white elastomer frustrates any further possible occurrence of *multiple* total internal reflections.

He has also suggested that the white elastomer might act as a classical integrating sphere. Curiously enough, it does not. Some simple tests bore this out. Three round, brilliant-cut, colourless, synthetic spinels were drilled with small holes which entered the culet and were aligned along the axis of symmetry. The holes were about 0.8mm diameter and of a depth of about one-quarter that of the total depth of the stone, similar to that shown in 'Abb. 2' of Figure 1.[7] The holes were filled with epoxy resins dyed strongly in red, green and blue. When the beam was focused near the culet but not touching the dyed epoxy-filled cavities, only the faintest tint of any of the three well-saturated colours could be discerned. When focused directly on the filled cavities, the fully-saturated colours showed up strongly. Figure 1 has been taken from a description of a US patent. Its claim rests on the fact that colourless synthetic stones can be transformed into uniform, strongly-coloured ones simply by providing a saturated dyed or pigmented small plug as a culet insert. This trick works very well because the (unfrustrated) multiple total internal reflections repeatedly interact with the plug. It is in effect a good integrating sphere!

Returning to the method and its purpose, it should be said again that the quantity which is being measured is solely the colouring power of a particular cut and polished stone. It is simply another intrinsic property of a coloured stone that can be measured visually or by an electronic machine. It differs from the measurement of refractive indices or B–G dispersions, or weights, or specific gravities, or scratch hardnesses, only because its quantitative assessment requires a more complex device than a refractometer with its monochromatic light source or sources, or a chemical balance, or a set of hardness testing pencils.

What indeed is the value of such colour measurements to gemmologists? Some of the problems confronting the gemstone industry which it is believed these measurements could help to solve have already been discussed.[3] They should be of value to those engaged in mining and gemstone rough production, in the cutting and marketing of unset stones, in controlling gemstone colour enhancements, in assessing alexandrite-type colour changes and in monitoring colour stability, fading and tenebrescence effects.

The measurements will be of little or no importance to jewellery designers and jewellery house sales-personnel. Their interests are concerned more about total colour appearance and not with body colours. Having said this, they should nevertheless be made aware of some of the colour mixing perils that jewellery design could entail, such as metamerism and simultaneous contrast.

Up to this point, the discussion has focused mainly on body colour, which is purely a matter of *colour grading*.

Turning now to the matter of *colour appearance*, it is important to know if this aspect can be quantitatively assessed in a similar manner. Since numbers are being sought, can the CIE Tristimulus Colour System quantify the colour appearance of an isolated gemstone or an array of set stones?

The core-data of this system is the CIE 1931 Standard Colorimetric Observer. Measured and standardized sixty years ago using trichromatric colorimetry, the system describes proportions of two calibrated colour stimuli which match a third (the test colour). Although examined and re-examined on many occasions since that time, the original core-data have been fully substantiated and have stood the tests of more advanced experimental techniques. It forms the basis of technologies such as colour television, colour photography and a host of industries that produce coloured objects to match

a designer's conception. The system has demonstrated its complete validity for quantifying the colours of the great majority of objects seen under the quite different surroundings occurring in everyday life.

In spite of its unbelievable successes, among its limitations are the facts that it does not predict colour appearance, nor does it predict colour discriminability. There are also two situations where the perceived colour is not reliably quantified by its tristimulus values. The first is known as *simultaneous contrast*, whose effects can only be assessed visually. The second involves a visual phenomenon known as *chromatic adaptation*.

However, recent advances in colour science are providing some remedies for these ailments. It must be noted that the new formulae and indices are no more than approximations to the truth. More significant improvements must be forthcoming before it can be claimed that the colour appearance can be measured realistically.

There are two very recent developments which promise a closer convergence between the CIE system and colour appearance predictions. The first[8] describes a new model of colour vision for predicting colour appearance. A supportive work[9] shows that this physiologically plausible model of colour vision, based on the CIE 1931 Standard Colorimetric Observer, can provide reasonably good predictions of the colour appearance of surface colours seen either in simulated daylight illumination (CIE Illuminant C) or in tungsten light (CIE Illuminant A).

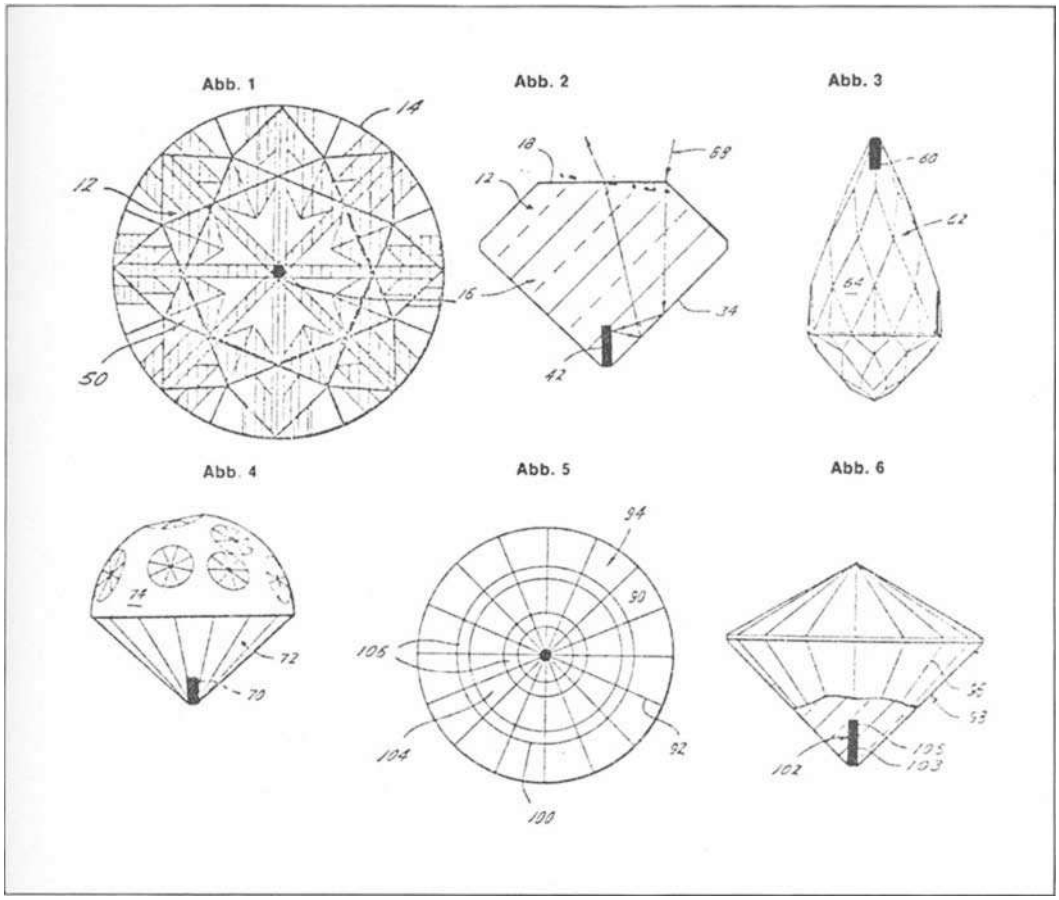

Fig. 1. Illustration showing the method of changing colourless articles into highly coloured ones by internal reflections from coloured inserts. Taken from US Patent Declaration 3 835 665 (13.4.1973).

The second advance concerns a colour order and notation system developed by the Swedish Color Center Foundation. Called the Natural Color System (NCS)[10] it is a psychometric model for colour description. The system has an associated collection of 1412 colour samples, which employs

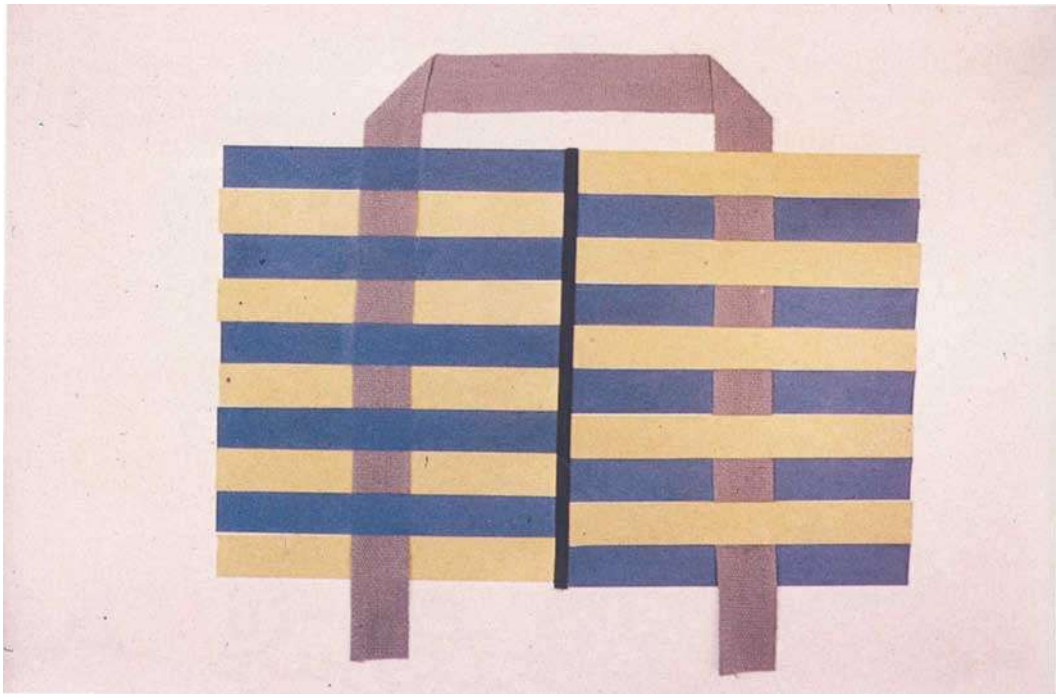

Fig. 2. The brown tape is the same colour throughout, but appears to change colour against the different coloured backgrounds.

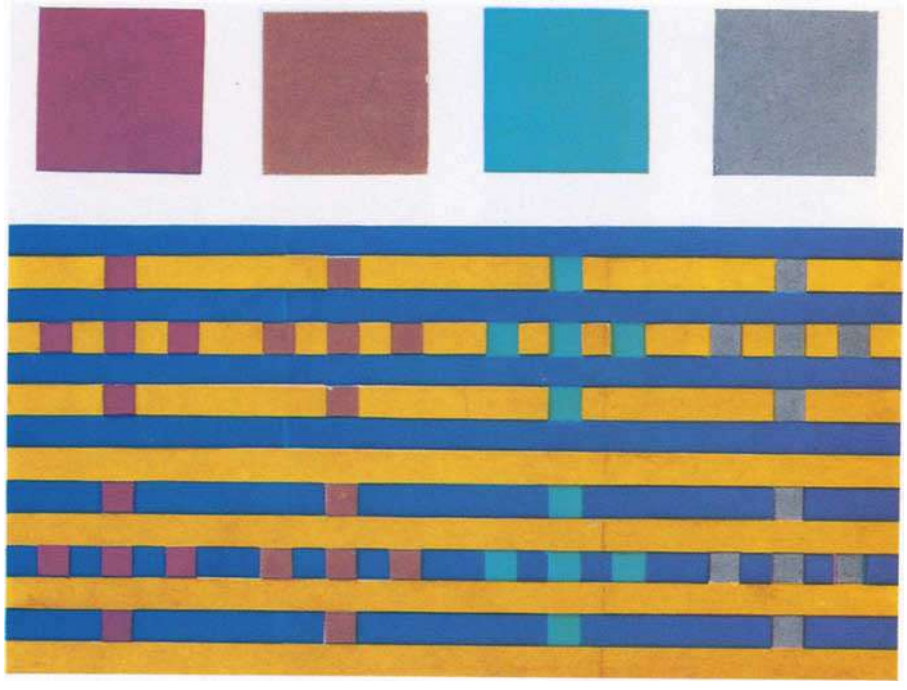

Fig. 3. Changes in colour due to the condition of viewing. Only the four colours shown in the large squares have been used in this photograph. The changes are best seen by tilting the illustration away from the viewer.

the same NCS symbol language; this is particularly easy to comprehend and use. The language is expressed both by graphical illustrations and by letter-digit notation and more importantly can also be expressed in CIE colour co-ordinates. It is therefore a good unifying visual system for describing colours and for approximately quantifying colour appearance, or 'what we actually see'. Indeed, the origin of the system in 1964 sprang from this underlying need of a phenomenological philosophy. One serious shortcoming for gemmologists is the lack of highly saturated samples, although of course, the notation system itself can deal with the most saturated colours. Another is the usual difficulty of visually comparing test stones with painted surfaces. Like is not compared with like, so that there are increased risks that different observers cannot agree about their matches.

The most remarkable fact about human colour vision is not that we fail to agree on colour matches, but that the level of general agreement is so high. There is such a multitude of complex physical and chemical processes and mechanisms constantly at work in the retina and visual cortex that it appears incredible that there can be such universal agreement. The mundane act of seeing with a fleeting glance that a crumpled piece of cloth is uniformly dyed must be immensely complicated. There is clearly more to seeing than just looking.

A good example of the complexities of colour vision with which no colour appearance model can yet cope is that of simultaneous contrast. Figure 2 is a photograph of a 'woven fabric' made by the author to illustrate the effect. It consists of alternating warps of blue and yellow ribbons and a brownish woof which can be seen to be woven into the warps. If this illustration is tilted away from the viewer so to foreshorten the image, it will be seen that the woof colour changes with respect to the warp. Perhaps a more spectacular example is shown in Figure 3. The effect is widely exploited in art in the form of neo-impressionistic paintings, in mosaic tile assemblies and in tapestries. A most effective display of the phenomenon was a carpet in which twelve colours were easily recognized in the geometrical design. As the carpet was a Wilton, which meant that only five yarns were used, the other seven colours resulted from simultaneous contrast.

Examples of jewellery exploiting this effect are not known to the author. However, there is the well-publicized failure of a regalia designer to recognize the phenomenon.[11] It concerned the design of the ceremonial sword presented to the people of Stalingrad in recognition of the heroic stand made by the city in the Second World War. A photograph (not in colour, regrettably) of the

Fig. 4. The Wilkinson Sword of Stalingrad.

Wilkinson sword is shown in Figure 4. The pommel was made from a Scottish quartz crystal. The hilt was bound with silk thread dyed to a brilliant turquoise colour and overlaid by Welsh pure gold wire. The combination had a pink colour reminiscent of inexpensive ashtrays of the time, made of dyed anodised aluminium. This example of a material substance converted into a sensory effect was quite dramatic, but this proved to be an inadequate reason to spare the design. Many fruitless experiments were made in attempts to restore the hue of the gold.

Acknowledgements

Thanks are due to Adam Hilger Ltd, for permission to reproduce Figure 3 from *The measurement of colour* by W.D. Wright, 1969. Also to Mr George Bull-Diamond of Charles Mathews Ltd. for a gift of the photograph of the Stalingrad Sword.

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Further development of a computer program for gem identification

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Seven years ago, I made the following comment in an article[1] in this *Journal* describing my first two computer programs for gem identification:
'From the results of this work I believe that with a larger memory (perhaps of 64K) and with faster data storage loading peripherals, both programs can be expanded to a point where they would make a useful contribution to gem identification.'

Two years later I had achieved this goal by expanding the memory of the computer and by replacing the tape cassette storage with a floppy disk reader. This enabled me to increase the number of gems covered by the programs from 80 to over 200, and to extend the program features and the variety of data displayed.[2]

The added features included an option to allow a gem's specific gravity to be input to the computer in the form of a number code which accommodated approximations made with the aid of heavy liquids (see Figure 7). Another feature was the provision of an input for a gem's optic sign as an extra identification criterion. In addition, when search limit 2 was chosen, the mismatch tolerance for refractive index was automatically widened to ±0.1 for those stones with an RI above the 1.80 limit of a standard refractometer. This allowed for the errors associated with the 'direct' or 'apparent depth' method of determining refractive index using a microscope. A further section, called 'Gem Calculations', was also added and this enabled hydrostatic weighing derived SGs, reflectivity values, critical angles and Brewster angles to be calculated for any gem. Finally, the program data was modified to contain the total possible range of RI and SG values associated with each gem.

Although the ability to input the expanded program from a magnetic disk rather than a tape cassette greatly speeded up the loading of the program, the greater number of gems covered and the increased amount of data to be searched by the program meant that the average identification time was as long as 20 seconds with the 8-bit computer then in use. A finite limit to the maximum memory capacity of the computer (52K) also prevented the program from being expanded any further or for any additional gems to be added. In particular, the test input criteria for gem identification had to be limited to RIs, optic sign, optical character and SG. This restriction sometimes resulted in the program finding and displaying additional identifications in which the colour and transparency were not in agreement with the specimen being tested.

Fig. 1. The author's IBM-compatible Amstrad PC1512DD computer installation used to develop the GEMDATA program.

By 1987, the specifications and costs of personal computers had vastly improved, and taking advantage of these changes I replaced my original equipment with a 16-bit Amstrad PC1512DD (Figure 1) whose larger memory (512K) then allowed me to expand further the gem identification section of the program.

Apart from the benefits of faster operation afforded by the 16-bit central processor unit in the new computer, and the availability of multi-coloured texts (Figure 2), the larger memory has now permitted a gem's colour and transparency to be taken into account as identification criteria (Figures 3–5). With the updated GEMDATA program, it is possible to input a choice of ten colours (plus colourless) and to specify the gem as

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Fig. 2. The GEMDATA 'menu' gives a choice of three program sections.

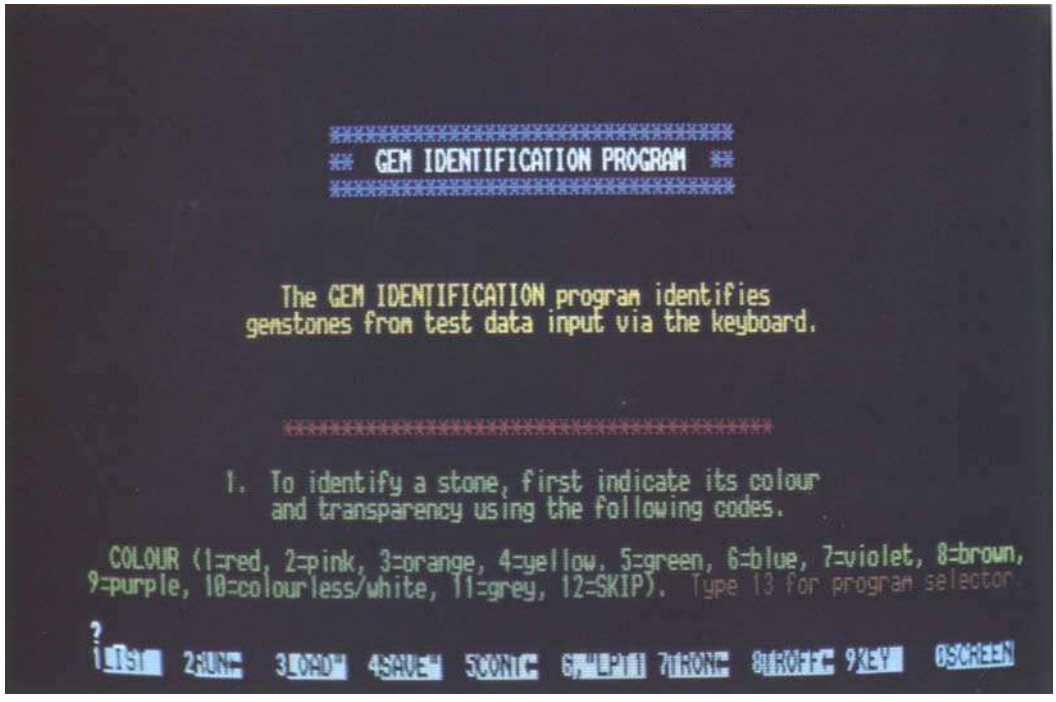

Fig. 3–5. 'Gem Identification' has been selected and the inputs '1' (colour = red), '2' (translucent), '1.6' (a single refractive index as measured on a standard refractometer), '1' (the gem under test shows doubly refracting on a polariscope) and '3.6' for SG have been typed in. The program displays the identification 'Rhodochrosite' (whose upper refractive index of 1.82 was 'off scale' on the refractometer). Identification time was three seconds.

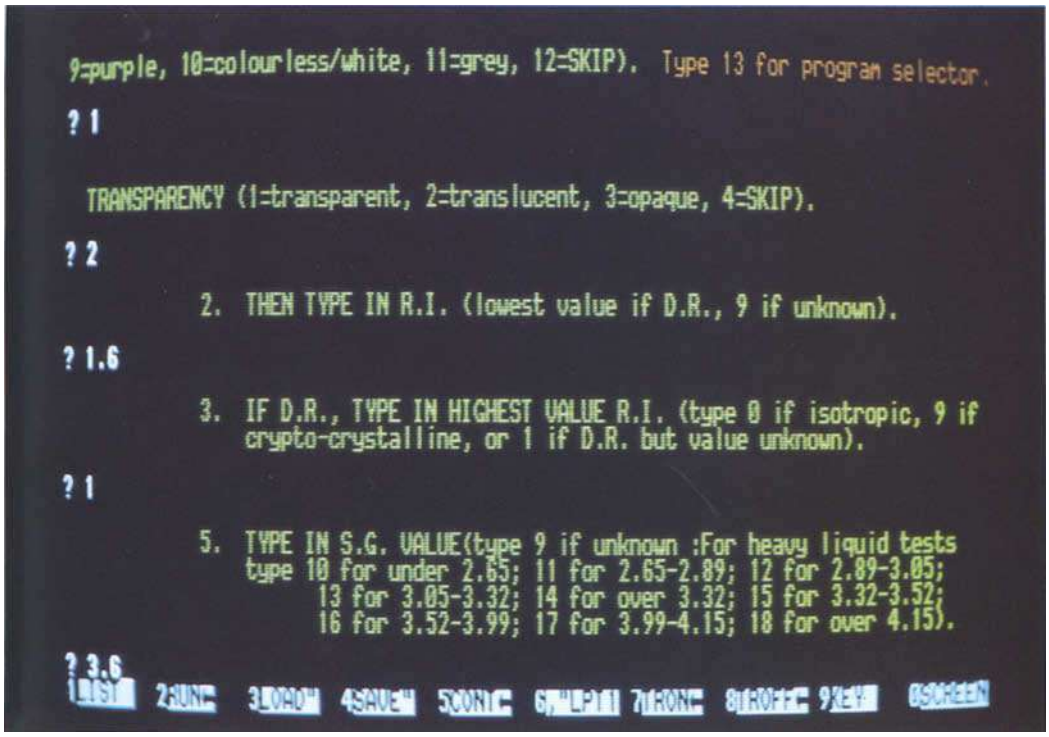
9=purple, 10=colourless/white, 11=grey, 12=SKIP). Type 13 for program selector.
? 1
TRANSPARENCY (1=transparent, 2=translucent, 3=opaque, 4=SKIP).
? 2
2. THEN TYPE IN R.I. (lowest value if D.R., 9 if unknown).
? 1.6
3. IF D.R., TYPE IN HIGHEST VALUE R.I. (type 0 if isotropic, 9 if crypto-crystalline, or 1 if D.R. but value unknown).
? 1
5. TYPE IN S.G. VALUE(type 9 if unknown :For heavy liquid tests type 10 for under 2.65; 11 for 2.65-2.89; 12 for 2.89-3.05; 13 for 3.05-3.32; 14 for over 3.32; 15 for 3.32-3.52; 16 for 3.52-3.99; 17 for 3.99-4.15; 18 for over 4.15).
? 3.6
1LIST 2RUN 3LOAD" 4SAVE" 5CONT 6,"LPT1 7TRON 8TROFF 9KEY 0SCREEN

Fig. 4.

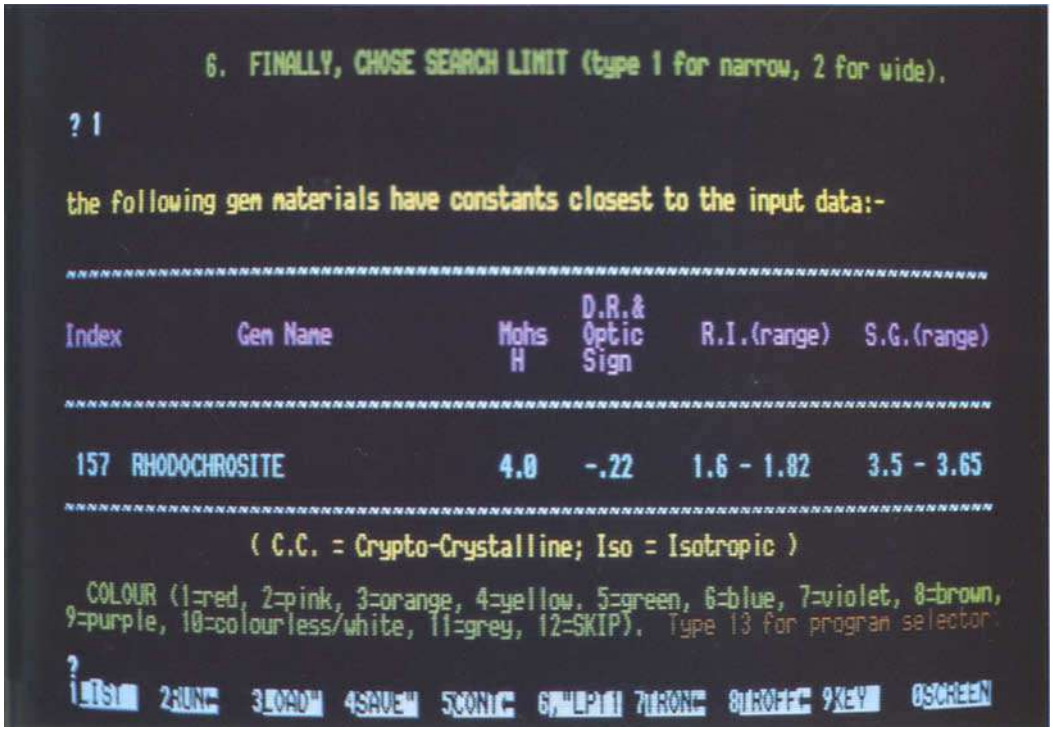
6. FINALLY, CHOSE SEARCH LIMIT (type 1 for narrow, 2 for wide).
? 1
the following gem materials have constants closest to the input data:-
Index Gen Name Mohs H D.R.& Optic Sign R.I.(range) S.G.(range)
157 RHODOCHROSITE 4.0 -.22 1.6 - 1.82 3.5 - 3.65
(C.C. = Crypto-Crystalline; Iso = Isotropic)
COLOUR (1=red, 2=pink, 3=orange, 4=yellow, 5=green, 6=blue, 7=violet, 8=brown, 9=purple, 10=colourless/white, 11=grey, 12=SKIP). Type 13 for program selector.
?
1LIST 2RUN 3LOAD" 4SAVE" 5CONT 6,"LPT1 7TRON 8TROFF 9KEY 0SCREEN

Fig. 5.

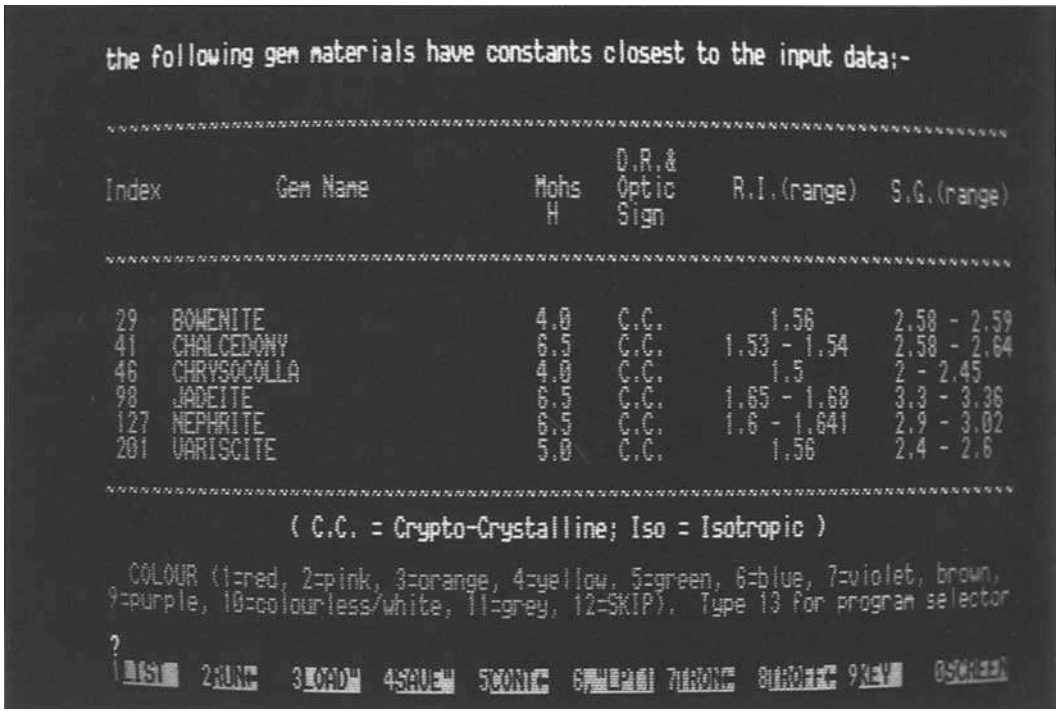

Fig. 6. The program has been instructed to display all green translucent crypto-crystalline stones (the inputs for RI and SG have been bypassed by using the program options).

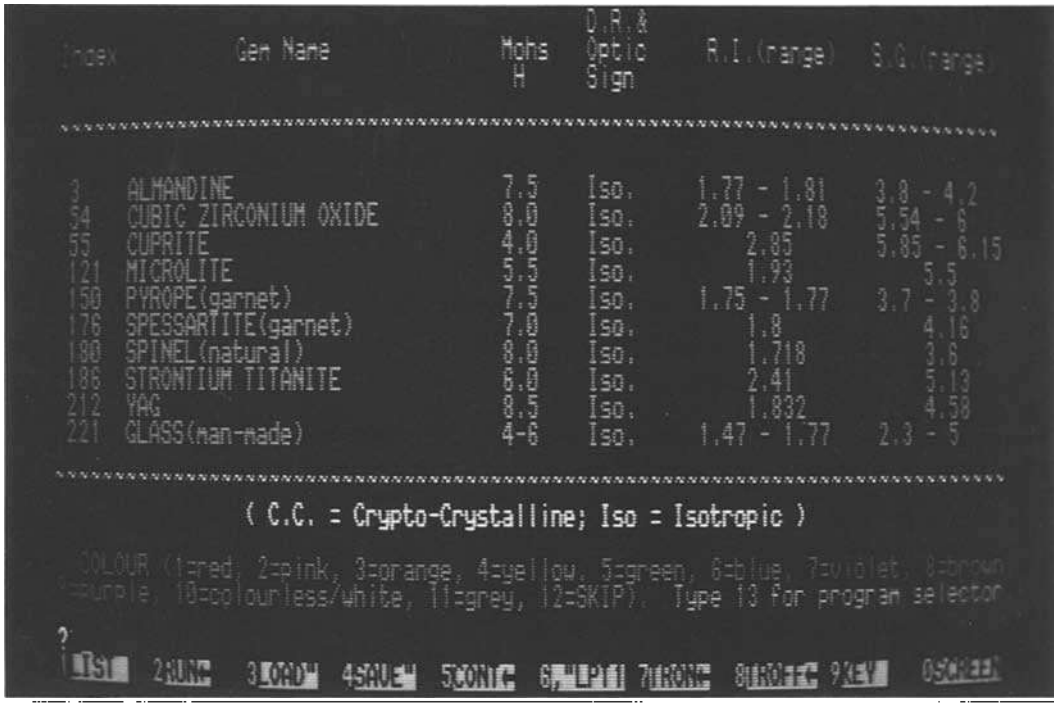

Fig. 7. Here, the program was instructed to display all red transparent singly-refracting gems having an SG of 3.32 and above.

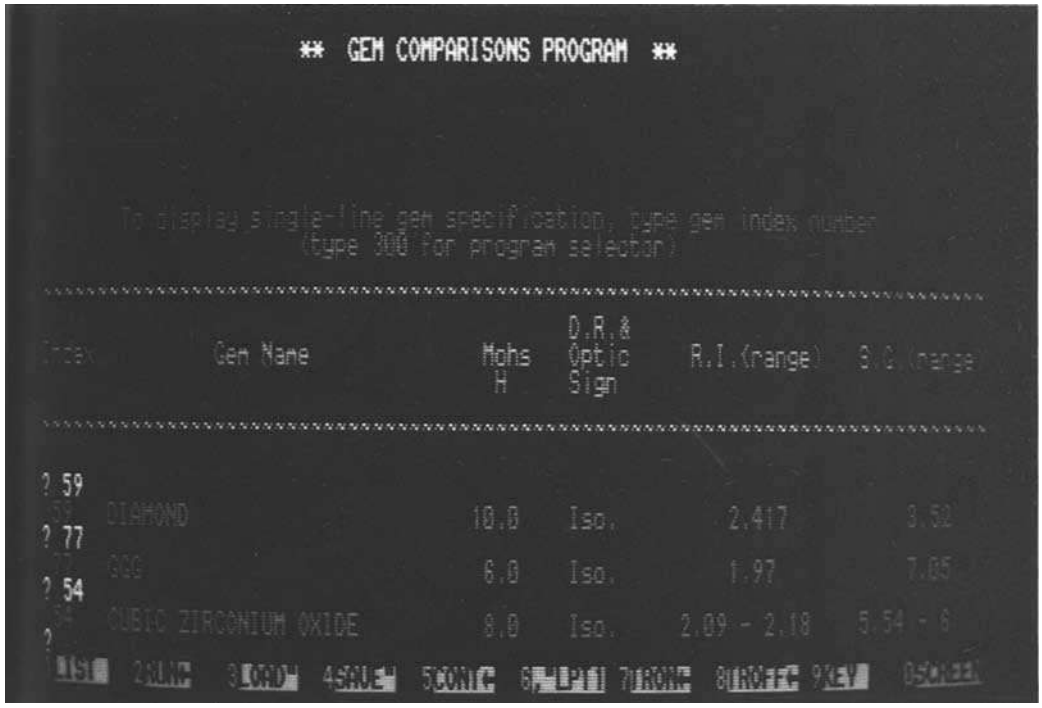

Fig. 8. The 'Gem Comparisons' section of the program allows for side-by-side display of the constants of gems selected from an index list.

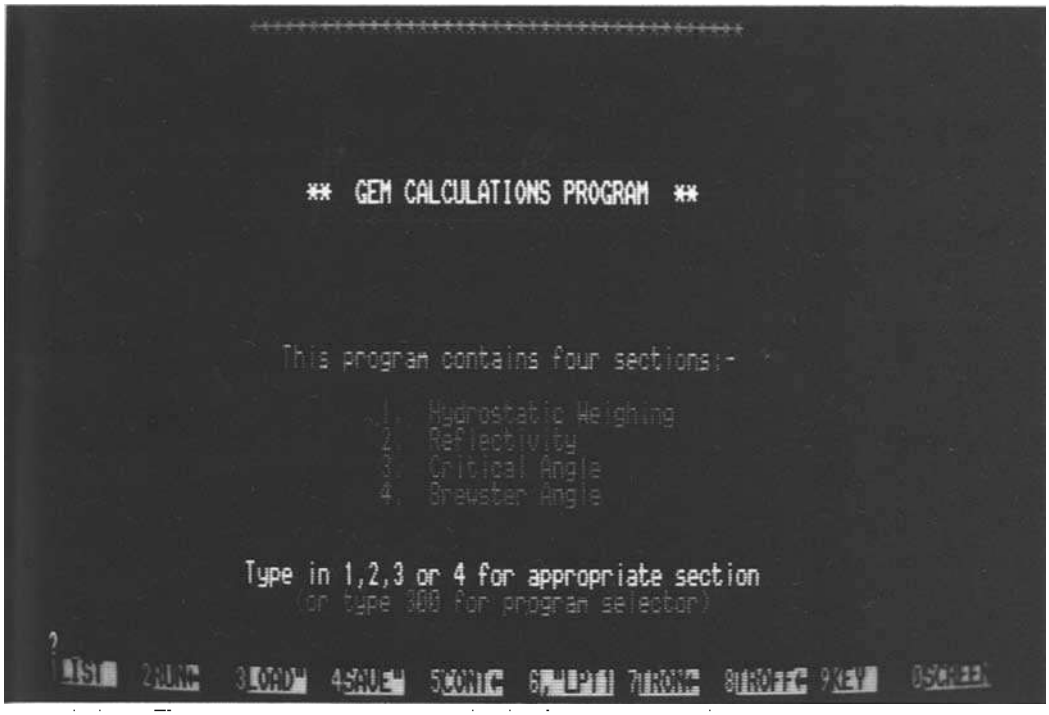

Fig. 9–12. The 'Gem Calculations' menu, and examples of its use for checking the reflectivity, critical angle and Brewster angle of diamond.

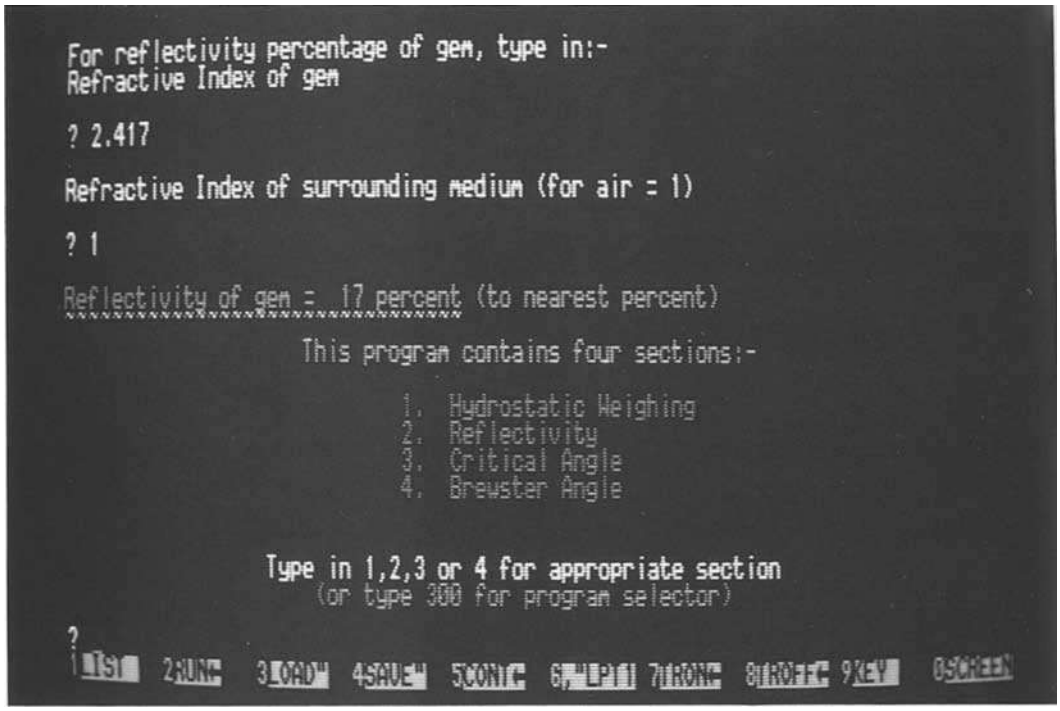
For reflectivity percentage of gem, type in:-
Refractive Index of gem
? 2.417
Refractive Index of surrounding medium (for air = 1)
? 1
Reflectivity of gem = 17 percent (to nearest percent)
This program contains four sections:-
1. Hydrostatic Weighing
2. Reflectivity
3. Critical Angle
4. Brewster Angle
Type in 1,2,3 or 4 for appropriate section
(or type 300 for program selector)
?
1LIST 2RUN" 3LOAD" 4SAVE" 5CONT 6,"LPT1 7TRON 8TROFF 9KEY 0SCREEN

Fig. 10.

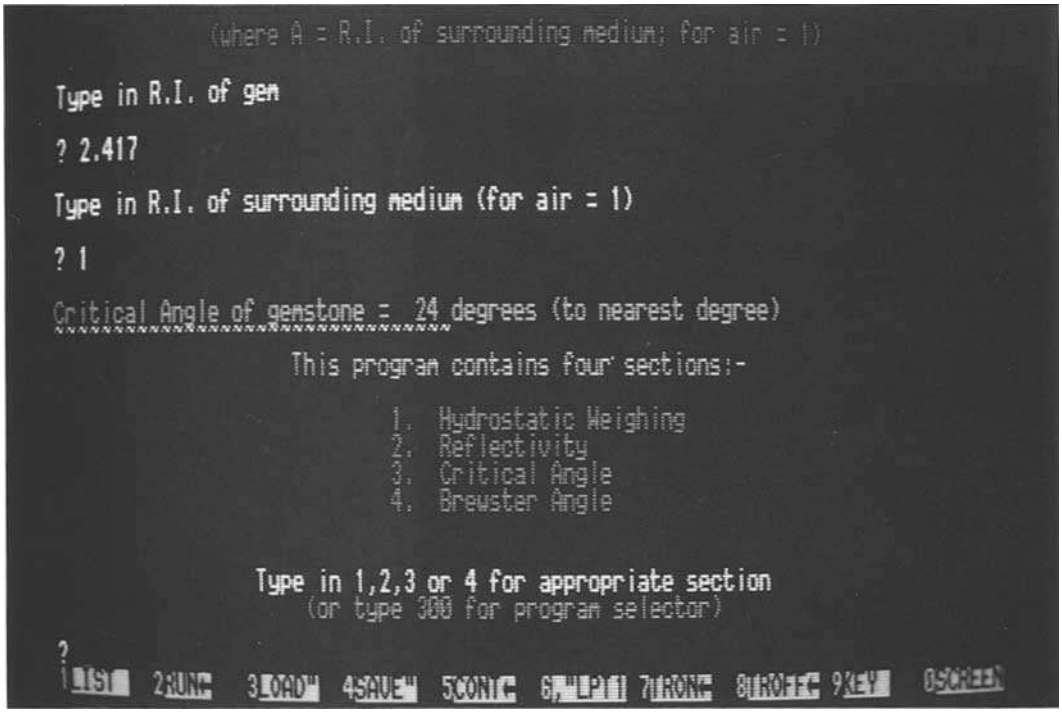
(where A = R.I. of surrounding medium; for air = 1)
Type in R.I. of gem
? 2.417
Type in R.I. of surrounding medium (for air = 1)
? 1
Critical Angle of gemstone = 24 degrees (to nearest degree)
This program contains four sections:-
1. Hydrostatic Weighing
2. Reflectivity
3. Critical Angle
4. Brewster Angle
Type in 1,2,3 or 4 for appropriate section
(or type 300 for program selector)
?
1LIST 2RUN" 3LOAD" 4SAVE" 5CONT 6,"LPT1 7TRON 8TROFF 9KEY 0SCREEN

Fig. 11.

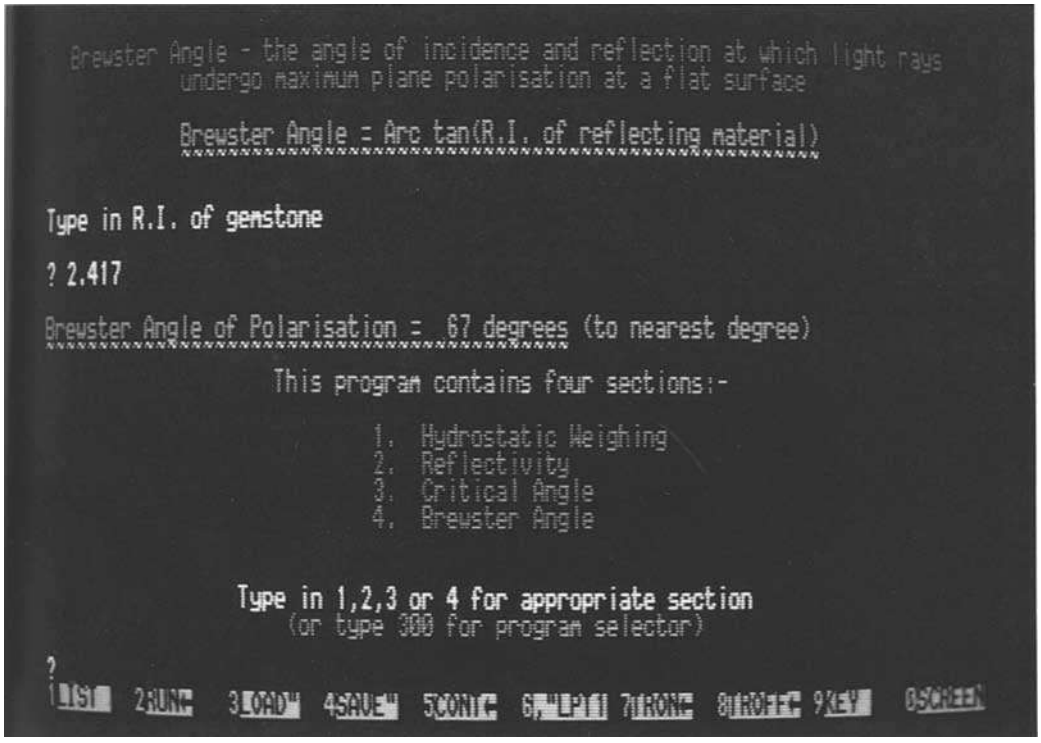

Fig. 12.

transparent, translucent or opaque. For flexibility, it is also possible to bypass or 'skip' the inputs for colour and/or transparency (as can be done for RI, optic sign and SG). This 'skip' facility has the added advantage of making it possible to display specific groups of gemstones. For example, the program can be asked to display all green translucent crypto-crystalline gems having any value of RI and SG (Figure 6), or to list all red transparent singly-refracting stones having an SG of 3.32 and upwards (Figure 7).

The facility for calling up separate program sections from a 'menu' is retained and allows a choice of 'Gem Identification' (using input test data), 'Gem Comparisons' (providing side-by-side displays of the constants of selected gems in the form of single-line specifications – Figure 8) and 'Gem Calculations' (hydrostatic weighing, reflectivity, critical angle and Brewster angle – Figures 9–12).

Additionally, the single-line gem specifications displayed in both the gem identification and comparison sections of the program have been modified to show Mohs hardness, optic sign/DR (or 'Iso.' for isotropic; 'C.C' for crypto-crystalline), RI range and SG range.

With the previous equipment, because of the incompatibility between disk operating systems, it was only possible to make the program accessible to would-be users in the form of a printed listing (which was some 700 lines in length). The Amstrad PC1512DD, however, is IBM-compatible, and the new GEMDATA program can be fed directly into similar computers which accept 5¼-inch double-density, double-sided floppy disks and have a minimum memory of 120K to accommodate both the program and the BASIC language in which the program is written.

As an increasing number of jewellers are turning to the computer as an aid to stock control and accounting, the addition of a program such as GEMDATA would make it possible to expand the clerical uses of the installation into the realms of gem identification and appraisal.

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Internal diffusion

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Abstract

Some minerals, such as rutile, hematite and ilmenite, found as inclusions in sapphires are capable of imparting body-colour to their host during high temperature heat treatment. The inclusions are cannibalized by the host sapphire for the chromophoric elements they contain. If the inclusions are not completely consumed by their host this 'internal diffusion' results in a zone of intensely coloured sapphire surrounding the remaining inclusions.

Introduction

The elemental causes at the atomic level of both the blue and the stable yellow colour in sapphires have been known and at least partially understood for some time. Over the past several years some excellent articles have been written by a number of well known and highly regarded gemmologists and research scientists that document these coloration mechanisms and the trace elements responsible for the resulting colour (Crowningshield and Nassau, 1981; Gunaratne, 1981; Nassau, 1981 and 1984; Keller, 1982; Schmetzer, Bosshart, and Hänni, 1983).

However, although the colour producing mechanism is generally understood and the colouring agent(s) is/are known, the exact source of the colouring agent(s) themselves is usually not mentioned and still remains, at least in some cases, unknown.

It seems to be generally accepted that the agents responsible for the blue and stable yellow colours in heat treated sapphires are either already naturally present as trace elements at the submicroscopic lattice level, as in the case of Sri Lankan 'geuda', or must be added in artificially from the exterior of the gem through a high temperature diffusion treatment.

In the case of a high temperature diffusion treatment the sources of the various colouring elements are jars of readily available purified laboratory chemicals, usually in oxide form, that are painted on to the prefaceted gem's surfaces just before treatment. The question of colouring element source only arises when we consider those gems that require no externally applied chemicals to attain body colour when they are subjected to a high temperature treatment. Are all these colouring agents, in, as an example the Sri Lankan geuda, already present throughout the gems as trace elements, or is there some other natural source that provides at least some of the colouring ions from within the gems?

In his paper on geuda sapphire coloration written in 1981 Herbert S. Gunaratne of the Sri Lankan State Gem Corporation hinted at a possible chromophore source with the following statement:

'Titanium and iron are both colouring elements to which is attributed responsibility for imparting colour to blue sapphires. These elements have been found in varying proportions as insignificant impurities which are jointly or by themselves responsible for the colour. In the geuda of the ideal stone the rutile present has remained, so to say, in a state of inactivity, in the sense that its true function as a colouring element has not fully revealed itself. On the other hand, the faint powder-blue tint in such a stone could be attributed to iron in some form, which, if subject to heat, totally disappears at certain temperatures, making the stone visibly whitish. On being subject to still higher temperatures (temperature closer to the melting point of titanium), the titanium begins to melt within the host while the host is still in a solid state. In this state the atoms of the rapidly melting titanium not only begin to readjust themselves once again in relation to crystallographic laws, but also to bring out its colouring properties which gradually diffuse into the host.'

Although Mr. Gunaratne does not specifically say so, from the paragraph quoted above it can be reasonably inferred that when he writes of titanium melting he is referring to the mineral rutile in the form of exsolution needles and not to metallic titanium in uncombined elemental form. In the last sentence he speaks of the colouring properties of the melting titanium (rutile) gradually diffusing into the stone. Although no mention as to where the iron (also needed for blue colour) is coming from, this still strongly suggests that he felt that the solid microscopically visible inclusions present in Sri

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Lankan geuda sapphires were responsible, at least in some way, for the resulting blue colour by diffusion into the surrounding corundum host.

With respect to yellow coloured sapphires from sources such as Australia and Thailand it has also been theorized more than once that inclusions may at least play a partial role in the colorizing process during heat treatment.

An excellent paper on gem corundum from Thailand written by Dr Peter C. Keller, Associate Director of the Los Angeles County Museum of Natural History, and published in 1982, points out one possible colouring element source in colour-stable heat-treated yellow and orange sapphires. This particular discussion on colour-cause is quoted as follows:

'The actual mechanism for the appearance of the golden yellow colour in the sapphire is open to speculation until the extensive research required to provide a conclusive answer can be completed. According to George Rossman. of the California Institute of Technology (personal communication, 1982). Trivalent iron alone will produce a pale yellow colour, but cannot be called upon for the rich golden colour observed in many of the treated stones seen in Chanthaburi. Rossman suggests that perhaps we are seeing incipient exsolution of the trivalent iron as sub-microscopic iron oxides in the corundum lattice. This mechanism would be very similar to the exsolution of hematite in plagioclase feldspar giving rise to the golden colour of sunstone. In the case of plagioclase, the hematite may become coarse enough to result in aventurescence. This phenomenon has not been observed in sapphire, although the process is not unlike the exsolution of titanium oxides (rutile) in corundum to produce the familiar silk inclusions. As noted above, however, detailed research will be needed to answer this question for certain.'

Here it was stated that the colour intensification of some golden yellow heat treated sapphires is in part thought to be the direct result of the presence of inclusions.

Another noteworthy paper discussing yellow and orange-brown heat-treated sapphires, authored by Dr Karl Schmetzer of West Germany, and George Bosshart and Dr Henry A. Hänni from Switzerland, was published in 1983.

In this paper the authors point out that although temperatures in excess of 1550°C are reportedly used in the annealing of yellow sapphires no explanation as to the cause of the heat treatment-generated yellow coloration can be given at this time. They then go on to speculate:

Possibly is it related to the resorption of pre-existent mineral inclusions during annealing. Chemical analyses (microprobe, X-ray fluorescence) indicate limited contents of Fe and sometimes also of Cr and Mg. Already before the heat treatment, these elements were present in some form inside the crystal (as incusion constituents or on Al sites of the corundum lattice) and become colour-efficient by the strong annealing.

Here again it is suggested that perhaps some inclusions in sapphires will supply their host with colouring ions during high temperature heat treatment.

In his definitive book *Gemstone enhancement* (1984) Dr Kurt Nassau also mentions inclusion caused colour in explaining that if pale to medium yellow corundum containing Fe^{3+} ions in the form of Fe_2O_3 is strongly heated it could aggregate the Fe_2O_3 to form particles of hematite and in this manner produce a deeper yellow-to-brown colour in the gem. One of the colour illustrations (by this author) in *Gemstone enhancement* (plate number XVI) shows orange-yellow halos in a heat-treated sapphire taken in diffused transmitted light at 25×.

What was not shown in the book was the matching companion micrograph taken in the same position, at the same magnification but under dark-field conditions. This second photomicrograph (Figure 1), when compared to the original photo shown in *Gemstone enhancement* (Figure 2), shows that for every orange-yellow halo there is a corresponding acicular inclusion at the centre of the halo. The connection here between inclusions, colour and heat treated host is obvious. The colouring agent (iron) has diffused from the inclusions into the surrounding sapphire.

Observations

After discovering this 'internal diffusion' colouring mechanism (Figure 3) twelve additional heat-treated yellow sapphires were examined very closely in both diffused transmitted and dark-field illumination using magnifications as high as 160×. In nine of the twelve treated sapphires tiny whitish appearing acicular inclusions, surrounded by yellow colour rinds, were observed. In the remaining three sapphires no specific source for the colour could be established.

Rutile (TiO_2: often containing at least some iron), hematite (alpha-Fe_2O_3: sometimes containing titanium) and ilmenite ($Fe^{+2}TiO_3$) have all been recognized as mineral inclusions in sapphires from various localities. Chemically they are also very closely related. Other chemically related inclusions such as pyrite (FeS_2), pyrrhotite ($Fe_{1-x}S$) and chalcopyrite ($CuFeS_2$) have also been identified in sapphires. Even though each of these compounds is universally acknowledged as a separate and distinct mineral, when studying their chemical formulas a common gemmological link is discovered. The

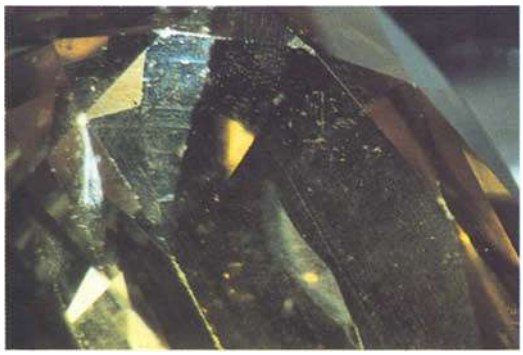


Fig. 1. Heat-treated orangish-yellow sapphire containing a multitude of tiny acicular (hematite?) inclusions. Dark-field illumination. 25x.

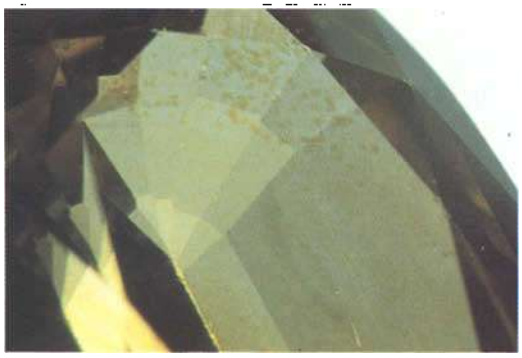


Fig. 2. Using diffused transmitted light on this same sapphire reveals an orangy-yellow coloured halo surrounding each of the minute whitish-appearing acicular inclusions. 25x.

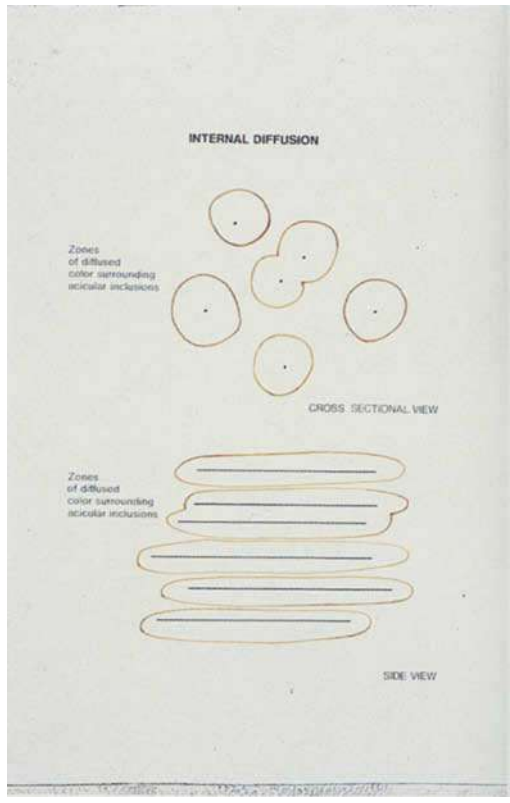


Fig. 3. Schematic diagram of the 'internal diffusion' mechanism showing both cross sectional and side views.

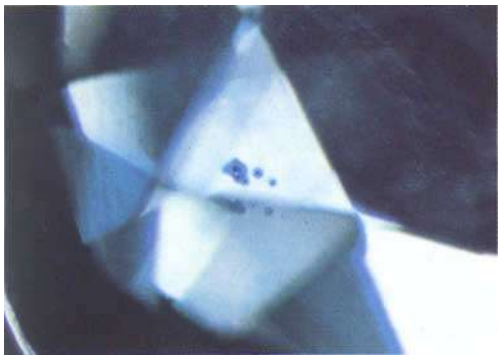
metallic elements that compose them, either separately or together, have the capacity of causing yellow to blue colour in corundum. So perhaps if both iron and titanium (which are both necessary to create blue colour in sapphire) were present at the same time as the chemical components of an inclusion then a blue-coloured halo would be generated around that inclusion during high temperature heat treatment if the temperature was high enough to volatilize the inclusion without melting the host.

Just such an inclusion cannibalizing mechanism apparently does exist. An extensive microscopically-aided search through a number of pale to dark blue heat-treated sapphires from the Phillipsburg area of Montana in the United States (47 faceted stones) and from Sri Lanka (38 faceted stones) yielded a few gems (6 from Montana and 2 from Sri Lanka) that showed obvious evidence of blue internal-colour-diffusion haloing generated by thermally activated inclusions. Examples of this visual evidence of inclusion caused coloration in one of the heat-treated Phillipsburg sapphires is shown in Figure 4 while this same effect in a Sri Lankan gem is shown in Figure 5.

Additional examples of 'internal diffusion' have also been found while studying blue flame-fusion (Verneuil) synthetic sapphires. When the powdered chemicals which are melted to grow these synthetic sapphires are unevenly mixed small pockets of the chromophoric oxides used to produce the blue colour may become concentrated and trapped in the melt layers. When this happens, as shown in Figure 6, colour diffuses away from these pockets into the successive growth layers creating blue-phantoms extending from the oxide-pockets.

Conclusion

From the visual evidence presented in this study it is apparent that microscopically visible inclusions provide at least some of the colouring ions in some high temperature heat-treated sapphires through 'internal diffusion'. What percentage of the colour in a given gem can actually be attributed to this



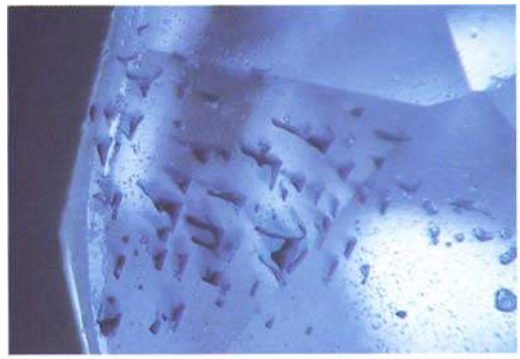


Fig. 4. (Above) Small cluster of anhedral black submetallic ilmenite inclusions encircled by blue 'internal diffusion' clouds in a pale blue sapphire from Phillipsburg, Montana. Diffused transmitted light. 45x.

Fig. 5. (Above right) This tight grouping of irregular titaniferous hematite crystallites has released both titanium and iron during heat treatment resulting in the surrounding zone of blue colour in this Sri Lankan Sapphire. Diffused transmitted light. 40x.

Fig. 6. (Right) Chromophoric oxide-pockets with internal diffusion generated blue-phantoms in a flame-fusion synthetic sapphire. Diffused transmitted light. 35x.

mechanism is open to speculation and will differ from stone to stone. It is probable that most of the colour in heat-treated yellow and blue sapphires results from the presence of either trace elements or submicroscopic inclusions, neither of which can be observed with a microscope.

Acknowledgements

The author would like to thank Mr William C. Kerr, GG, of Long Beach, California, for providing some of the Montana sapphires used in this study.

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The background to diamond grading

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Abstract

The background to the assessment of diamond quality is given with emphasis on the present grading systems.

Introduction

When considering the purchase of any commodity, be it a house, a car, a kilo of fruit or a diamond, one naturally wants to know whether the price being asked is reasonable for the quality of the item offered. To judge whether value for money is being obtained, one has to find a means by which the quality can be appraised. In the case of a polished diamond, quality is decided by reference to the so-called 'Four Cs', i.e. Carat weight, Colour, Clarity and Cut.

This article is an introduction to a series which will review the present status of laboratory-based diamond grading and the methods used to assess the 4 Cs. Subsequent articles will examine the systems and nomenclature used in greater detail. The author recognizes that throughout the world many systems have been devised, used locally, but are not necessarily known on the international market.

For centuries the sole criterion used by the trade to assess diamond quality was that of size (weight). In 1750, David Jeffries[1] stated: *'The principle, or rule is, that the proportional increase, or value of Diamonds is the square of their weight, whether rough or manufactured.'*

The background to diamond grading

The formula used by the trade was $n^2P = R$, where n is the weight in carats, P the price of a stone of one carat and R the total value.

An example Jeffries quotes is *'a rough diamond of two carrats [*sic*], at the rate of £2 per carat . . . multiply 2 by 2, the square of its weight then multiply the product of 4 by £2 . . . that makes £8 which is the true value of a rough diamond of 2 carats'.*

The square weight rule appears to have applied as late as 1877[2], although by 1918 the rule had fallen out of favour as J.R. Sutton shows in his book *Diamond*[3]. He quotes some diamond values of that year which illustrate the relationship between price and size which still holds true today, i.e. as the weight increases, the price *per carat* increases.

Example: Bultfontein (a mine in South Africa) *Diamond Values Sept 1918.*

Market Value in Shillings (20 shillings = £1)

Weight (ct)	*Price per carat*	*Price per stone*
1	*146*	*146*
2	*242*	*484*
4	*296.5*	*1186*
7	*325.5*	*2278*

With the increase in the number of diamonds coming on to the market at the turn of the century, many from the Cape area of South Africa, interest became focused on the *colour* of the stones. At this time colour (or more correctly the lack of colour) in diamond was described in quite vague terms. A jeweller in Paris (at that time the centre of the diamond trade) might describe the colour of an exceptional diamond as *'of the best first water'*; a reference to the water-like transparency of the stone. Poorer colours might be described as *'of the second water'*. It became apparent that many stones from the Cape were not of the best colour. There was and still is a tremendous variation of colour, from the absolutely colourless stones, very few in number hence in great demand, to the more common pale yellow stones. Certain South African mines were noted for certain quality stones. For example the Jagersfontein mine in the Orange Free State was known to produce many fine water-white crystals thus such stones were called 'Jagers'. Such names were incorporated into an *international* colour grading scale in use in the 1930s (see Table 1).

These terms, known as 'old terms' or 'old Engish terms' still survive in certain quarters of the trade but have been superseded by other nomenclatures (see Table 2).

An interest in the internal characteristics, flaws or inclusions in diamonds only arose when the construction of a reliable jewellers' eye-glass (or loupe) had been perfected.

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Table 1. Colour grades of 'white' diamonds used in the 1930s.

Jager (the best colour)
River
Top Wesselton
Wesselton
Top Crystal
Crystal
Top Cape
Cape
Light Yellow
Yellow (the worst colour)

At the beginning of this century two clarity grades were in use in Paris, *'piqué'* used to describe the major proportion of diamonds containing visible flaws, and *'clean'* for the much rarer hence greatly prized diamond devoid of flaws or inclusions. By the 1920s the terms 'very, very slight imperfect' and 'very slight imperfect' were being used to describe stones with minor inclusions.

By the 1930s a progression of grades was established in which the number and size of the inclusions affected the clarity grade. The Gemological Institute of America (GIA), established in 1931, had devised the following scale:–

Flawless
Very, very slightly imperfect
Very slightly imperfect
Slightly imperfect
Imperfect

By now the term 'piqué' had fallen out of favour in the United States and was replaced by the word 'imperfect' or just 'I'.

At present this scale has been modified and extended as can be seen in Table 2.

The best clarity grade used in the GIA system is 'internally flawless' – a phrase invented in 1968. 'Loupe clean', a term coined at the turn of the century, is used in other systems.

The importance of *Cut* in diamond quality is the subject of a separate article but it can be noted that its importance has only recently been appreciated. Even today the aspect of cut is often ignored when a diamond is valued.

We have seen how the interest in diamond quality has resulted in size, colour, clarity and then cut being appreciated.

Anyone with the required knowledge and experience can grade the quality of a diamond. However, the remainder of this article will concentrate on the grading systems and the independent laboratories that issue diamond reports and certificates.

Table 2. The three diamond grading systems.

	GIA	IDC	CIBJO
COLOUR			
scale	D	Exceptional white (+)	Exceptional white (+)
	E	Exceptional white	Exceptional white
	F	Rare white (+)	Rare white (+)
	G	Rare white	Rare white
	H	White	White
	I–J	Slightly tinted white	Slightly tinted white
	K–L	Tinted white	Tinted white
	M–N	Tinted colour 1	Tinted colour
	O–P	Tinted colour 2	Tinted colour
	Q–R	Tinted colour 3	Tinted colour
	S–Z	Tinted colour 4	Tinted colour
CLARITY			
scale	Internally flawless	Loupe clean	Loupe clean
	vvs 1	vvs 1	vvs 1
	vvs 2	vvs 2	vvs 2
	vs 1	vs 1	vs 1
	vs 2	vs 2	vs 2
	si 1	si	si 1
	si 2	si	si 2
	I 1	Piqué I	Piqué I
	I 2	Piqué II	Piqué II
	I 3	Piqué III	Piqué III

GB 5360

The Gem Testing Laboratory of Great Britain

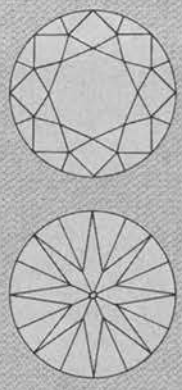
Officially approved by the

INTERNATIONAL CONFEDERATION *of* JEWELLERY, SILVERWARE, DIAMONDS, PEARLS AND STONES

CIBJO

DIAMOND REPORT

Carat weight:	1.17
Colour grade:	Rare White (G).
Clarity grade:	vs1
Shape and cut:	Round brilliant.
Measurements:	approx. 6.79 x 6.89 x 4.08 mm.
Proportions: Height:	59 % Table: 64 %
Finish: Symmetry:	Good-medium.
Polish:	Good.
Girdle:	Thin-thick, bruted.
UV-fluorescence:	None.
Comments:	External characteristics.



This diamond report is based on the Rules of application decided upon by CIBJO up to 1978, in particular on grading with the ten-power aplanatic and achromatic lens and on colour comparison with the CIBJO master diamonds.

The diamond has been tested independently in an absolutely objective way by at least two experts according to the present knowledge in the field of diamond grading.

The report does not make any statement with respect to the monetary value of the diamond.

Only the original report with signatures and embossed stamp is a valid identification document. Misuse of this document will lead to prosecution.

The Gem Testing Laboratory of Great Britain

Date 30th July 1987.

Signed E.C. Emms.

Eric C. Emms.

The Gem Testing Laboratory of Great Britain, 27 Greville Street, London, EC1N 8SU

Figure 1. A London CIBJO Diamond Report.

In 1953 the GIA held its first diamond grading class for jewellers. Its diamond grading certification service arose in New York from a demand from GIA students to have their stock diamonds graded by the GIA. The GIA diamond grading system evolved from this demand. By the mid 1950s their certificate or diamond report had been formalized. Diamonds graded at this time were of exceptional quality (of the top two colours and top clarity). Crowningshield[4] states that only since the 1970s have lower qualities been graded.

In Europe, other efforts were made to standardize diamond grading. In 1969 the Trade Associations of Jewellers in Denmark, Finland, Norway and Sweden published the Scandinavian Diamond Nomenclature and Grading Standards (Scan. D.N.) This was a grading manual which laid down clarity and cut standards as well as defining colour grades. Scan. D.N. was revised in 1980.

In 1971 the Diamond Commission of the International Confederation of Jewellery, Silverware, Diamonds, Pearls and Stones (CIBJO) was established, ten years after CIBJO was founded. The aim of the Commission was to harmonize diamond grading terminology throughout Europe and eventually the world. In 1979 CIBJO produced its Rules for the Diamond Trade in which it laid down standards for diamond grading. The CIBJO grades are given in Table 2.

Also established at this time was another European organization, the International Diamond Council (IDC). The Council was originally a joint committee comprising members of the World Federation of Diamond Bourses and the International Diamond Manufacturers' Association, formed in 1975. After several meetings, IDC produced its 'International Rules for Grading Polished Diamonds' in 1978.

By the end of the 1970s, we see that three organizations existed with their own diamond grading systems and terminologies. The differences between the systems lies in the grading procedures of each system and not in their nomenclatures. These differences will be explored in further articles.

The independent laboratories throughout the world subscribe to one of these systems. Laboratories in London (The Gem Testing Laboratory of Great Britain), Switzerland, Germany, Austria, Spain, Japan and other countries follow the CIBJO Rules. The GIA have two diamond grading establishments in the US (New York and Los Angeles). Laboratories in Antwerp (the Diamond High Council – HRD), Johannesburg (Jewellery Council of South Africa) and Tel Aviv follow the IDC Rules. Each laboratory issues a written report on loose polished diamonds. An example of a CIBJO Diamond Report is shown in Figure 1.

As to the future, it is obviously desirable that there should be not three, but one universal grading system used by all laboratories. One may also see a move to a more automated grading procedure. This aspect will be reviewed in a later paper.

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2. Nichol, J., 1877. *Encyclopaedia Britannica*, 9th edn. London.
3. Sutton, J.R., 1928. *Diamond – a descriptive treatise*. Thomas Murphy & Co., London.
4. Crowningshield, G.R., 1977. *Proceedings of the XVI International Diamond Conference*.

[*Manuscript received 24 July 1987*].

Some DIY gemmological instruments

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Barmulloch College, Glasgow

Abstract

Some simple and inexpensive DIY gemmological instruments are described, namely a polariscope, a dichroscope and a light intensity unit.

Use it up, wear it out;
Make it do, or do without.

New England maxim.

Introduction

I suspect that many gemmologists will at some time have made an aid for the diagnostic investigation of gemstones, and one often finds that the construction and design of the completed instrument is dictated by the ready availability and proximity of so-called 'bits and pieces'. Such diverse items used for the construction of the instruments have been a circular eyeglass from welding goggles, a moulded plano-convex lens from a signal box, a plastic container for 35 mm film, a watchmaker's eyeglass, a disco light, an on/off switch from an electric blanket and a ring with flange of unknown origin.

Polariscope

Components required for the polariscope (Figures 1 and 2):

Box – length 5", height 4½", breadth 3¼". Made from ½" plywood. Glued and panel-pinned except base where wood screws were used to facilitate base removal. Hole diameter on top of box 1¼".

Light source – 25W 240V pigmy lamp.

Bottom polaroid – lower polaroid sandwiched between 1¾" diameter glass and glued centrally with hole in top of box.

Top polaroid – polaroid film is cut to give a snug fit in a light batten holder and fitted in crossed position to

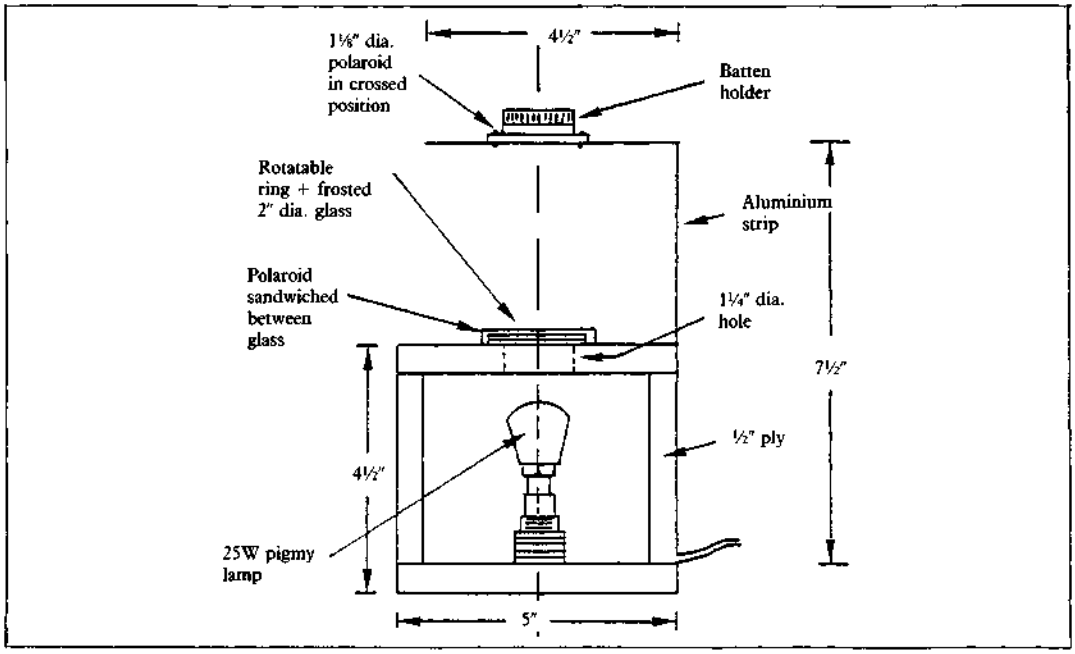

Fig. 1. Diagram of polariscope.

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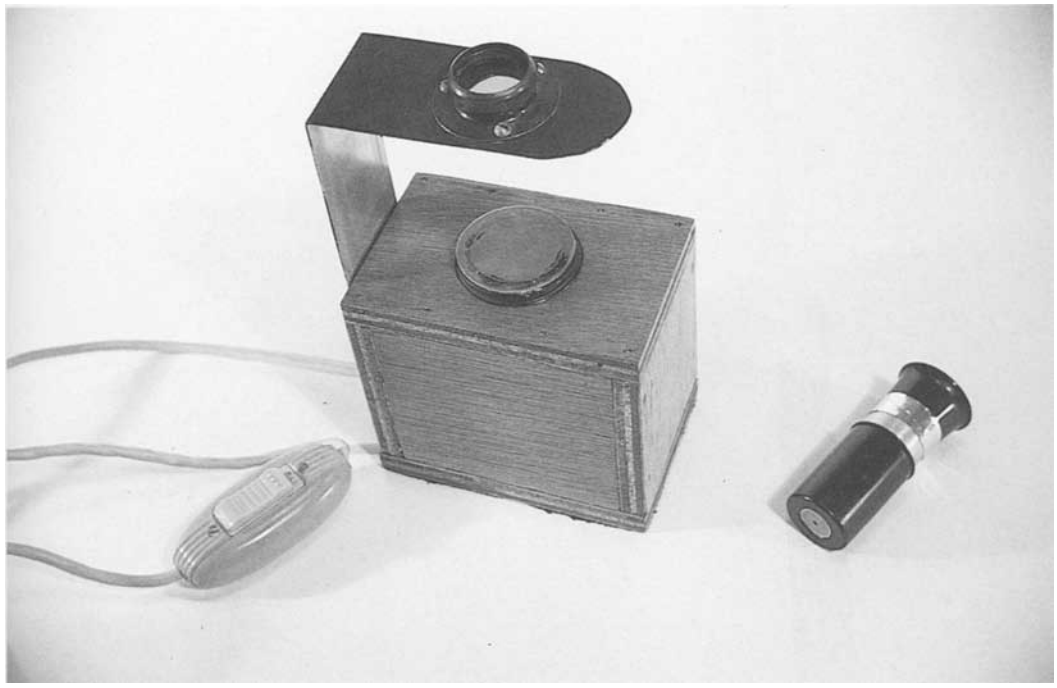

Fig. 2. Polariscope and dichroscope.

bottom polaroid. The top polaroid and holder is held by an aluminium supporting strip which was painted matt black.
Turntable – a 2" diameter piece of glass (from welding goggles) was frosted with silicon carbide grit and glued with Araldite to a metal ring with flange (similar to a jam pot cover with hole).
Switch – on/off switch.

Dichroscope

Components required for the dichroscope (Figures 2 and 3):

Black plastic container – type used for 35 mm film.
Aluminium tube – 2¼" in length and a snug fit inside the plastic container.
Watchmaker's eyeglass – 4" focal length.
Calcite rhomb – held in the aluminium tube by a cork ring.
Plastic tape – used to bind eyeglass to aluminium tube.
Paper disc – with the aid of a low-power microscope a square hole of 2 mm wide was cut with a razor blade. If on viewing the resultant images of opening overlap, a smaller hole should be cut. If images are

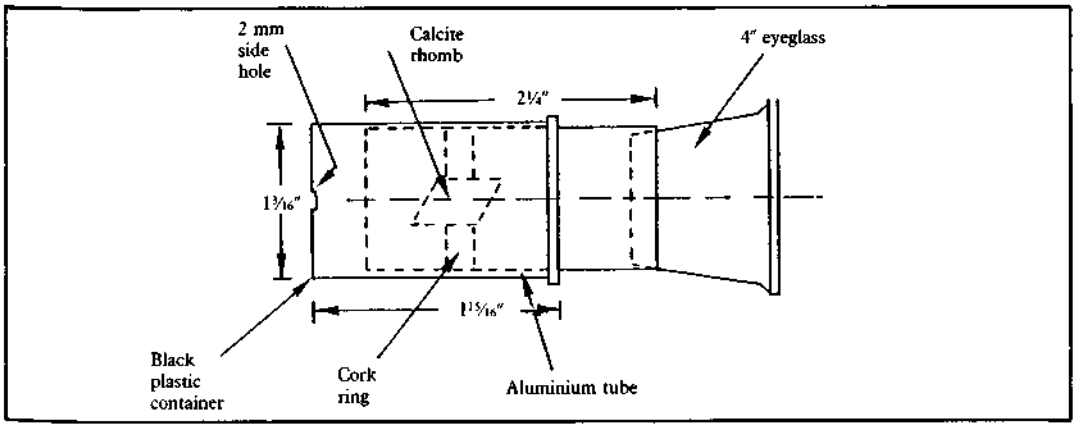

Fig. 3. Diagram of dichroscope.

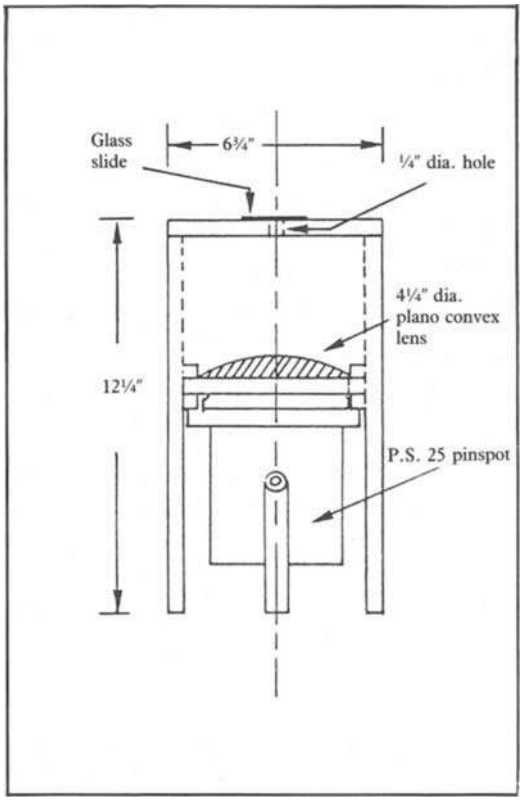

Fig. 4. Diagram of light intensity unit.

Fig. 5. Light intensity unit.

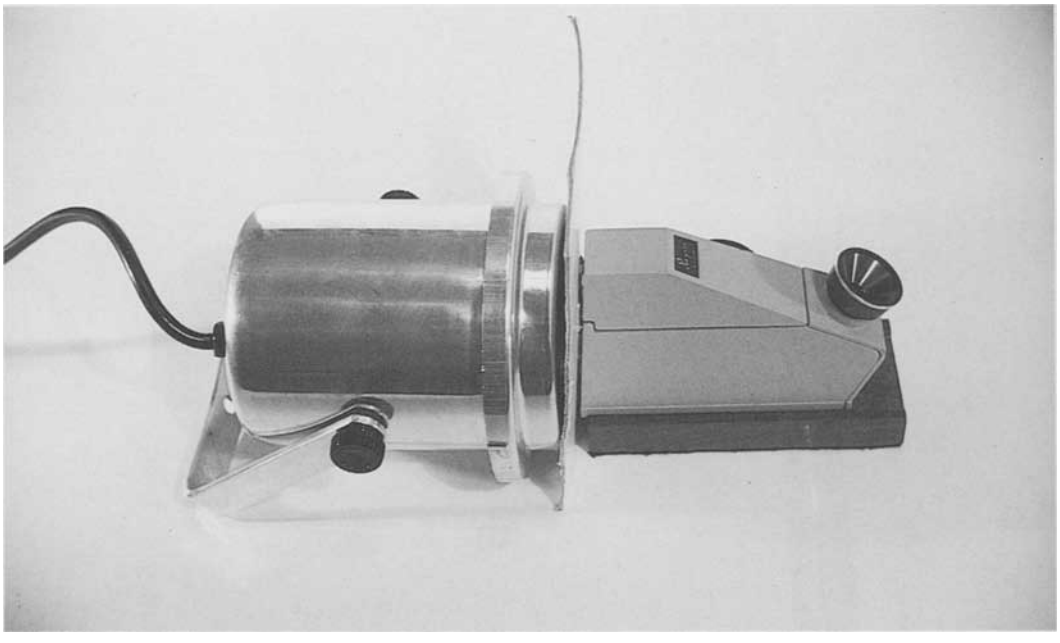

Fig. 6. Light intensity unit used horizontally with the refractometer.

insufficiently close to one another then a larger square should be cut.

All surfaces inside the tube were painted matt black to minimize spurious reflections. Some secondary images of the opening were seen on viewing, perhaps due to the absence of glass prisms at either end of the rhomb. However, the instrument works – and thus justifies its use.

Light intensity unit

Components required for the light intensity unit (Figures 4, 5 and 6):

Box – height 12¼", depth 6¼", breadth 6¾", constructed from ½" plywood. Glued and pinned. Box is open at base and part side for insertion of light source.

Light source – P.S. Pinspot 25W 5.5V from Sis Ltd, 57 St Andrews Road, Northampton.

Lens – 4¼" diameter moulded plano convex lens.

Glass slide – microscope slide taped to top of box.

The pinspot disco lamp may be used vertically as a light source in conjunction with the box for spectroscopic work (Figure 5) or used horizontally with a yellow/green filter for refractometer work (Figure 6).

[*Manuscript received 2 February 1987.*]

A cheap dichroscope

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Abstract

A method of making a dichroscope using polaroid sheet.

Description and use

As mentioned by G.F. Herbert Smith*, a simple and effective dichroscope can easily be constructed using polaroid sheet. Cut two squares of polaroid; approximately 1.50 cm on edge is adequate. These are cemented (an epoxy resin is suitable) to a glass microscope slide in contact down one edge and with the directions of polarization at 90°C (see Figure 1). The edge in contact should be as flush as possible. A second glass slide can be cemented on the top for protection if desired.

To use: large stones can simply be placed over the join and rotated to achieve maximum effect.

Small stones can be examined by placing them under a microscope so that they are out of focus and the field of view is saturated with colour. The dichroscope can then be rested on the top of the microscope and rotated for best effect. Removing the eyepiece may be helpful here.

The blue-grey tint of the polaroid may mask very weak dichroism but presents little trouble with most stones.

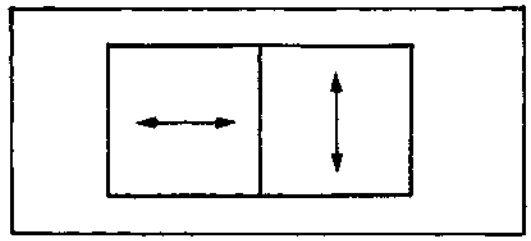

Fig. 1. Plan of dichroscope showing microscope slide with two squares of polaroid cemented to it with directions of polarizations at 90°.

*G.F. Herbert Smith, 1972. *Gemstones*, 14th edn, 108. Chapman & Hall, London.

[*Manuscript received 28 January 1987.*]

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An account of chrysoberyl-bearing pegmatite near Pattara, Sri Lanka

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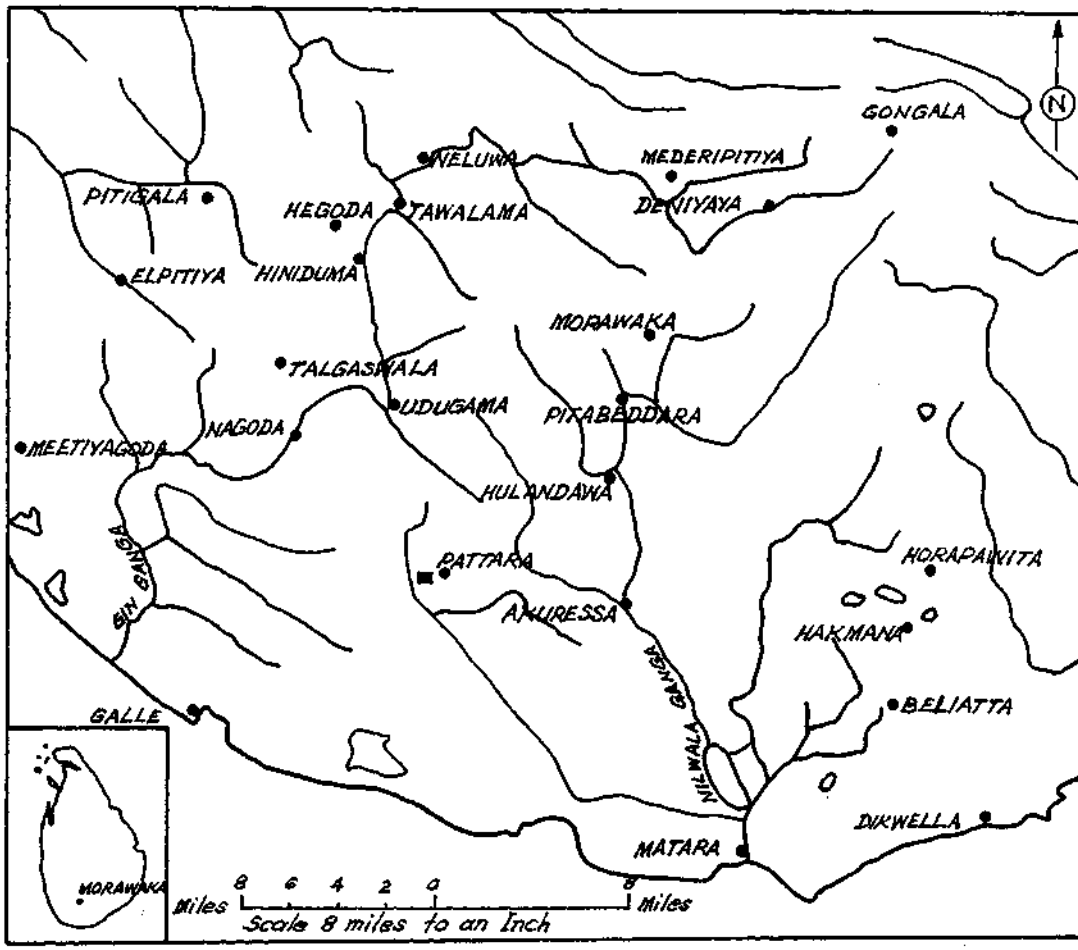
Introduction

The genesis of gemstones in Sri Lanka has been a subject for much discussion. Gems are mostly mined from alluvial deposits underlain by Precambrian metamorphic rocks. Blue corundum crystals have been discovered in crystalline limestone at Kolonné (Gunaratne, 1976); the origin of these was undoubtedly during the metamorphism of crystalline rocks within the island. Chrysoberyl of dark green colour has also been found near Ulvita in a pegmatite body (personal communication from Mr D. Jayawardena, Director, Geological Survey Department), but this material is not suitable for faceting. Recently a pegmatite bearing gem-quality chrysoberyl was located near Pattara in the Morawaka area. Gem mining fields in the Morawaka area are shown in Figure 1. Figure 2 shows mining activities at the pegmatite deposit. The detailed exploration of the deposit is in progress.

Fig. 2. Mining activities at Pattara chrysoberyl-bearing pegmatite deposit.



■ Chrysoberyl pegmatite.

● Gem mining areas.

Fig. 1. Distribution of gem deposits in Morawaka area.

Geology

The occurrences of chrysoberyl, including alexandrite and cat's-eyes, are more frequently found in and around Morawaka and Deniyaya than in the other gem mining areas in Sri Lanka. A notable feature of the gem gravels in this part of the island is the higher concentration of green zircons than other minerals and the absence of corundum.

The geology of the Pattara area is shown in Figure 3. The pegmatite body is horizontal and cylindrical in shape, with a diameter of about 30 cm. It is located at a depth of about 8 m (see Figure 4). In the zone of pegmatite mineralization pyrite, columbite-tantalite, muscovite and phlogopite were identified as associated minerals. Mineralization of this chrysoberyl pegmatite body is within the biotite-gneiss and the pegmatite body occurs parallel to the axis of the syncline.

Chemical and physical properties

Chrysoberyl mined from the pegmatite is transparent, apple green in colour, and varies in size from 1 mm to 8 mm. Some worked specimens displayed chatoyancy, whilst a few possessed sufficient colour change to be termed alexandrite.

(Source: Geological Survey Department)

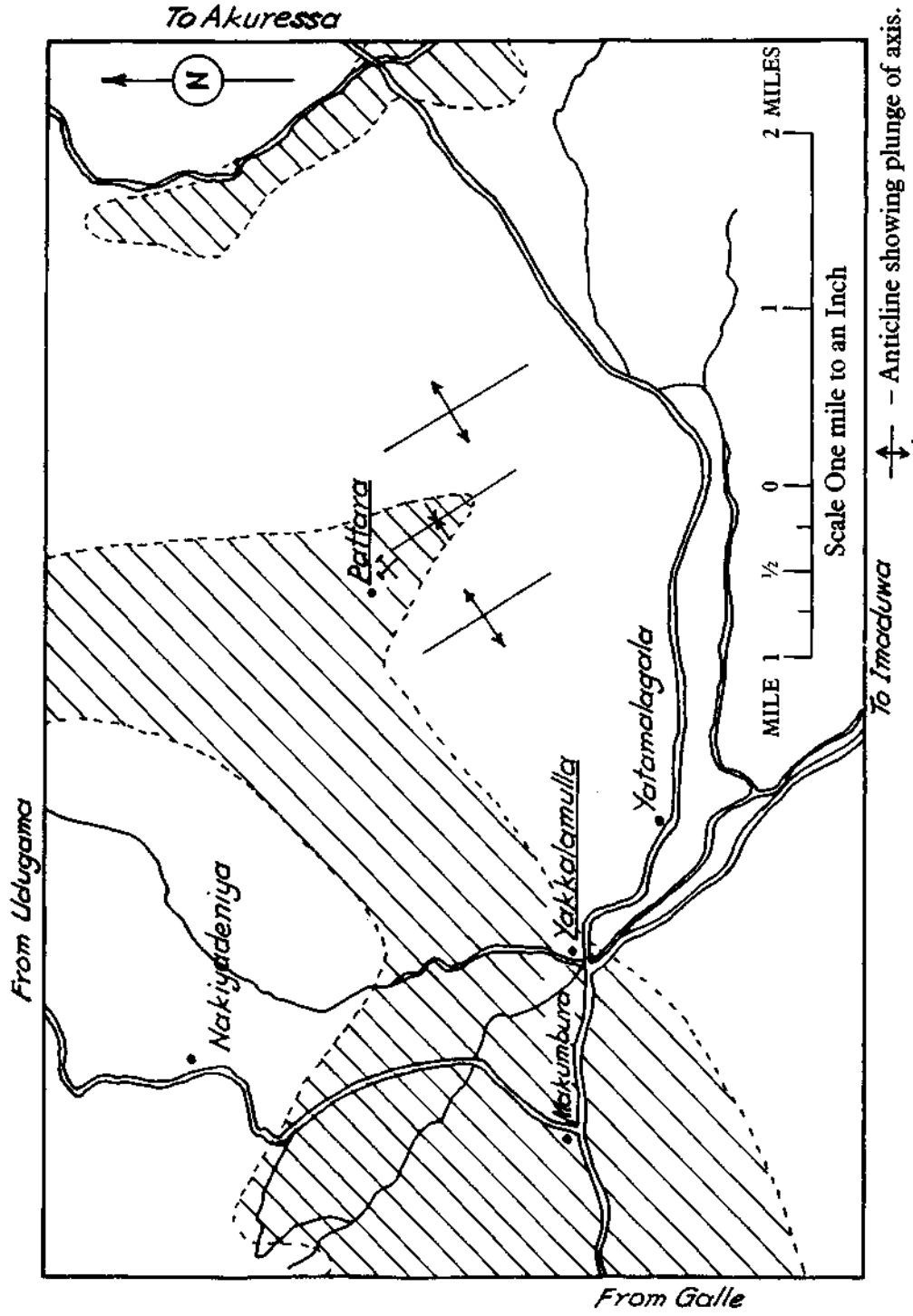


Fig. 3. Geological map around Yakkalamulla area.

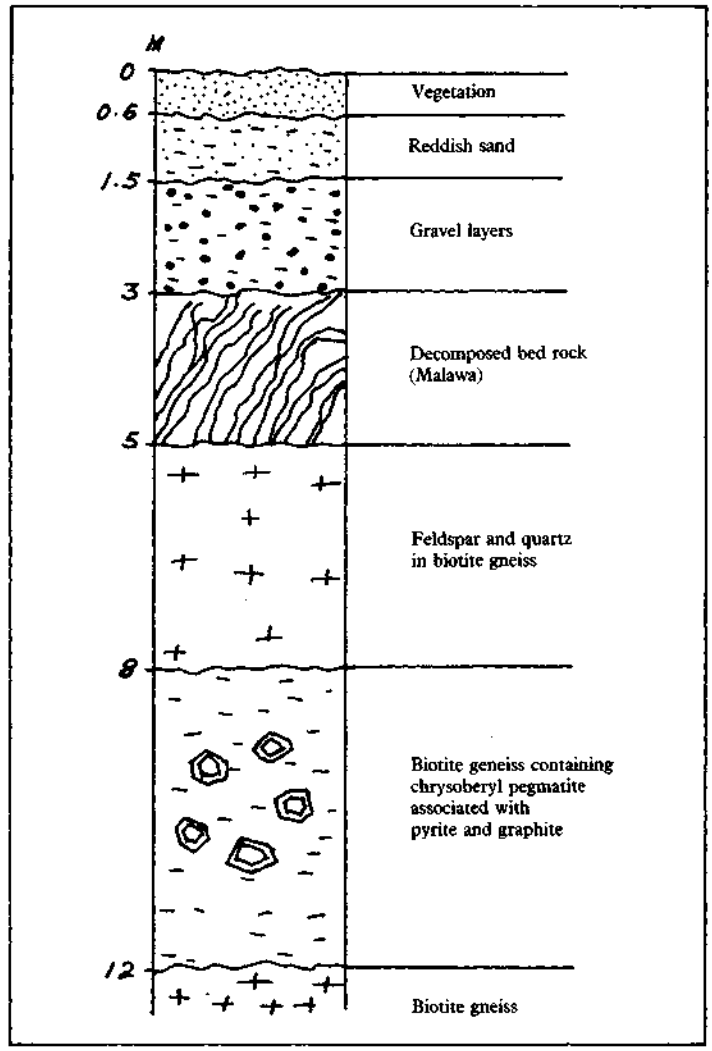


Fig. 4. Cross section of chrysoberyl pegmatite at Pattara.

The identity of the Pattara chrysoberyl was confirmed by X-ray diffraction analysis at the British Museum (Natural History). Atomic absorption analysis by V.K. Din gave the following results in percentages by weight: AL_2O_3 80.9, Fe_2O_3 1.04 (total Fe), BeO 17.3; total 99.24. The chrysoberyl contains as trace elements 600 ppm chromium and 700 ppm gallium.

References

Gunaratne, H.S., 1976. On the occurrence of gem corundum in Kolonné. *Journal of Gemmology*, XV, 1, 29–30.

[*Manuscript received 24 June 1986, revised 19 February 1987.*]

Gemmological Abstracts

ALMQUIST, A., 1987. Minnesota's thomsonite. *Lapidary Journal*, **41**, 1, 57–62, 2 figs in colour.

Thomsonite, whose properties are given, can be found at a number of beach locations along the north shore of Lake Superior in Minnesota. M.O'D.

APPEL, P.W.U., JENSEN, A., 1987. A new gem material from Greenland: iridescent orthoamphibole. *Gems and Gemology*, **23**, 1, 36–42, 7 figs in colour.

Describes an ornamental grey to black mineral with iridescent spangles or patches, reminiscent of labradorescence, oriented parallel to a pinacoid face. Composition is complex, but basically a Mg/Fe hydrated silicate with Na and Al in varying amounts.

Biaxial, RI varying around 1.64–1.66. SG from 3.18 to 3.37. Fluoresces dark violet in UV. Marketed in Greenland as Nuummite, from Nuuk, its place of origin. R.K.M.

BALFOUR, I., 1987. Famous diamonds of the world, XXX. Pigot. *Indiaqua*, **46** (1987/1), 149–53.

Named after George Pigot, controversial Governor of Madras, the oval 48.63 ct diamond was probably acquired as a gift, and as such was partly the reason for Pigot's arrest and imprisonment in 1776. After his death in jail in 1777, the stone was sold for around £10,000, and later became the cause of three law suits following an abortive attempt to sell the stone to Napoleon. The Pasha of Egypt acquired the Pigot in 1822 for £30,000, but since that time the stone's whereabouts are unknown. P.G.R.

BALITSKY, V.S., BALITSKAYA, O.V. 1986. The amethyst-citrine dichromatism in quartz and its origin. *Physics and chemistry of minerals*, **13**, 415–21, 5 figs.

The amethyst-citrine dichromatism was studied as a function of the growth conditions of the specimens. The origin of the coloration is related to the variable way in which the colour-producing impurities are incorporated into the crystal; the impurities are dependent on growth direction and growth rate. The charge compensators also affect the thermal stability of the amethyst colour centres. M.O'D.

BANCROFT, P., 1987. Burnished splendor. *Lapidary Journal*, **41**, 2, 25–32, 5 figs (1 in colour).

Two celebrated mines, Charcas, San Luis Potosi, Mexico, and Morro Velho, Minas Gerais, Brazil, are described, with particular reference to silver and gold mining respectively. M.O'D.

BECK, C.W., LAMBERT, J.B., FRYE, J.S. 1986. Beckerite. *Physics & Chemistry of Minerals*, **13**, 6, 411–4.

Beckerite, a minor component of the amber fossil resins of northern Europe, has previously been classified as being mineralogically distinct from common Baltic amber, or succinite, on the basis of physical properties such as density, and chemical properties such as saponification number. It is shown here that beckerite and succinite are spectrographically identical, according to IR and 13C NMR methods. The deviations of beckerite are attributed to the presence of low levels of contaminants, such as decomposed wood and insect excrement. P.Br.

BERK, M., 1987. Wearable science. *Lapidary Journal*, **40**, 12, 25–31, 1 fig in colour.

General review of the use of man-made stones and their commercial relationship to natural ones. M.O'D.

BORELLI, A., CIPRIANI, C., INNOCENTI, C., TROSTI, R., 1986. Caratterizatione del lapis lazuli. (Characterization of lapis-lazuli.) *La Gemmologia*, **11**, 4, 24–7, 4 figs.

The minerals which together constitute lapis-lazuli are named and described; diopside, phlogopite, potassium feldspar, sodalite, calcite, wollastonite and pyrite occur with lazurite. Lazurite and wollastonite occur together in Chilean material

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while lazurite and diopside are found in lapis from Siberia and Afghanistan. M.O'D.

BROWN, G., 1986. Sphene. *Wahroongai News*, **20**, 11, 7–9, 3 figs.

A concise account of sphene, written from the point of view of the mineralogist. M.O'D.

BROWN, G., 1987. Chatham synthetic yellow sapphires. *Wahroongai News*, **21**, 1, 10.

Yellow sapphires are reported to have been made by the San Franciso firm of Chatham. SG is said to be 4.0 and RI 1.762–1.770 with a DR of 0.008. No other details are given apart from inclusions normal in flux-grown material. M.O'D.

BROWN, G., 1987. Peridot. *Wahroongai News*, **21**, 1, 11–14, 3 figs.

A concise comprehensive account of olivine and the peridot gem variety. M.O'D.

BROWN, G., 1987. Gem scapolite. *Wahroongai News*, **21**, 2, 13–17, 4 figs.

A detailed account of the mineralogy and gemstone potential of the scapolite family. M.O'D.

BROWN, G., 1987. Opal. *Wahroongai News*, **21**, 3, 14–25, 11 figs.

A useful overview of precious and synthetic opal. M.O'D.

BROWN, G., SNOW, J., 1987. Ivorina – a new ivory imitation. *Australian Gemmologist*, **16**, 5, 178–80, 3 figs.

An American imitation ivory is shown to be formulated casein, a milk derivative which is far from new. H 2 to 3, easily peeled, SG 1.34, RI 1.55; fluoresces white to bluish-white; mouldable under heat. R.K.M.

BROWN, G., SNOW, J., KELLY, S.M.B., 1987. A gemmological study club miscellany. *Australian Gemmologist*, **16**, 5, 195–8, 13 figs in colour.

A jet bead with SG 1.182 was lower than values quoted in most textbooks, but within the 1.10 to 1.40 range for brown coal, of which jet is a variety. A string of coated plastic beads imitating Biwa cultured pearls was found to show no central cavity under X-rays and was easily detectable by lens. A 1.08 ct sapphire, probably from Anakie, Queensland, changed from khaki-green in daylight to brownish-mauve in incandescent light – microscope revealed needles or fibres in straight bands. Orissa garnets, from Sarif International of Jaipur, were shown to be of the pyrope-almandine series. A home-made Australian 'synthetic' opal was found to be a bullet-shaped clear plastic dome filled with opal fragments embedded in a thermo-setting plastic; it did not have the normal characteristics of synthetic opal; bubbles were present and the container was easily recognized from the back. R.K.M.

BUKIN, G.V., GODOVIKOV, A.A., KLYAKHIN, V.A., SOBOLEV, V.S., 1986. Growth of emerald single crystals. *Growth of Crystals*, **13**, 251–60, 13 figs.

A short account of the various growth methods for emerald. M.O'D.

CAI, X., CAO, J., FU, Y., TANG, R. 1985. (ESR study of 'Guizhou jadeite'.) *Acta Mineralogica Sinica*, **5**, 3, 221–8. (Chinese with English abstract.)

An investigation of the green gemstone known as 'Guizhou jadeite' by electron spin resonance spectroscopy shows it to be a mixture of white quartz, green dickite and an organic substance. The green colour in the dickite is shown to be due to the presence of Cr^{3+}. R.A.H.

CAVENEY, R.J., 1987. De Beers Diamond Research Report No. 23. *Indiaqua*, **46** (1987/1), 141–5.

This review of the technical achievements at the Johannesburg Diamond Research Laboratory includes the improvement of diamond recovery by grease and X-ray sorting, the optimization of rock crushers at Kimberley where feedback control systems have been introduced, and a method of reducing the operating costs and water consumption at the mines by the identification and rejection of waste rock from the ore as early as possible in the treatment process. P.G.R.

DE MICHELE, V., 1986. La bilancia idrostatica, un'invenzione giovanile di Galileo Galilei. (The hydrostatic balance, a youthful invention of Galileo Galilei.) *La Gemmologia*, **11**, 4, 28–35.

The hydrostatic balance was invented by Galileo Galilei in 1586 and his account of the instrument is reproduced. M.O'D.

FEDERMANN, D. 1986. Der Iolith: der neue 'Billig'-Saphir. (Iolite, the new inexpensive blue sapphire.) *Goldschmiede Zeitung*, **81**, 11, 104, 1 fig in colour.

Suggests iolite as an alternative to blue sapphire for jewellery use. M.O'D.

FOORD, E.E. 1986. Le pegmatiti di Mesa Grande, San Diego County, California. (The Mesa Grande pegmatites, San Diego County, California.) *Rivista mineralogia Italiana*, **9**, 3, 111–26, 19 figs (14 in colour).

An account of the tourmaline and other pegmatitic

gem and other minerals found in San Diego County, California. First published in *Mineralogical Record*, 8, 6. M.O'D.

FRITSCH, E., STOCKTON, C.M., 1987. Infrared spectroscopy in gem identification. *Gems and Gemology*, 23, 1, 18–26, 12 figs, mostly in colour.

Organic molecules give sharpest absorption bands in infrared and provide a safe test for opals impregnated with organic polymers, and for turquoise, for water in hydrothermal synthetics and for identifying types Ia, Ib, IIa and IIb in diamond. Experimenting continues, particularly with coloured diamonds, natural/synthetic amethyst and corundum, impregnation of gems other than opal and with gem identification by infrared means.

A separate account of the Nicolet 6SX Transform Infrared Spectrophotometer is given. R.K.M.

FRYER, C.W. (Ed.), CROWNINGSHIELD, R., HURWIT, K.N., KANE, R.E., 1987. Gem Trade Lab notes. *Gems and Gemology*, 23, 1, 43–9, 19 figs in colour.

A large light green paste with RI 1.529 and SG about 2.50 with straight parallel strain banding on polariscope was deceptive if accepted on sight. A diamond with unusual bright green inclusions (probably diopside or enstatite) and a yellow diamond with a large rectangular prism knot are described. Of two diamonds colour tested, one was a natural fancy brown, the other, yellow (0.23 ct), fluoresced chalky-blue in short-wave UV and was inert in long-wave UV, showed no absorption lines and had an hour-glass pattern of graining, identified as one of the new Japanese synthetic diamonds, the first encountered in a Trade situation.

A faceted diaspore was seen with a colour change from yellow-green to yellow-brown, RI 1.702–1.750 with typical absorption lines in the blue and violet. Opaque black water-worn pebbles from diamond localities in South America identified by X-ray diffraction as goethite-like although SG and H did not match that mineral, possibly partially altered. A hematite tested by its strong magnetic polarity was identified as lodestone, a form of magnetite which can oxidize to hematite. A 'nephrite' necklace with RI 1.55, SG 2.65 and H 7, was shown to be green dyed quartzite.

A black calcareous 'pearl' from a clam had 'golf ball' surface patterning resembling black *Hexagonaria* coral and fluoresced a faint orange in long-wave UV. A colour picture of pearls against two contrasting backgrounds demonstrated that apparent pearl colour is affected by background.

A fossiliferous chalcedony was identified as *Turritella* agate, the result of quartz replacing the original limestone of included shells, this one contained flecks of gold. A range of three cat's-eye and star quartzes exhibited variations of the normal phenomena. A ruby doublet was identified in which both parts were natural material, a bezel setting would make this difficult to detect [polariscope and unmatched extinction?]. A number of heat treated rubies had smooth shallow oval or round spalling depressions in pavilion facet surfaces. A sapphire, probably heat-treated 'geuda', showed a small zone of brown colour. Report mentions that Australian stones heated to lighten colour do not need repolishing and are, so far, undetectable: many are sold mixed in Thai parcels. Most items are illustrated. R.K.M.

GARCIA, R., LEGUEY, S. 1986. Gemmological study of minerals from the spodumene group. *Morphology and Phase Equilibria of Minerals*, Sofia: IMA, 2, 421–31.

Chemical analyses and cell parameters are given for spodumene kunzite and hiddenite from Minas Gerais, Brazil. R.A.H.

GARCIA-GIMENEZ, R., LEGUEY-JIMENEZ, S., 1987. Co-ordonnees chromatiques C.I.E. sur les tourmalines de Tanzanie. (CIE chromatic co-ordinates for Tanzanian tourmalines.) *Revue de Gemmologie*, 90, 17–19, 6 figs (1 in colour).

The various columns shown by Tanzanian tourmalines are evaluated using CIE colour co-ordinates. M.O'D.

GARCÍA GIMÉNEZ, R., MORANTE, M., MEDINA, J.A., LEGUEY, S. 1985. Posibilidades gemológicas de los ópalos y materiales silíceos de la zona de Esquivias Valdemoro en la cuenca de Madrid. (Gemmological possibilities of the opal and siliceous materials of the zone of Esquivias Valdemoro in the Madrid basin.) *Boletín de la Sociedad Española de Mineralogía*, 8, 65–72.

The mineralogical, optical and textural characteristics of siliceous opaline minerals with diverse coloration are analysed from the gemmological viewpoint. The samples studied are located at different levels and in thicknesses varying 0.15–0.20 m and 0.59–0.8 m, associated with sepiolite and palygorskite deposits in the Esquivias and Cerro Batallones zone south of Madrid. Black and white opals are found, with cristobalite as the principal component in both. Organic matter with paramagnetic activity and the laminate texture are the causes of the coloration and iridescence in the black variety. The Al impurities and the globular texture explain the nacreous whiteness and fluorescence in the wite opals. The organic content

and high porosity of these opals permit modification of their colour by thermal treatment of dyeing. P.Br.

GUO, J., CHEN, F., DEN, H., TAN, Y., RONG, Z., DEN, E., 1986. (The colour of placer diamonds in Hunan.) *Acta Mineralogica Sinica*, **6**, 2, 132–8. (Chinese with English abstract.)

In these yellow, brown and green diamonds there are two types of colour centre; one is represented by nitrogen atom centres (single N atoms and N3 centres) and the other by irradiation damage centres (GR 1, 637, 595, H3, H4 and 3H). The geological implications of these centres are discussed. The 595 centre is quite common in these natural diamonds of Hunan and should not be used as the only criterion to distinguish untreated stones; the 3H centre has been detected in irradiated natural diamond. R.A.H.

HÄNNI, H.A., BOSSHART, G., 1987. Schäden an geschliffenen Diamanten. (Damage to cut diamonds.) *Goldschmiede und Uhrmacher Zeitung*, **85**, 5, 83–5, 9 figs.

An English version of this article was published in the *Journal of Gemmology*, **20**, 6, 339–43. M.O'D.

HARDER, H., 1987. Das Brennen von Saphiren. (Heating of sapphire.) Lapis, **12**, 4, 15–19, 6 figs (3 in colour).

The heat treatment of mainly colourless corundum to give a blue colour is described. M.O'D.

HARDER, H., SCHNEIDER, A. 1986. Isomorpher Einbau von Eisen und Titan zur Erklärung der blauen Farbe von Rutil- und Spinell-haltigen seidig weissen Korunden nach einer Wärmebehandlung. (Solid solution of iron and titanium as the explanation of the blue in rutile and spinel containing corundum with silk-rich or milky appearance after heat treatment.) *Neues Jahrbuch für Mineralogie*, 5, 209–18, 5 figs.

Silk-rich and milky corundum has been altered to a sapphire blue after heating to temperatures above 1550°C. The blue in natural sapphire is ascribed to electron transition between Fe^{2+} and Fe^{3+} and in synthetic blue sapphire to the transition between Fe^{2+} and Ti^{4+}. A rutile and spinel matrix containing milky corundum rich in silk had a low Ti and Fe content. Heating the matrix to 1600°C for only 30 minutes sufficed to resolve almost all the Ti and Fe of the rutile and spinel into the corundum, causing a fine sapphire blue by the transition between Fe^{2+} and Ti^{4+} which was now possible. M.O'D.

KATO, M., 1987. (Scintillation.) Journal of the Gemmological Society of Japan, **12**, 1/4, 12–19, 9 figs. (In Japanese.)

The author postulates that scintillation consists of radiation and reflection from facets with the greater part being played by the former. Angular measurements are made and discussed. M.O'D.

KATO, M., 1987. (Star facet brilliancy.) Journal of the Gemmological Society of Japan, **12**, 1/4, 20–3, 6 figs. (In Japanese.)

An attempt was made to increase the brilliancy of a diamond by cutting additional star-type facets on the pavilion. Results found that the brilliancy was somewhat improved though there was some twinkling and no flash. M.O'D.

KOIVULA, J.I., 1987. Gems news. *Gems & Gemology*. **23**, 1, 52–5, 4 figs in colour.

A 'diamond' ring, reported by a South African laboratory, was proved to be a cubic zirconia with a diamond coating and was said to have fooled a thermal diamond probe. A reference to O'Donoghue's 'identifying man-made gems' is inaccurate here.

Tucson Gem and Mineral Show '87 is reported in short paragraphs under different gem headings. Iris agate, colour-zoned fluorite sold as amethyst, a fine carved quartz container and a red-purple scapolite are illustrated. R.K.M.

KOIVULA, J.I., 1987. Inclusion related iron theft in amethyst. *Australian Gemmologist*, **16**, 5, 191–2. 3 figs in colour.

Acicular inclusions of iron minerals, goethite and lepidocrocite, viewed end-on, were found to be surrounded by zones of colourless quartz, indicating iron-depletion by the inclusions which had the greater need for the metal. R.K.M.

KOSNAR, R.A. 1986. La Montagna Italiana del Colorado. (Italian Mountain, Colorado.) *Rivista Mineralogica Italiana*, **9**, 3, 131–5, 7 figs (6 in colour).

Among the gem minerals found at this location are yellow andradite, vesuvianite, hessonite and epidote. M.O'D.

LAHTI, S., SAIKKONNEN, R., 1986. Kunzite from the Haalpaluoma pegmatite quarry, western Finland. *Bulletin of the Geological Society of Finland*, **58**, 2, 47–52, 1 fig. in colour.

A purple transparent kunzite crystal of about 7 cm in length has been found at the Haalpaluoma feldspar quarry in western Finland. The kunzite is embedded in a purple, fine-scaled lepidolite. RI is given as 1.660, 1.665 and 1.679. M.O'D.

LEUNG, C.S., MERIGOUX, H., POIROT, J.P., ZECCHINI, P. 1986. Use of infrared spectrometry in gemmology. *Morphology and Phase Equilibria of Minerals*, Sofia: IMA, 2, 441–8.

IR spectroscopy offers a rapid technique for checking whether a stone is natural or synthetic. Both reflection and transmission methods are useful: the first gives mineral identification (even while mounted in jewellery) and the second allows a distinction to be made between natural and synthetic stones. Examples are given for beryl, chrysoberyl, quartz and topaz. R.A.H.

LICHANG, Q., 1985. Synthetic diamond in China. *Progress in Crystal Growth and Characterization*, **11**, 4, 245–61, 1 fig.

A short account of work done on the synthesis of diamond in China; deals mainly with organization and staffing with notes on a number of possible techniques for diamond growth. M.O'D.

MALISA, E., KINNUNEN, K., KOLJONEN, T., 1986. Notes on fluid inclusions of vanadiferous zoisite (tanzanite) and green grossular in Merelani area, northern Tanzania. *Bulletin of the Geological Society of Finland*, 58, 2, 51–8, 9 figs (3 in colour).

Tanzanite crystals occur mainly in boudinaged pegmatic veins and hydrothermal fracture fillings in a brecciated and hydrothermally altered graphite-bearing diopside gneiss. There appear to be two generations, one (brown) being older than the other (blue) type; the latter has more pronounced pyramidal faces. Negative crystal-shaped primary inclusions may be surrounded by liquid or gas filled microcracks in the tan-coloured tanzanites, but are not reported from the blue ones. It may be that the blue crystals were originally tan coloured and were altered to blue as temperature rose in the surrounding rocks after crystallization.

Graphite flakes and secondary fluid inclusion cavities are found in gem-quality green grossular associated with the tanzanite. M.O'D.

MATTSON, S.M., ROSSMAN, G.R., 1987. $Fe^{2+}-Fe^{3+}$ interactions in tourmaline. *Physics and Chemistry of Minerals*, **14**, 163–71, 11 figs.

Colour and spectroscopic properties of Fe-bearing tourmalines do not vary smoothly with Fe concentration. Details of a possible new cause of the manifestation of the interaction between two states of Fe are given. M.O'D.

MYAKYU, K., 1987. Le jade birman. (Burmese jade.) *Revue de Gemmologie*, **90**, 4–6, 2 figs in colour.

A short account of the jade-bearing localities in Burma, with geographical co-ordinates. M.O'D.

NASSAU, K., 1987. The current decade: synthetic gemstones in the 1980s. *Lapidary Journal*, **40**, 12, 32–42, 6 figs in colour.

The present position of man-made gem materials is reviewed. Details and references to the products are given, together with means of identification. M.O'D.

NASSAU, K., SHIGLEY, J.E. 1987. A study of the General Electric synthetic jadeite. *Gems & Gemology*, **23**, 1, 27–35, 10 figs in colour.

GE have synthesized small discs of jadeite in white, grey, green, lavender and black, by means of high pressure apparatus used in the synthesis of diamond. Process took up to 24 hours at 30 to 50 kilobars of pressure and at temperatures of 1200°C to 1400°C. Samples were rather harder than natural jadeite, but fluoresced similarly. RI about 1.65+, SG by hydrostatic weighing around 3.27. Spectra resembled those for natural jadeite but 437 nm line was missing. The illustrations suggest that the synthetic discs lack somewhat in homogeneity and resemble poor quality fissured natural jadeite. Might be improved upon, but extreme cost of process suggests that this is unlikely. R.K.M.

O'DONOGHUE, M., 1986. Kamienie szlachetne i ozdobne wysp brytyjskich. (Gem minerals of Great Britain.) *Mineralogia Polonica*, 17, 1, 111–14.

Gem quality and ornamental minerals from the British Isles are described and discussed. M.O'D.

O'DONOGHUE, M., 1987. Gems & Gemmology. *Watchmaker, Jeweller and Silversmith*, May 1987, 37–9, 3 figs.

Subjects reviewed include the sale of the Duchess of Windsor's jewels, inclusions in amber and corundum, recent books and information on opal and on instruments. Notices of papers in the *Journal of Gemmology*, 1987, 20, 5, are included. (Author's abstract) M.O'D.

O'DONOGHUE, M., 1987. Poland as a gemmological centre. *Indian Gemmologist*, **1**, 2, 31–3.

A visit to Poland in 1981 included the Skawina plant where synthetic corundum is manufactured. Other Polish minerals include chrysoprase. (Author's abstract) M.O'D.

O'LEARY, B., 1987. Some more on crystal opal. *Australian Gemmologist*, **16**, 5, 175–7.

An anecdotal history of the vexed term 'crystal' which has become attached to certain fine specimens of the amorphous gem opal. R.K.M.

ORLOVA, M.P., CURANOVA, V.N., SOSEDKO, T.A., CHEREPANOV, V.A., SHADENKOV, E.M. 1986. Mineralogy and genesis of chrome-diopside from the Inagli Massif (Aldan). *Morphology and Phase Equilibrium of Minerals*, Sofia: IMA, **2**, 449–60, 1 map.

Gem varieties of chrome diopside from the pegmatites of the Inagli alkaline ultrabasic massif, Siberia, have Cr_2O_3 0.07–1.58% with total Fe as Fe_2O_3 1.3%. The crystals are often zoned, with Mg and Cr decreasing towards their margins. With increasing Cr content, there is a tendency for the *c* parameter to increase while *b* decreases slightly. In some of the transparent emerald-green varieties appreciable Na_2O marks the entry of the acmite molecule. R.A.H.

PETROSYAN, A.G., 1986. General method of formulation and crystal growth of ornamental garnets. *Crystal Research and Technology*, **21**, 11, 1375–81, 5 figs.

The shift of absorption lines from Eu^{2+}, Yb^{2+} and Zr^{3+} ions resulting from crystal field variations in c-sites of the garnet lattice is considered with regard to the possible growth of ornamental garnets with a smooth colour range from violet to red. M.O'D.

POUGH, F.H., 1987. Trophy tourmalines. *Lapidary Journal*, **40**, 11, 20–32, 4 figs in colour.

A general account of the tourmaline group of gemstones with beautiful illustrations. A table of end-member compositions is given. M.O'D.

POUGH, F.H., 1987. Amethyst. *Lapidary Journal*, **40**, 11, 16–18.

A short account of the amethyst gemstones, including comments on synthetic material and the commercial role of the stone. M.O'D.

POUGH, F.H., 1987. Gem treatment: lapis lazuli. *Lapidary Journal*, **41**, 1, 18.

A brief note on the ways in which lapis-lazuli can be imitated and treated. M.O'D.

POUGH, F.H., 1987. Moonstone and feldspars. *Lapidary Journal*, **41**, 2, 15–18.

Some of the ways in which the feldspar gemstones can be treated should have been discussed as the article forms part of a continuing series on such matters but the author correctly says that feldspars are not usually altered in any way. M.O'D.

PROUT, B.A.W., 1986. Cut steel jewellery. *Wahroongai News*, **20**, 12, 10.

A short account of the manufacture of a diamond substitute from cut steel. M.O'D.

RAYMOND, J., 1987. Down in the dumps. *Lapidary Journal*, **40**, 11, 65–70, 2 figs (1 in colour).

The writer describes working on the dumps at Mount Mica, Maine, where tourmaline and quartz crystals are occasionally found. M.O'D.

READ, P.G., 1987. Thermal conductivity versus reflectivity. *Indian Gemmolgoist*, **1**, 2, 21–4, 4 figs.

The Gemtek thermal conductivity diamond tester is described. M.O'D.

READ, P.G. 1987. The gemmologist's mecca. *Canadian Jeweller*, January 1987, 12.

Contains a description of the gem displays in the headquarters of A. Ruppenthal KG at Idar-Oberstein, Germany, with a brief history of how the surrounding district developed into one of the gem centres of Europe. (Author's abstract). P.G.R.

READ, P.G., 1987. The chameleon gems. *Canadian Jeweller*, February 1987, 14.

Colour change in gems such as alexandrite and the rare colour-change varieties of spinel, corundum, tourmaline ('chameleonite' and diamond are discussed. Colour change simulants of alexandrite are listed together with identifying features. (Author's abstract) P.G.F.

READ, P.G., 1987. High-tech enhancements. *Canadian Jeweller*, March 1987, 14.

Several gem enhancement processes, which are spin-offs from high-tech industries, are listed including the recently publicized process of diamond coating (currently being developed for use in machine tools and for the production of radiation-proof microchips required in the USA Star Wars programme), A warning is given that identification methods may have to be revised if the process is used to coat diamond simulants such as cubic zirconium oxide. (Author's abstract) P.G.R.

READ, P.G., 1987. Balancing acts. *Canadian Jeweller*, April 1987, 14.

Traces the history of the development of the jeweller's electronic balance, and compares the weighing specifications and costs of typical precision and portable versions. (Author's abstract) P.G.R.

ROSEN, E., 1987. Appraising multi-coloured tourmaline. *Lapidary Journal*, **40**, 11, 50–6, 2 figs (1 in colour).

Criteria for assessing the commercial potential of multi-coloured tourmalines are given. M.O'D.

SCHMETZER, K., 1987. Production techniques of commercially available Knischka synthetic rubies – an additional note. *Australian Gemmologist*, **16**, 5, 192–4, 6 figs in colour.

Chemical investigation of flux and crucible residues reveals that platinum platelets and needles, from the crucible, and oxides of sodium, tungsten and tantalum, from the flux, may be found in commercial productions of Knischka synthetic rubies. These do not occur in natural rubies and provide a basis for routine identification of the synthetics. The commercial runs are spontaneously nucleated and seed crystals are not used. R.K.M.

SCHMETZER, K., 1987. Microscopic observation of twinning microstructure in natural amethyst. *Neues Jahrbuch für Mineralogie Monatshefte*, **1**, 8–15, 8 figs.

Micro-twinning in natural amethyst was investigated by optical methods. In one extraordinary sample from Brazil direct observation of twin boundaries was possible. In agreement with the model of McLaren and Pitkethly (1982)* polysynthetic Brazil twin boundaries in each growth sector confined to one of the major rhombohedral faces, e.g. r $(10\bar{1}1)$, are found to be orientated parallel to the two remaining major rhombohedral faces, e.g. r′ $(\bar{1}101)$ and r″ $(0\bar{1}11)$. In subsequent composition planes an alternating orientation of the predominant twin boundaries was observed. The external forms and orientations of liquid and two-phase inclusions in healed fractures of natural amethyst reflect the internal structure of the polysynthetically twinned crystals. The inclusions which are located within growth sectors confined to one major rhombohedral face form striations consisting of inclusions without particular elongated cavities. These stripes alternate with striations consisting of inclusions without particular external forms in the sequence abab. In one healing fracture located within growth sectors confined to two rhombohedral faces, striations with two different orientations of parallel elongated inclusions alternate with striations consisting of inclusions without dominant external forms in the sequence abababacac. The striations are located within the zones of Brewster fringes which are identical with the zones of continuous composition surfaces with lamellar microstructures parallel $\{10\bar{1}1\}$. These surfaces separate lamellae of right-handed and left-handed quartz. (Author's abstract.) K.S.

*McLaren, A.C., Pitkethly, D.R. 1982. The twinning microstructure and growth of amethyst quartz. *Physics and Chemistry of Minerals*, 8, 128–35.

SEGNIT, E.R., 1987. Decorative serpentinite from the Marble Bar area. *Australian Gemmologist*, **16**, 5, 182–3, 198, 4 figs in colour.

Marketed unfortunately as 'Pilbara jade', this soft material, found in the north-west of Western Australia, adds to the list of decorative stones. Dark green with grey-white areas and chrysotile veins. R.K.M.

SIBER, H.J., 1987. Peru heute. (Peru today.) *Lapis*, 12, 6, 17–28, 22 figs (11 in colour).

In recent years minerals from Peru have appeared frequently on the market. Fine quartz and rhodochrosite specimens are among those of gem quality. M.O'D.

SIMONTON, T.C., ROY, R., KOMARNENI, S., BREVEL, E. 1986. Microstructure and mechanical properties of synthetic opal: a chemically bonded ceramic. *Journal of Materials Research*, **1**, 5, 667–74.

Using optical, scanning and electron microscopy plus X-ray, chemical and DTA, it is concluded that synthetic opal is composed of non-crystalline silica and crystalline (tetragonal) zirconia balls. K.A.R.

SLIWA, A.S., NGULWE, C.A. 1984. Geological setting of Zambian emerald deposits. *Precambrian Research*, 25, 1–3, 213–28.

The Kafubu emerald deposits occur within rocks of the Muva supergroup which form the youngest part of the pre-Katangan basement immediately SW of the well-known Copperbelt of Zambia. Within the Muva supergroup are persistent bands of talc-chlorite-amphibole (tremolite/actinolite) -magnetite schist, which are intruded by pegmatites. These pegmatites are believed to be related to neighbouring granite rocks which originated or were rejuvenated during early stages of Pan-African orogeny. Pegmatites occur as feldspar-quartz-muscovite bodies or as minor quartz-tourmaline veins. Contact aureoles of the pegmatitic veins with the ultramafic schists are usually altered to phlogopite-biotite-tourmaline aggregates and the minor veins are often concordant to the foliation of the country rocks. The emeralds are found in the contact zones, and sometimes within the quartz-tourmaline veins. The emerald fields are considered comparable in quantity and quality of material to the well-known Colombian fields, but their lithological setting differs considerably. Striking similarities were found between the Zambian occurrences and those of South Africa and Zimbabwe. R.A.H.

STRIPP, D.M., 1987. More on Morefield. *Lapidary Journal*, **41**, 1, 21–6, 3 figs (2 in colour).

The Morefield mine at Amelia, Virginia, produces amazonite and other ornamental minerals, including agate, apatite, beryl and zircon. M.O'D.

SUNAGAWA, I. 1986. Morphology of diamonds. *Morphology and Phase Equilibria of Minerals*, Sofia: IMA, 2, 195–207.

Observations on morphology and surface microtopography of diamond crystals of three different origins are summarized and the observations are critically analysed in the light of present understanding of the growth mechanisms and morphology of crystals. The three types of diamonds are: (1) natural diamonds, including both single-crystals and polycrystalline aggregates. Both ultramafic suites (in kimberlite) and eclogite suites are discussed. All natural diamonds are grown from the solution phase of silicate compositions under diamond stable conditions; (2) synthetic diamonds grown by static high P under diamond stable conditions. They are grown from metal-carbon solution phases; (3) synthetic diamonds grown by pyrolysis or chemical vapour deposition processes of CH_4 or C_2H_2 under $P < 1$ atm. and high T conditions. They are grown under diamond unstable conditions from the vapour phase. Analysis of growth rates vs chemical potential provides information concerning the mutual relations among polycrystalline aggregates, dendritic, hopper and polyhedral crystals. Analysis of morphological characteristics of single crystalline diamonds and their surface microtopographs are based on the extent to which their morphologies deviate from the theoretical morphology. J.M.H.

TAY, T.S., 1987. Structural aspects of fingerprint inclusions in corundum. *Australian Gemmologist*, **16**, 5, 188–90, 5 figs in colour.

Microscopic examination showed that 'fingerprints', partially healed cracks in natural corundum, are often oriented in alignment with parting planes. Synthetic flux-grown corundum also shows 'fingerprints', but not in parallel alignment. R.K.M.

THEMELIS, T., 1987. Quenched cracked. *Lapidary Journal*, **40**, 11, 19, 2 figs in colour.

Describes the practice of heating and quenching certain transparent stones, with particular reference to ruby. Low-grade Chatham and Kashan stones are said to be regularly heated and quenched to give natural-looking inclusions. M.O'D.

THEMELIS, T., 1987. Idaho geuda. *Lapidary Journal*, **40**, 11, 57–62, 3 figs in colour.

Whitish corundum from central-east Idaho can be treated to give a blue colour as with some Sri Lankan material. The Idaho crystals come from a site called Floodwood Blue in Clearwater County. Details of mining and constants of the stones are given. M.O'D.

THEMELIS, T., 1987. Seed in synthetic ruby. *Lapidary Journal*, **40**, 12, 19, 2 figs in colour.

Two photographs of Chatham rubies are described with respect to their inclusions. M.O'D.

THEMELIS, T., 1987. Inclusion of the month: Lechleitner synthetic emerald. *Lapidary Journal*, **41**, 1, 19, 2 figs in colour.

Characteristic inclusions of the Lechleitner emerald are illustrated. M.O'D.

THEMELIS, T., 1987. Trapiche emerald. *Lapidary Journal*, **41**, 2, 19, 3 figs in colour.

The formation and structure of trapiche emerald are briefly discussed. M.O'D.

THOMAS, S.L., 1987. 'Modern' jewelry: Retro to Abstract. *Gems & Gemology*, **23**, 1, 3.17, 15 figs in colour.

A nicely illustrated account of the broader themes in jewellery design from the strangely named 'Retro' style in about 1940, onwards to the less easily identified styles of recent years. Many famous names are mentioned. R.K.M.

TORIWAKI, J., YOKOI, S., 1987. Rendering gems by computer graphics. *Journal of the Gemmological Society of Japan*, **12**, 1/4, 3–11, 17 figs (1 in colour). (In Japanese.)

The fashioning of gemstones can be helped by plotting the proportions and angles on a computer using a graphics package. M.O'D.

TROSSARELLI, C., 1986. Alessandrite sintetica prodotta in URSS. (Russian synthetic alexandrite.) *La Gemmologia*, **11**, 4, 6–22, 32 figs in colour.

Synthetic alexandrite made in the USSR is examined and its internal features illustrated in a bilingual paper. From an examination of rough and cut material it appears that they are produced by different methods, the cut by flux growth and the rough by crystal pulling. M.O'D.

VIKAMSEY, I., 1987. Kohinoor – the famous diamond. *Indian Gemmologist*, **1**, 2, 25–33, 7 figs.

The history of the Koh-i-Noor diamond is given. M.O'D.

VON KNORRING, O., CONDLIFFE, E., TONG, Y.L., 1986. Some mineralogical and geochemical aspects of chromium-bearing skarn minerals

from Northern Karelia, Finland. *Bulletin of the Geological Society of Finland*, 58, 1, 277–92, 8 figs.

Characteristic chrome-bearing minerals from the skarn association at Outukumpu, northern Karelia, Finland, are re-examined. They include uvarovite, chrome tourmaline and chrome diopside. Uvarovite from this location is low in Fe, unlike examples described from other places. The best developed uvarovite crystals are found in a quartz-banded, chromian diopside-sulphide skarn. The crystals show dodecahedral and trapezohedral forms in a glassy quartz matrix. M.O'D.

WATANABE, K, 1987. Inclusions in flux-grown crystals of corundum. *Crystal Research and Technology*, 22, 3, 345–55, 13 figs.

Flux-grown corundum has been found to contain flux inclusions, negative crystals and cavities. The process of inclusion formation is described. M.O'D.

YELLIN, J, 1987. Amber glow. *Lapidary Journal*, 40, 11, 46–7, 5 figs in colour.

A short photographic essay on amber. M.O'D.

ZEITNER, J.C., 1987. Enter China. *Lapidary Journal*, 40, 11, 42–5, 3 figs in colour.

Gem material is coming on to the international market from China, including coral, jade, quartz and turquoise. M.O'D.

ZEITNER, J.C., 1987. Tourmalines of Pala. *Lapidary Journal*, 40, 11, 34–41, 3 figs (2 in colour).

Tourmaline from the pegmatites in the Pala area of San Diego County, southern California, are described with notes on the history of mining in the area. M.O'D.

ZEITNER, J.C., 1987. No 'sin' in synthetics. *Lapidary Journal*, 40, 12, 20–4, 3 figs in colour.

A short account of the better-known man-made gemstones. M.O'D.

ZEITNER, J.C., 1987. Riotous thundereggs of Madras, Oregon. *Lapidary Journal*, 41, 1, 27–32, 2 figs in colour.

Fine plume agate and thundereggs are found at mines in the Madras area of Jefferson County, Oregon. The locality and access are described. M.O'D.

ZHANG, D.B., HE, X.M., CHEN, J.P., WANG, J.C., TANG, Y.F., HU, B.L., 1986. Research on crystal growth and defects in cubic zirconia. *Journal of Crystal Growth*, 79, 336–40, 6 figs.

Cubic zirconia grown by the skull melting method is investigated. Specimens had distribution coefficients of stabilizers Y_2O_3 and CaO greater and less than 1 respectively. Nearly colourless large single crystals were obtained using 10–12 mol% Y_2O_3 as stabilizer. SEM studies show that Si, Ca, Mg, Y, etc., occur mainly at the ends and in the centre of the crystal. M.O'D.

ZHANG, L.H., 1985. GGG and related compounds. *Progress in Crystal Growth and Characterization*, 11, 1, 283–9, 2 figs.

Gives notes on the growth and structure of GGG with a list of possible dopants. M.O'D.

ARGYLE DIAMONDS JOINT VENTRE, 1987. *Rio Tinto Zinc Corporation Review*, 2 (June 1987), 13.

Full production from Argyle (world's largest diamond mine) began in March 1986. J.R.H.C.

ARGYLE DIAMOND MINE in AUSTRALIA, 1987. *Rio Tinto Zinc Corporation PLC Annual Report and Accounts for 1986*, 10.

The Argyle Mine, much the largest diamond mine in the world, completed its first full year of production with 29 200 000 ct output (mainly industrial, but also gems, including the rare pink). J.R.H.C.

AUSTRALIAN COLOURED DIAMONDS, 1987. *Wahroongai News*, 10, 1, 17.

A system of listing reference colours for Australian diamonds is proposed with forty different descriptions. Many Australian diamonds show faint colours. M.O'D.

BERYLL. (Beryl.), 1987. *Goldschmiede und Uhrmacher Zeitung*, 85, 4, 98–115, 28 figs (18 in colour).

The beryl gems are reviewed by a number of authors. M.O'D.

BLUE JOHN. 1986. *Wahroongai News*, 20, 12, 17–19.

An account of the Blue John variety of fluorite largely taken from Ollerenshaw and Harrison, *The history of Blue John stone*, 2nd edition. M.O'D.

FLUORESCENCE 1986. *Wahroongai News*, 20, 11, 12–13.

A table of the fluorescent effects seen in gem minerals. It is taken from the *Information Sheet* of the New South Wales Department of Mineral Resources. M.O'D.

Book Reviews

AREM, J.E., 1987. *Colour encyclopedia of gemstones.* 2nd edn. Van Nostrand Reinhold, New York. pp. vii, 248. Illus in colour. £39.75.

The updated edition of this book is as attractive as the first and with about 30 new species of gemstone to add, as well as some new varieties of already established ones, the text is again of considerable importance to the gemmologist. Moreover it is so arranged as to be quite easily assimilated by the discriminating reader who may not know much about the minerals from which the gemstones are fashioned.

As before, the gem species are arranged alphabetically though attention has been paid to the grouping of minerals in families where appropriate. Such groupings go far to explain the small differences in constants which so baffle the student, who often finds it hard to grasp the interplay of different elements in a mineral belonging to a group. This and other mineralogical matters are lucidly discussed in the preceding chapters, which also include useful explanations of colour measurement and specification. Details of the alteration of colour are specifically omitted, however. I would recommend the early portions of the book as an excellent study of the geology and mineralogy of gemstones.

In the descriptive portion of the book, entries take the same form as before with all important features provided, as well as notes on the commercial significance of the stones. Tables give the constants of some major gemstones which occur in a wide variety of environments, and this makes it easier for the reader to find the details he wants at a glance. Particularly welcome to this reviewer is the continuation of this section into the field of man-made products – the first time that they have received just this kind of well-deserved recognition. They are also illustrated in colour.

It is, of course, the colour pictures which were so great a feature of the previous edition and they are even more beautiful this time round – and there are more of them. All that expert positioning and lighting can do has been done and the specimens thus look their best. It is idle to criticize this as some have, as gemstones, unlike minerals in general, are meant to look beautiful and these superb pictures are completely successful. I recommend readers to look first at the coloured pictures of the man-made stones (bismuth germanium oxide and cadmium sulphide, for example) to see what a man-made product can look like.

There are several lists and tables as well as a bibliography and index. For such a book the price is amazingly reasonable and it will lift the spirit as the stones themselves do. M.O'D.

BECKER, V., 1987. *The jewellery of Rene Lalique.* Worshipful Company of Goldsmiths, London. pp.192. Illus. in colour. Price on application.

This most attractive book is the catalogue of an exhibition held from 28 May to 24 July 1987. Each piece carries a short caption and there is a short glossary and a bibliography. The permanent location for each piece is given, where appropriate. Quality of the illustrations is very high and the author and publishers are to be congratulated. M.O'D.

CLARK, G., 1986. *Symbols of excellence.* The University Press, Cambridge. pp.x, 126. 12 colour plates, 43 figures. £12.95.

Professor Grahame Clark has written a delightful and scholarly book (the printing of Pubic instead of Punic on p.10 is unfortunate!). After a first Introductory chapter, the following five chapters cover respectively Organic materials, Jade, Precious metals, Precious stones and The symbolic roles of precious substances, and Professor Clark's novel treatment of familiar subjects is most refreshing.

Rather unusually, the dust cover is worthy of careful preservation, as it bears an admirable and impressive illustration in colour of the fourteenth century silver-gilt gem-set and enamelled reliquary bust of Charlemagne (in the Aachen Cathedral Treasury), which is not reproduced inside the book. J.R.H.C.

DESAUTELS, P., 1987. *The jade kingdom.* Van Nostrand Reinhold, New York. pp. viii,118.

 ISSN: 0022-1252

Illus. in black-and-white and in colour. £31.45.

It is not easy to discuss the jade minerals without writing too academically or in so general and journalistic a manner that the book will have little to attract the reader. This book manages to avoid both extremes and though it does go a little overboard with diagrams in the text the general level and appearance should command a respectable readership.

Sensibly the book begins with a definition of jade and introduces nephrite and jadeite with some of their simulants, the latter having a short chapter to themselves. Jade testing comes next and is followed by sources of jade. I was particularly pleased to see the complex topic of jade occurrence succinctly dealt with here and a table at the end of the chapter gives a surprisingly large number of countries in which worked jade objects from prehistoric times had been found.

We then begin to survey the significance of jade to the Chinese and to look at Chinese symbolism in artefacts generally. One important point is missed here; an object was particuarly venerated by the Chinese if it could be inscribed. Many jade artefacts are so inscribed, and I should have liked to see some examples of this, as the choice of character can often give a clue to the dating of a piece. Such a section could have displaced the somewhat tedious series of whole-page drawings of figures and objects which are not particularly well executed, nor is their significance really adequately explained.

Jade in the New World deals with Mesoamerican jade, and subsequent chapters cover New Zealand and Asian material. The book ends with a discussion of jade fashioning (again with over-large diagrams) and with a bibliography and index.

Apart from the loose and breathless style so often found in books of this level, I found this well worth reading and can recommend it. The colour pictures are first class. M.O'D.

Fraquet, H., 1987. *Amber*. Butterworths, London. pp.xii. 176. Illus. in black-and-white and in colour. £25.00.

Amber differs from other gem materials in that it usually forms the whole of an artefact. For the researcher this means that a good deal of time and attention has to be devoted to the development of the artefacts, which in the case of amber go back to Palaeolithic times. Chapter 2 of the book (the first chapter is the profile, a feature common to the *Butterworths Gem Book series*) deals with the use of amber in antiquity up to a time felicitously called 'Unsettled Europe', the first millennium AD. This period has a chapter to itself, including its own bibliography; the other chapters also have short bibliographies. The Renaissance period and artefacts dating from the thirteenth to the eighteenth centuries are described in chapter 4. Before the marked increase in the use of amber for ornament in the nineteenth and twentieth centuries and the simultaneous development of substitutes, a short chapter on the medicinal use of amber is inserted. Gemmologists will find the book interesting up to this point and both interesting and important thereafter. Considerable research has been carried out into commercial history, both of amber and its imitations, and provides welcome notes of authenticity in a field notoriously subject to conjecture. Later chapters deal with amber from Asia, Sicily, Romania, the Dominican Republic and Mexico. Then follow chapters on resins, amber identification, more advanced identification techniques, the botanical parentage of resins and inclusions. Three appendices are devoted to the geological ages, amber in the USA and infrared spectra of amber samples respectively.

This book should be purchased by all practising gemmologists who will read it with ease and great enjoyment. It is no small feat to produce a book with so much authenticated material and the English is lucid. The colour pictures, occupying a section to themselves, have reproduced well. M.O'D.

Jensen, D.E., 1978. *Minerals of New York State*. Ward Press, Rochester. pp.220. Illus. in black-and-white and in colour. £7.95.

This is a professionally-written state mineralogy in which the minerals are arranged alphabetically after introductory material giving details of mining history and mineralogy in the state. There is an excellent bibliography. Minerals of gemmological interest include lapis-lazuli and labradorite. M.O'D.

Joris, A., 1986. *A destiny in diamonds*. Boolarong Publications, Brisbane. pp.vi, 113. Illus. in black- and-white. £18.00.

This autobiography of a well-known figure in the Australian industrial diamond world contains a good deal of anecdote and useful information written in an easy style. Those with an interest in the Australian diamond scene and in its history should buy the book. M.O'D.

Kesse, G.O., 1985. *The mineral and rock resources of Ghana*. Balkema, Rotterdam. pp.xiv, 610. Illus. in black-and-white. Fl 150.00.

Pages 362-400 describe Ghana's diamond deposits with details of diamond discoveries and mining. The mode of occurrence of the diamond crystals is discussed and production statistics included. M.O'D.

Loneck, A. 1986. *Opals, rivers of illusions*. Gemcraft, East Malvern, Victoria. pp.64. Illus. in black-

and-white and in colour. Price on application.

This attractive book can be recommended; though written in a breathless style with a multiplicity of paragraphs and though too many varietal and other names are thrown up and left unexplained, the text none the less is well worth reading and very informative. Details of recent research on the cause of play of colour were new to me and could well be expanded elsewhere. Notes on production in countries other than Australia are also welcome.

M.O'D.

LOUDERBACK, G.D., 1985. *Benitoite, California state gemstone.* The Gemmary, Redondo Beach, California. Irregular pagination. Illus. in black-and-white. £5.00.

This is a most interesting and useful reprint of two papers on benitoite first published in 1907 and 1909. They appeared in the *Bulletin* of the Department of Geology of the University of California and deal with the discovery, composition, properties and crystallography of the mineral. M.O'D.

MEARS, K., 1986. *The crown jewels, Tower of London.* Department of the Environment, London. pp.44. Illus. in colour. £1.95.

A new popular guide to the crown jewels in always welcome. This is attractively presented, with just enough history and the emphasis on the excellent colour pictures of the regalia. M.O'D.

MULLER, H., 1987. *Jet.* Butterworths, London. pp.ix, 149. Illus. in black-and-white and in colour. £22.50.

This is the only monograph on jet to have been published and is particularly welcome on that account alone. One of the series *Butterworths Gem Books* it gives not only the description of the material and its properties that we have come to expect from this series but also goes into considerable detail on the working and distribution of jet. This in-depth survey is possible because the handling of jet has traditionally been confined to one place in the world, Whitby in North Yorkshire.

The book opens with a profile of jet, following the convention of the series. Details of geology and mining follow, with a chapter on jet in history and another on the Whitby jet industry. Notes on the care of jet are included in this chapter.

The general reader will probably find the next chapter the most immediately appealing as it describes the many types of ornament that have been fashioned from jet. Dating of jet pieces is notoriously difficult but the author does her best to give dates for the major styles,and this alone is most useful.

Jet is then followed through the rest of the world before details of the simulants are given. Some of these, I have to admit, have their own attraction, and I have often sought a piece of worked vulcanite! Appendices give short notes on where jet may be found; on jet fashioning; a list of Whitby jet ornament manufacturers 1849, and of jet merchants and ornament manufacturers 1867 from the same town; similar lists are given for 1890 and 1905. There is an index and each chapter includes its own bibliography. The central section of colour pictures is successful, especially when we bear in mind that jet is black.

All who are concerned with the study of ornamental materials should buy this very reasonably-priced book. M.O'D.

O'DONOGHUE, M., 1986. *The literature of gemstones.* British Library, Science Reference and Information Service, ISBN 0-7123-0738-9. pp75 plus 2 pages of crystal diagrams. £12.00.

This is an extremely useful little book (booklet would, I think, be a better description), by the Curator of Earth Sciences at the British Library. Starting with a general preface and introduction, it attempts, quite successfully, to list the more important works on gemmology under the following categories: encyclopaedic works, general comprehensive surveys, gem testing, gem testing instruments, quick reference publications, textbooks, synthetic gemstones, fashioning, works on individual species, jewellery, gemstones of particular localities, bibliographies, abstracts, journals, gemstone prices, guides to collections, and regalia.

The works are listed with their publication details, including if and where held by the British Library, and, in many cases, with helpful descriptions by the author. The book ends with a useful index, followed, inexplicably, with two pages of beryl and corundum crystal diagrams.

The literature of gemmology is extremely large, so the selection is necessarily a personal one by the author. Many people will, I suspect, be surprised by the omission of some of their favourite works. The reviewer was personally most surprised by the exclusion of *Diamonds and precious stones* by Emanuel, 1865 and 1867, as this book contains an extremely extensive bibliography of historic books on gemstones.

I would, however, certainly recommend *The literature of gemstones* (together with the author's companion work *The literature of mineralogy*) to anyone interested in gemmology, in spite of the unfortunately high price of a soft covered booklet of little more than photostat quality. N.B.I.

O'Donoghue, M., 1985. *Putevoditel po mineralam.* (Beginner's guide to minerals.) Nedra, Leningrad. pp.206. Illus. in black-and-white and in colour. C.50.

Translation of a work first published by Newnes-Butterworth in 1982. (Author's review) M.O'D.

Panczner, W.D., 1987. *Minerals of Mexico.* Van Nostrand Reinhold, New York. pp.xiii, 459. Illus. in black-and- white and in colour. £38.65.

Mexico, a leading producer of a large number of metal ores, is also important to the gemstone trade for its fine opals, topaz and rarer minerals such as smithsonite and chrome sphene. A useful guide was published by G.F. Kunz in 1902 but this lengthy paper, in *Transactions of the American Institute of Mining Engineers,* is now one of gemmology's rare pieces.

The present book lists the minerals in alphabetical order after chapters giving details of the geography, geology, mineralogy and mining history. At the end there is a gazetteer, particularly useful for those with access to geological maps of the country. Reproduction of the descriptive section is, successfully, from typewriting which helps to keep the price manageable for these days. The bibliography is large and welcome. M.O'D.

Roedder, E., 1984. *Fluid inclusions.* Mineralogical Society of America, Washington. pp.vi, 644. Illus. in black-and-white. Price on application.

This volume forms no. 12 of the series *Reviews in mineralogy,* formerly *Short course notes.* The latter series title indicates the aim of the publishers to present the latest information on a variety of mineralogical topics, and the author in this case introduces studies of all types of inclusions, gas, liquid or melt. Unlike other books in the series, this is a single-author work, and the author has carried out a very comprehensive survey of the subject.

After an introduction to fluid inclusions, the author describes how they arise and how they may be altered by trapping in their host. Then come chapters on inclusion identification and on the interpretation of their presence. Chapters on various environments follow, and there are subject and locality indexes and a very comprehensive set of references. Gemmologists will find much bearing on their subject; students of diamond formation, in particular, will turn to chapter 17, on upper mantle environments, in which there are several sections on diamond. M.O'D.

Sobolev, N.V., 1977. *Deep-seated inclusions in kimberlites and the problem of the composition of the Upper Mantle.* American Geophysical Union, Washington. pp.viii, 279. Illus. in black-and-white. Price on application.

Though published some time ago, this is so important a text that readers should be aware of it, since it gives an insight into the formation of and inclusions in diamond. The Russian edition was published in 1974. There is an extensive bibliography. M.O'D.

Vargas, G., and Vargas, M., 1985. *Descriptions of gem materials.* 3rd edn. Vargas, Thermal, California. pp.x, 180. Price on application.

Descriptions of gem materials has now become a standard work. Two alphabetical sequences cover natural and synthetic, materials and there are useful appendices giving stones arranged by their hardness, their specific gravities and their refractive indices, for the book is aimed primarily at the lapidary. Each entry gives chemical composition and other customary details, together with mode of occurrence and short details of place of origin and outstanding market features. Among the newcomers to this edition are clinohumite and sugilite. Virtually all minerals of possible ornamental significance are included and the section on synthetic stones includes some intriguing items. For the sake of academic completeness the crystal system of most synthetic tellurium oxide is tetragonal (the natural material is paratellurite). There is a short bibliography. As a general reference book the work succeeds admirably and is well worth obtaining. M.O'D.

Woodward, C., and Harding, R., 1987. *Gemstones.* British Museum (Natural History), London. pp.60. Illus. in colour. £4.95.

This is a most welcome and very well produced guide to the newly united gemstone collection of the British Museum (Natural History) and the Institute of Geological Sciences (now British Geological Survey). The standard of the coloured illustrations equals and even exceeds that of similar productions from overseas, and it is with considerable pleasure that we can now say that the world's best gemstone collections have a fitting guide. After introducing simple crystallography, light, cutting and the general rarity of gemstones, the book goes on to describe the major gem species, rarities and synthetics. Inclusions, gemstone deposits, gem testing and famous gems conclude this excellent book which could easily serve as an introductory gemmology text. M.O'D.

Proceedings of the Gemmological Association of Great Britain and Association Notices

OBITUARY

Mr Geoffrey Nicholls Betts, FGA (D.1959), died unexpectedly on 3 March 1987, aged 66.

His first occupation was in the legal profession and throughout his career he retained the elegant handwriting and attention to detail which he learned there.

He later entered the family jewellery and pawnbroking business in Birmingham, gaining considerable experience dealing in second-hand goods.

Following a period of wartime service in the Army, he studied gemmology at the Birmingham Jewellery School, obtaining his FGA in 1959.

In 1960 he joined Fattorini & Sons in Bradford as manager, diamond buyer and valuer, later becoming a director. There he developed his undoubted skills in the appraisal of gemstones. His encouragement and guidance to younger people who were making their way in the profession will be remembered with affection by those who came under his influence. He was well known and respected throughout the trade.

In his private life Geoff was an enthusiastic golfer, a keen bridge player and a former member of the Heaton Amateur Operatic Society. He will be sadly missed by his many friends.

He leaves a widow, a son, two daughters and six grand-children. D.M.L.

Mr Maurice L. Butterfield, FGA (D.1949), Stockport, died on 31 August 1986.

Mr Neville Deane, FGA (D.1954, Tully Medallist), Bewdley, died on 1 March 1987 aged 88. A full obituary will appear in the next issue of the *Journal*.

Mr Arthur Kermeth, FGA (D.1929), London, died on 2 October 1986 aged 76.

Mr Eric Renfrey, DFC, JP, FGA (D.1967 with Distinction), Ormskirk, died in March 1987.

Mr John Rogers, FGA (D.1980), Portrush, died on 2 September 1986.

GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to Mr Julian R. Dimayaakyak, Naga City, Philippines, for a sample of tektite glass.

NEWS OF FELLOWS

On 20 May 1987 at the Annual Conference of the National Association of Goldsmiths held at the Grand Hotel Excelsior, Valetta, Malta, Mr Kenneth Scarratt, FGA, gave an illustrated lecture entitled 'Gemstone enhancement'.

On 27 May 1987 at Northwick House, Owles Road, Bournemouth, Mr Peter G. Read, C.Eng., MIEE, MIERE, FGA, gave an illustrated talk to the Wessex Branch of the National Association of Goldsmiths entitled 'The design of gem test instruments'. After the talk he gave a demonstration of prototypes of the new Rayner sodium lamp unit and a thermal version of the Rayner DiamondScan.

From 23 to 25 June 1987 Mr Michael O'Donoghue, MA, FGS, FGA, lectured during a series of courses given by the Precious Stone Training Services.

On 8 July 1987 at The British Library Mr O'Donoghue chaired a Seminar on New Materials Information Sources.

MEMBERS' MEETINGS

London

On 31 March 1987 at the Flett Theatre, Geological Museum, Exhibition Road, South Kensington, London SW7, Mr Konrad Wild gave a lecture entitled 'Gem cutting in Idar-Oberstein'.

On 16 June 1987 at the Flett Theatre, following the Annual General Meeting (see p.505) a Gemmological Forum was held, chaired by Mr David J. Callaghan, FGA, Chairman of the Council. The panel consisted of the following: Mr Christopher R. Cavey, FGA, Dr Jamie B. Nelson, Ph.D., FRMS, F.Inst.P., FGS, FGA, Mr Michael J. O'Donoghue, MA, FGS, FGA, Mr Peter G. Read, C.Eng., MIEE, MIERE, FGA, Miss Judy Rudoe and Mr Kenneth Scarratt, FGA. The subjects covered were as follows: how different types of animal ivory can be distinguished; why people see gemstone colours differently; how gemstone crystal growth began and why some growth methods are chosen in preference to others; developments in the use of the computer for gemmology; what we can learn from contemporary portraits about eighteenth and nineteenth century jewellery that looks rather cumber-

some or impractical to wear; and the position today with regard to synthetic gem-quality diamond.

On 10 September 1987 at the Flett Theatre Professor I. Sunagawa of the Institute of Mineralogy, Petrology and Economic Geology, Tohoku University, Japan, gave a lecture entitled 'Gemmology and the science of crystal growth'. In addition to slides, Professor Sunagawa illustrated his presentation with two films entitled 'Wonders of crystals' and 'In-situ observation of crystal growth in aqueous solution and high temperature silicate solution'.

Midlands Branch

On 24 April 1987 at Dr Johnson House, Bull Street, Birmingham, the Annual General Meeting was held, at which Mr Peter J. West, FGA, and Mr David M. Larcher, FGA, were re-elected Chairman and Secretary respectively. This was followed by an illustrated talk by Mr Gwilym Jones, FGA, with an emphasis on diagnostic inclusions in gemstones.

North West Branch

On 20 May 1987 at Church House, Hanover Street, Liverpool 1, Mr Alan Williams, FGA, introduced the controversial topic of the value of gemmological knowledge to the salesman in multiple jewellery shops. This evoked a lively discussion.

On 17 June 1987 at Church House Mrs Helen Muller, FGA, gave an illustrated talk on jet, its origin, history and artefacts, and the identification of jet from its substitutes.

On 1 July 1987 at Church House Mrs Valerie Duke presented a beautifully photographed illustration of the development of jewellery fashions to complement costumes from 1066 to the 1900s. The latter section of the evening was a display of Brazilian gemstones.

On 16 September 1987 at Church House Dr J.W. Harris, B.Sc., M.Sc., Ph.D., of the Department of Applied Geology, University of Strathclyde, gave an illustrated lecture entitled 'The characteristics and ages of mineral inclusions in diamonds'.

South Yorkshire and District Branch

On 20 May 1987 at the Sheffield City Polytechnic, Pond Street, Sheffield, the Annual General Meeting was held at which Mr George Massie, FGA, was elected Chairman and Mrs Susan E. Payne, BA, FGA, re-elected Secretary. This was followed by an illustrated talk by Mrs Helen Muller on jet and its simulants.

On 24 June 1987 at Sheffield City Polytechnic, Mr G. Millington gave an illustrated talk on gemstone inclusions.

COUNCIL MEETING

At the meeting of the Council held on 27 April 1987 at the Royal Automobile Club, 89 Pall Mall, London SW1, the business transacted included the election to membership of the following:

Fellowship

Amarasiri, Sujatha, Colombo, Sri Lanka. 1986.
Chandrasena, Vishwakanthie, Colombo, Sri Lanka. 1986.
Dirlam, Dona M., Santa Monica, Calif., USA. 1982.
Lam, Keturah M.H., Kowloon, Hong Kong. 1986.
Rehbinder, Anne C.M., Vallentuna, Sweden. 1986.

Ordinary Membership

Albizi, Eva D., Bangkok, Thailand.
Allison, Rudie J., Fort Madison, Iowa, USA.
Arington, Stanley C., Auburn, Ala., USA.
Ashton, David, London.
Bauco, Robert, London.
Belson, Timothy E., Harrogate.
Bjelke-Weis, Anine N., Andorra.
Boyce, Jeremy P., Zurich, Switzerland.
Bradley, Peter F., Fort Myers, Fla., USA.
Brown, Charlie N., Cambridge.
Clelland-Brown, John, Edinburgh.
Dash, Suzanna, London.
Davis, Simon, Watford.
Eldredge, Anan, Anchorage, Alas., USA.
Franklin, Neil, Newcastle-upon-Tyne.
Fricker, Alan J., London.
Glynn, Peter J., Oman.
Hajdukiewicz, J., Northolt.
Harris, Jeffrey W., Glasgow.
Hughes, Brian R., Bangkok, Thailand.
Huppach, Friedrich H., Colne.
Isackson, Earl T., Seattle, Wash., USA.
Jeanneret, Charles, London.
Jefferies, Barrie W., Lewes.
Jefferies, Zhora, Lewes.
John, Christine, Sunningdale.
Keen, Paul, London.
Knight, James H., Godalming.
Lekamge, Neil S., Kandy, Sri Lanka.
Lloyd, Florence M., Harpenden.
Mantilla, Armando, Beaverton, Oreg, USA.
Mirakaj, L., Brussels, Belgium.
Moore, R. Joy, Rochester, USA.
Muston, Nicholas J., Hove.
Pattni, Unnat N., London.
Phyall, A.P., London.
Richter, Dudley C., Nashville, Tenn., USA.
Schatzle-Parisod, Arlette, Kaiseraugst, Switzerland.
Sneeringer, Margaret R., Co. Dublin, Ireland.
Stromberg, Anders N., Enskede, Sweden.
Stromberg, Ingrid M., Enskede, Sweden.
Vildiridis, Athanassios, London.
Wasilewski, Igor, Brussels, Belgium.
Williamson, David D., St Clair Shores, Mich., USA.

ANNUAL GENERAL MEETING 1987

The 56th Annual General Meeting of the Association was held on 16 June 1987 at the Flett Theatre, Geological Museum, Exhibition Road, South Kensington, London SW7.

The Chairman, Mr David Callaghan, FGA, presided over the meeting. He expanded on some of the items in the Annual Report and emphasized that 1986 had been a year of change for the Association. He reminded members that it was a year since the sudden death of Mr Harry Wheeler, former Secretary of the Association.

He announced that the Preliminary section of the new home study course was launched in the autumn, and that the Diploma section would be ready by September 1987.

1986 had been a tough year financially for the Association. This resulted in a review of all systems at headquarters and a much tighter control over spending and planning. As a result of the new course, a further grant had been received from the Distributive Industry Training Trust of nearly £20,000.

In November Mr Jonathan P. Brown, FGA, was appointed Secretary following the resignation of Mr Con Lenan, and Mr John Russell took over as Financial Controller to the Association.

Mr Callaghan then thanked members of the Council and the staff at headquarters for their help and support during the year. Mr Nigel Israel, Treasurer of the Association, presented the audited accounts for the year ended 31 December 1986, illustrated by coloured charts. The adoption of the Report and Accounts was duly proposed, seconded by Mr Christopher Cavey, and carried.

Sir Frank Claringbull, Mr David J. Callaghan, Mr Noel W. Deeks and Mr Nigel B. Israel were re-elected President, Chairman, Vice-Chairman and Honorary Treasurer respectively. Mrs E. Stern, Dr J. Nelson and Messrs A. French, D. Larcher, A. Morgan and W. Nowak were re- elected, and Drs A. Allnutt, R. Harding, J. Harris, G. Harrison Jones, Messrs E. Bruton, A.E. Farn, E.A. Jobbins, D. Kent, P. Read and K. Scarratt elected, to the Council.

Messrs Ernst and Whinney were reappointed Auditors, and the proceedings then terminated.

LETTERS TO THE EDITOR

From A.E. Farn, FGA

Dear Sir,

The first article I read when I receive my copy of *The Journal of Gemmology* is 'Notes from the Laboratory'. These give me great pleasure and enjoyment. One article in particular in the April 1987 issue which interested me was on saussurite*. In Ken Scarratt's excellent article he mentions the work done by yourself and our mutual and late friend Dr E.H. Rutland on saussurite in 1974†. This triggered my memory of what may well have been one of the bird carvings mentioned. When shipments of these kinds of materials come over a demand occurs for testing both by buyers and vendors who specialize in jade-like materials. Some end up at the Geological Museum, others arrive at the Laboratory.

In September 1973 the Laboratory received a carving in what appeared to be jadeite-jade of a bird similar to many we had tested over the years. The carving very closely resembled jadeite-jade in texture and variegated colour. We did a density test in a large plastic tub and obtained a result of 2.85; a distant-vision refractive index reading was taken at 1.57; a line in the blue at 455.0 nm indicated some zoisite in the chemical composition – we had no powder camera at that time.

Dr Rutland, who was acting Head of Department in your absence, confirmed our findings. I was pleased at the conclusion since I no longer had my old colleagues Anderson, Payne and Webster to call upon. My new and enthusiastic staff were also new to saussurite as indeed was I.

I wrote a short article giving details of the test, which appeared in the *Retail Jeweller* for 5 September 1973. Whilst not on the lines of 'Notes from the Laboratory', it did, however, record the interesting material saussurite which was so new to us all.

During a courtesy call to the Paris Laboratory very shortly after, I was shown a carving of a bird in what appeared to be jadeite-jade. Armed with my recent knowledge and borrowing a hand spectroscope, I suggested it to be saussurite, and they too had arrived at the same result using their powder camera.

I shall continue to read 'Notes from the Laboratory' by Ken Scarratt with enjoyment, respect and a touch of gemmological nostalgia.

Yours etc.,
A.E. Farn
23 June 1987
Seaford, E. Sussex.

From J.R.H. Chisholm, MA, FGA

Dear Sir,

M.D.S. Lewis, B.Sc., ARCS, FGA, CG

The late Malcolm D.S. Lewis was a rather more prolific writer than his Obituary (*J.Gemm.*, 1987, 20, 5, 314–15) seemed to indicate, and he had more

*Journal of Gemmology, 20, 6, 356-8. – Ed.

†Journal of Gemmology, XIV, 1, 1-7. – Ed.

articles to his credit than the eight in the *Journal* listed there.

I do not pretend that the following list is complete, but it comprises his articles in *The Gemmologist* so far as I can trace them on my shelves: and, of course, besides his articles in *The Gemmologist* and the *Journal* he contributed to other periodicals as well.

Articles in *The Gemmologist*:

Chemical tests for paste and quartz, 1946, **XV**, 175, 37–8.

Feigl's test for amorphous silica as applied to opal and turquoise, 1947, **XVI**. 192, 217–18.

Bauer's test for paste and real stones and other aspects of adhesion, 1947, **XVI**, 196, 324–6.

The structure of gemstones, Part I. Introduction, 1948, **XVII**, 199, 27–31.

The structure of gemstones, Part II. Hardness, cleavage, 1948, **XVII**, 200, 53–7.

The structure of gemstones, Part III. Isomorphous replacement, symmetry and temperature, 1948, **XVII**, 201, 86–9.

The structure of gemstones, Part IV. Optical properties. 1948, **XVII**, 202, 103–6.

The structure of gemstones, Part V. Polishing, Beilby layer, abrasion, 1948, **XVII**, 203, 141–51.

The structure of gemstones, Part VI. Adhesion, drop tests, 1948, **XVII**, 204, 163–7.

The structure of gemstones, Part VII. Conductivity, the glassy state, feel, 1948, **XVII**, 205, 190–2/210.

The historical background of English jewellery (Anglo-Saxon and Mediaeval), 1948, **XVII**, 206, 220–30.

The historical background of English jewellery (2. Renaissance, Elizabethan), 1948, **XVII**, 207, 254–63.

The historical background of English jewellery (3. 17th and 18th centuries), 1948, **XVII**, 209, 321–7.

I cannot trace that he ever used the letters GG after his name, and I do not think he sought or obtained the Graduate Gemologist Diploma of the Gemological Institute of America as stated in the Obituary, but after successfully completing the necessary examinations he was awarded the title of Certified Gemologist by the American Gem Society in 1947.

It is recorded in the *Journal* (I, 3, 36) that in that same year (1947) he attended the GA's first Annual Dinner at the Waldorf Hotel on 15 May and (*J.Gemm.*, I, 3, 34) he made a donation to the Association of £2.2.0, which was then, of course, of much greater value than £2.10 would be now (indeed it was substantially more than the Association's then annual subscription).

Yours etc.,
J.R.H. Chisholm
7 April 1987
Holly Lodge, Lytham St Annes, FY8 3HP.

CORRIGENDUM

On p.380 above, second column, line 4, for 'Brazil' read 'Mexico'. This typing error is regretted, both by the abstractor and the editor.

GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

The Arms and Crest of the Association, conferred by a grant of Arms made by the Kings of Arms under royal authority. The cross is a variation of that in the Arms of the National Association of Goldsmiths of Great Britain and Ireland. In the middle is a gold jewelled book representing the study of gemmology and the examination work of the Association. Above it is a top plan of a rose-cut diamond inside a ring, suggesting the scrutiny of gems by magnification under a lens. The lozenges represent uncut octahedra and the gem-set ring indicates the use of gems in ornamentation. The lynx of the crest at the top was credited, in ancient times, with being able to see through opaque substances. He represents the lapidary and the student scrutinizing every aspect of gemmology. In the paws is one of the oldest heraldic emblems, an escarbuncle, to represent a very brilliant jewel, usually a ruby. The radiating arms suggest light diffused by the escarbuncle and their tips are shown as jewels representing the colours of the spectrum.

Historical Note

The Gemmological Association of Great Britain was originally founded in 1908 as the Education Committee of the National Association of Goldsmiths and reconstituted in 1931 as the Gemmological Association. Its name was extended to Gemmological Association of Great Britain in 1938, and finally in 1944 it was incorporated in that name under the Companies Acts as a company limited by guarantee (registered in England, no. 433063).

Affiliated Associations are the Gemmological Association of Australia, the Canadian Gemmological Association, the Gem and Mineral Society of Zimbabwe, the Gemmological Association of Hong Kong, the Gemmological Association of South Africa and the Singapore Gemologist Society.

The *Journal of Gemmology* was first published by the Association in 1947. It is a quarterly, published in January, April, July, and October each year, and is issued free to Fellows and Members of the Association. Opinions expressed by authors are not necessarily endorsed by the Association.

Notes for Contributors

The Editors are glad to consider original articles shedding new light on subjects of gemmological interest for publication in the *Journal*. Articles are not normally accepted which have already been published elsewhere in English, and an article is accepted only on the understanding that (1) full information as to any previous publication (whether in English or another language) has been given, (2) it is not under consideration for publication elsewhere and (3) it will not be published elsewhere without the consent of the Editors.

Papers should be submitted in duplicate on A4 paper. They should be typed with double line spacing with ample margins of at least 25mm all round. The title should be as brief as is consistent with clear indication of the content of the paper. It should be followed by the names (with initials) of the authors and by their addresses. A short abstract of 50–100 words should be provided. Papers may be of any length, but long papers of more than 10 000 words (unless capable of division into parts or of exceptional importance) are unlikely to be acceptable, whereas a short paper of 400–500 words may achieve early publication.

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Compiled by Mary Burland

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