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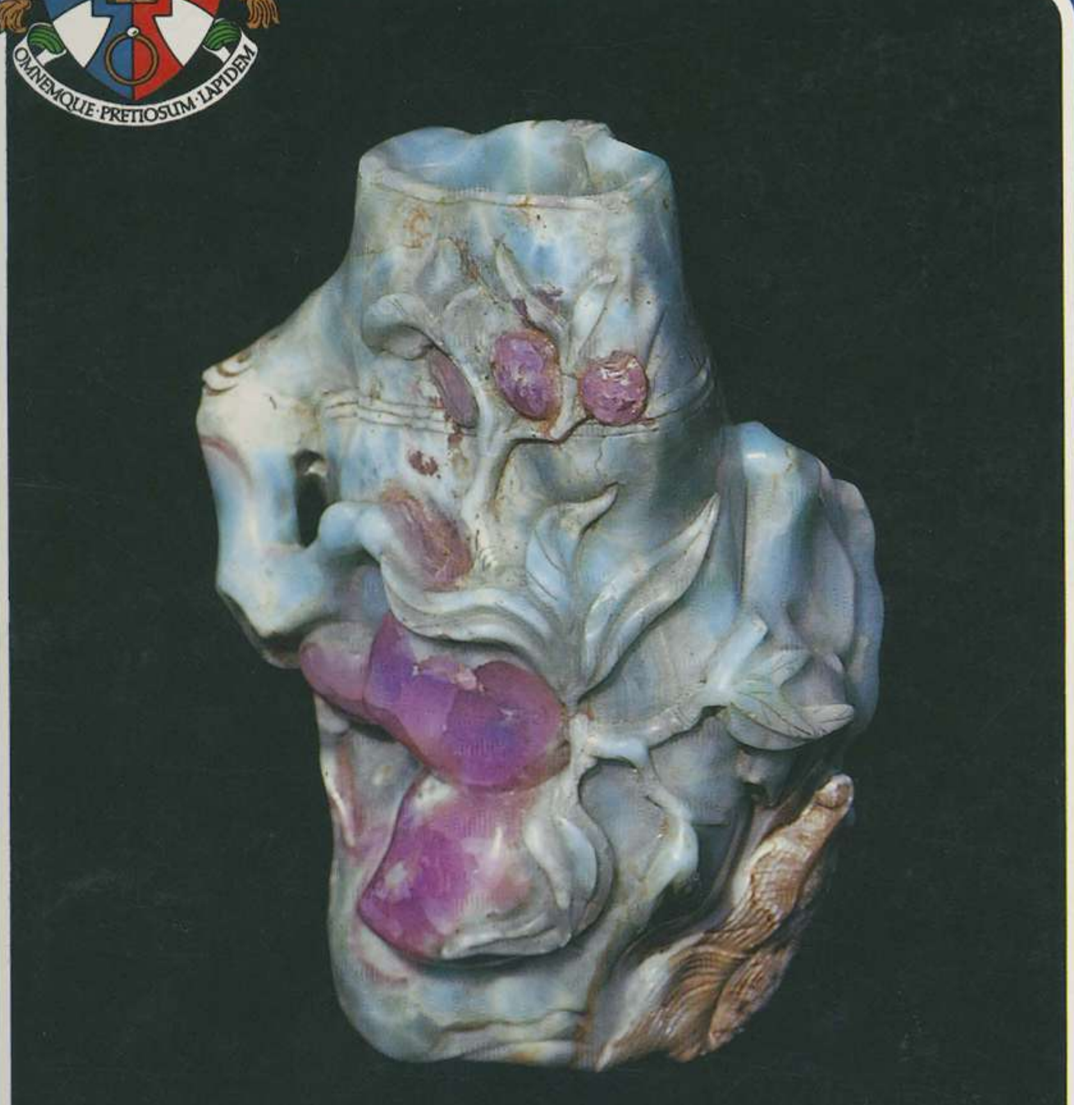

GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

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Cover Picture

Chinese vase carved in banded blue aragonite and purple cobaltocalcite. Kindly lent for many years for display to the Geological Museum, London, by Mr and Mrs J.H. Common.
Photograph by E.A. Jobbins

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AVE ATQUE VALE*

HARRY WHEELER, Secretary 1973–1982

We report with great sadness the death of Mr H.J.B. Wheeler on 5 June 1986. He had served the Association (and the National Association of Goldsmiths) with distinction for almost half a century and his friendly face and ever ready advice will be greatly missed by his friends. During his period of office the Association broadened its international connections and its world-wide prestige was recognized by the support given to its Jubilee celebrations in 1981. A full obituary appears on page 256.

By courtesy of Mr J. Goodall.

JONATHAN BROWN, Secretary 1986–

We welcome Mr J.P. Brown as the new Secretary of the Association, following the resignation of Con Lenan to take up another post. Jonathan Brown joined the Association in 1972, working with former Secretaries Gordon Andrews and Harry Wheeler. In 1971 he gained his F.G.A. with distinction and won the Tully Medal. In 1979 he left the GA to study law and was called to the Bar in 1980. He rejoined the Association in 1983 and has since made a very significant contribution to the education services of both Associations. We wish him well in the broader responsibilities of his new posts, Secretary of the Gemmological Association and Chief Executive of the National Association of Goldsmiths.

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* Hail and farewell, Catullus, *Odes*, ode ci, 1.10.

Glass fillings in sapphire

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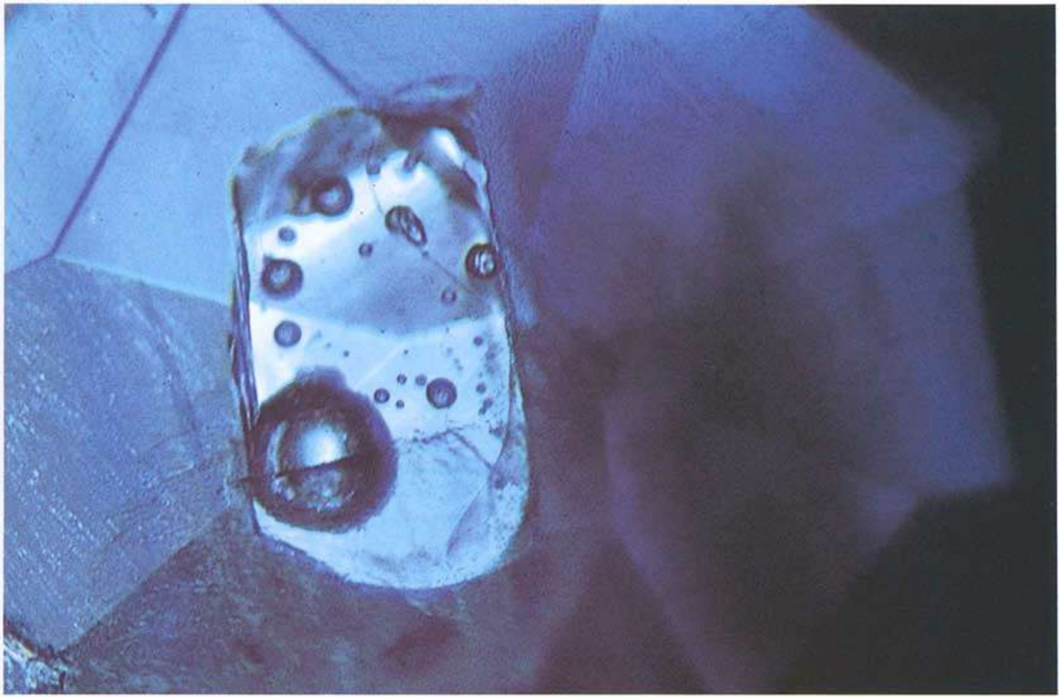

Fig. 1. Area of glass containing bubbles near culet of 1.28 ct sapphire. The largest bubble is 0.5 mm in diameter.

Abstract

Electron microprobe analyses of a filling at the surface of a faceted sapphire indicate that it is an aluminosilicate glass. Its composition is compared with a range of glasses found in rubies, and the possibilities of a natural or of a man-made origin are discussed. It is concluded that the glass in this sapphire is man-made.

Introduction

Rubies and sapphires 'repaired' with glass have been described recently by Scarratt (1983), Hughes (1984 a:b.), Kane (1984), and Scarratt and Harding (1984). The glass fillings generally appear on the surface of cut stones, and in a very interesting account of the phenomenon Kane concluded that the simplest way to detect fillings in such stones is to examine them carefully in reflected light or to immerse them in liquid and look for small areas in the stone which contain bubbles.

Sapphires with glass fillings are much rarer than filled rubies but the stone described by Scarratt (1983) and dating from 1976 has what appears to be a vitreous inclusion containing many bubbles. This inclusion does not break the surface. The 1.28 ct sapphire described below does have a vitreous inclusion at its surface and this stone has a known history since 1979. Kane (1984, p.199) argued that

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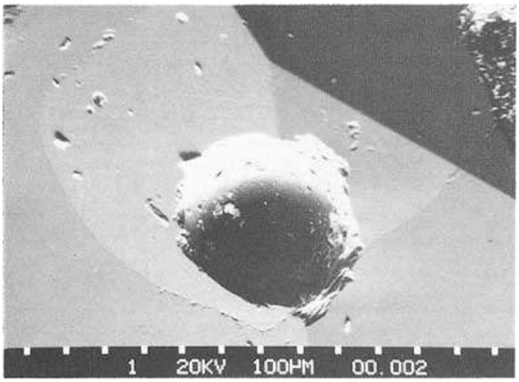

Fig. 2. Glass filling with hemispherical cavity (bubble) as seen using Cambridge Instruments Microscan 9. Compare with Figures 3 and 4.

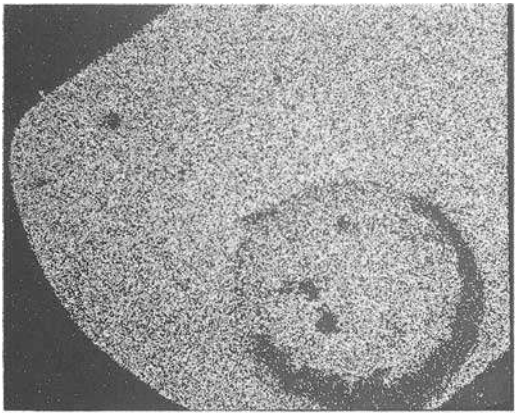

Fig. 3. X-ray picture of distribution and concentration of silicon in the glass and host sapphire. The sharp boundary between glass and sapphire is well shown, and the shape of the area and position of the bubble (0.5 mm diam.) may be compared with Figure 2.

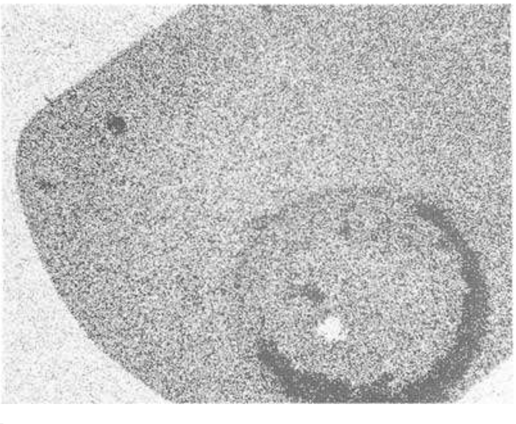

Fig. 4. X-ray picture of distribution and concentration of aluminium in the glass and host sapphire. Note the sharp boundary between the glass and sapphire.

determination of the nature of small fillings in rubies was of minor importance, but the present authors feel firstly that sapphires present a different problem because of their different geological origins, and secondly that identification of fillings is important in building up a comprehensive picture of the inclusions and treatments found in sapphires. The 1.28 ct stone mentioned above is a round mixed-cut stone and features relating to the glass filling in it are shown in Figures 1–4.

Composition of the glass filling

Electron microprobe analyses of the glass were made using a Cambridge Instruments Geoscan with Link Systems energy dispersive detector and computer. An accelerating voltage of 15kV, a specimen current of 5×10^{-9} amps and an electron beam focused to approximately $50\mu m$ (i.e. a defocused beam for glass analyses) were used. Elements of atomic number 11 (Na) and above can be measured by this method and the limits of detection for each of the oxides are about 0.2 wt%. Figures 2, 3 and 4 were obtained using a Cambridge Instruments Microscan 9 with an electron beam focused to $1\mu m$.

The glass filling is located close to the culet, measures less than 1mm across, and contains numerous small bubbles. Analyses of four different spots were made and show that the major elements may vary between different areas by up to 10 wt%. The range of analyses and the mean are given in Table 1, and show that it is essentially an alumino-silicate glass. It should be noted that such elements as Li, Be or B, and the water content have not been determined, but the totals of the other oxides of 97–99% indicate that, should they be present, their amounts are not large.

The composition of the glass in the sapphire compares closely with that found in the ruby described by Scarratt and Harding (1984) and for comparative purposes this is shown in Table 1, column 3. The main differences are higher CaO and Na_2O contents of the glass in the sapphire. The analyses in columns 2 and 3 are dissimilar from Stockton's analyses of glasses in rubies A and B (Kane, 1984, p. 197) but compare more closely with her analyses C and D (op. cit.) which are reproduced in Table 1. Analyses A and B both have high CaO and MgO contents and the natural glass (Table 1, column 5) is notable for its low content of alkali metals.

There are three possible origins for the glass found in a ruby or sapphire. It may be (1) a natural volcanic glass, or (2) a man-made synthetic glass, or it may be (3) the result of melting of natural inclusions. Let us consider these in more detail:

Table 1. Electron microprobe analyses of glass.

Wt%	1	2	3	4	5
SiO_2	53-64	57.5	59.0	56.9	56.8
TiO_2	<0.2	<0.2	<0.2	0.1	0.4
Al_2O_3	23-32	29.4	28.4	31.9	26.4
FeO	1.5-2.7	2.1	0.7	0.3	1.5
MgO	0.3-0.9	0.6	0.5	0.1	1.9
CaO	1.1-1.8	1.5	<0.2	0.1	6.5
Na_2O	6.5-7.2	6.7	2.6	1.7	0.4
K_2O	0.6-0.9	0.7	5.4	3.5	0.6
MnO	<0.2	<0.2	<0.2	<0.1	<0.1
Total		98.5	96.6	94.6	94.5

Notes. Total iron is given as FeO.

1. Range of oxides in glass filling in the 1.28 ct sapphire.
2. Mean of 10 analyses of glass filling in the 1.28 ct sapphire.
3. Mean composition of glass filling in ruby (Scarratt and Harding, 1984).
4. Glass C (artificially induced) in ruby (Stockton in Kane, 1984).
5. Glass D (natural) in ruby (Stockton in Kane, 1984).

1. Most natural glasses occur in volcanic environments either as lavas or as fragments in volcanic ashes and tuffs. Rubies are only rarely associated with lavas and there is only one major volcanic province – that of Thailand and Kampuchea (Cambodia) – where rubies are mined. Sapphires are much more commonly associated with volcanic activity (Figures 5 and 6) and occur notably in the basaltic provinces in New South Wales, Thailand-Kampuchea and the Jos Plateau, Nigeria. In these districts the sapphires have rounded lustrous surfaces (Figure 5) which are not a result of cold mechanical abrasion but more likely of hot magmatic corrosion or partial resorption. It is probable that at some stage these sapphire crystals were part of a deep crustal rock that was invaded and shattered by upward moving basaltic magma. Fragments of rock and sapphire were incorporated in the magma flow and some were eventually extruded at the Earth's surface. Those that did make it to the top survived a hostile chemical environment which left its mark in the form of rounded corrosion edges and pits in the crystals. It is quite possible that in this eruptive environment glassy lava may adhere to the sapphires.

Although as yet we have not seen any sapphires with undisputed volcanic glass, it is nevertheless relevant to inquire into what kinds of volcanic glass one might expect in the Australian, Thai or Nigerian provinces.

The basalts in these provinces are classed as alkali basalts, and, in comparison with other basalts, they have low SiO_2 and high alkali and TiO_2 contents. An example of an alkali basalt from northern Thailand is given in Table 2, column 1, and rocks of this composition may also be found in the Australian and Nigerian sapphire provinces mentioned above.

If this analysis is compared with that of the glass filling (Table 2, column 4) the most striking differences are the lower values of SiO_2 and Al_2O_3 in the basalt. These differences rule out any likelihood that the glass filling resulted from quenching of a magma of this composition. However, this composition is not the only one that can be found in basalts. Some basalts are completely microcrystalline, but others consist partly of crystals and partly of residual glass, and this glass has a composition which differs quite considerably from the overall composition of the basalt.

In 1966 Wilkinson described residual glasses in basalts from New South Wales (see Table 2, column 2) and these compositions compare more closely with those of the glass fillings. However they still differ quite considerably in Al_2O_3 content.

Having examined the compositions of basalts and some residual glasses in naturally occurring rocks, is there any prospect of finding a natural glass with the SiO_2 and Al_2O_3 contents of that found in the sapphire? There are not yet enough experimental

Table 2. Analyses of basalt.

Wt%	1	2	3	4	5
SiO_2	46.0	52.8	55-62	57.5	59.5
TiO_2	2.1	1.1		<0.2	<0.2
Al_2O_3	15.0	20.6	15-25	29.4	24.3
Fe_2O_3	3.5	1.2		n.d.	n.d.
FeO	6.2	2.7		2.1	0.4
MgO	8.3	0.5		0.6	0.6
CaO	8.2	2.6		1.5	0.8
Na_2O	3.0	5.1		6.7	14.4
K_2O	2.9	5.1		0.7	<0.2
H_2O	3.3	7.2		n.d.	n.d.
MnO	0.2	<0.1		<0.2	<0.2
P_2O_5	0.6	0.9		<0.2	<0.2
Total	99.3	99.8		98.5	100.0

Notes. n.d. means not determined.

1. Basanite, northern Thailand (Barr and Macdonald, 1979).
2. Alkali basalt, New South Wales (Wilkinson, 1966).
3. Range of SiO_2 and Al_2O_3 in glass compositions obtained from melting basalt (Helz, 1976).
4. See Table 1, Note 2.
5. White jadeite, Burma. MI 16820. (Anal. R. R. Harding).

data to state categorically that glasses with 57% SiO_2 and 30% Al_2O_3 can occur in nature, but Helz (1976) has shown that glasses with 62% SiO_2 and 25% Al_2O_3 are possible (Table 2, column 3). Her melting experiments were carried out on Hawaiian basalts at 5 kb water pressure (equivalent to conditions 15 km deep in the crust). With magmas of this or other alkaline compositions it may be possible that under different conditions of pressure and gas composition, liquids of even higher Al_2O_3 content may be generated.

Fig. 5. Weathered alkali basalt containing sapphire from the Jos Plateau, Nigeria. The sapphires have rounded edges, possibly from magmatic corrosion, and exhibit a high lustre. *Photo: E.A. Jobbins.*

2. In considering whether the glass fillings in rubies were of artificial origin, Kane (1984) commented that rubies with glass fillings showed evidence of heat treatment, and that some rubies contained very many tiny glass fillings whose over-all weight was insignificant compared with that of the host. In addition he referred to a practice of coating rubies and sapphires with different substances (pastes) prior to their heat treatment and suggested that the compositions of the glass fillings were directly related to the oxide present in either the crucible material or the coating material. These oxides include those of Ca, Mg, Na and Si. In the glass analyses of both Kane and ourselves Al_2O_3 also is a major constituent and this may well be derived from crucible material which, in some cases, is known to be corundum.

Element maps showing the distribution of Si and Al in the glass, host sapphire and the boundary between the two are shown in Figures 3 and 4. They show that the glass is essentially chemically homogeneous (similar patterns were obtained for Na and Fe distributions), and that there is a sharp change in composition at the sapphire-glass boundary. Any possibility that Al in the glass had been derived from the sapphire is not supported by these results. If Al in the glass had come from the sapphire, a higher concentration of Al would be expected nearer the sapphire and the glass would be inhomogeneous.

Fig. 6. Lamprophyre containing sapphire from Montana, USA. *Photo: E.A. Jobbins.*

Silicate glasses high in alumina are known to have higher melting temperatures, to be more viscous and difficult to clear of bubbles than many other glasses, and they seem an odd choice for the purpose of filling tiny cavities in rubies and sapphires.

3. A third possible origin for glass inclusions is by the melting and quenching of natural crystal or crystal and liquid inclusions. The commonest inclusions in ruby and sapphire are acicular crystals of rutile (TiO_2). Other crystal inclusions recorded are spinel ($MgAl_2O_4$), zircon ($ZrSiO_4$), mica ($KMg_3AlSi_3O_{10}(OH,F)_2$), apatite ($Ca_5(PO_4)_3(OH,F,Cl)$), calcium aluminium silicates such as zoisite, anorthite and margarite, and amphiboles. Some glassy substances in heat-treated rubies from east Africa show spinel and zoisite compositions (Dr H.A. Hänni, personal communication). Many rubies and sapphires also contain healed feathers with tiny amounts of trapped brine solutions.

Some zeolites or clay minerals resemble the composition of glass D given by Kane (1984, p. 197), but none is directly comparable with the glass in the 1.28 ct sapphire. This is essentially a sodium aluminium silicate and the proportions of Na: Al: Si do not correspond precisely with those of any known mineral. The minerals closest in composition to the glass are jadeite ($NaAlSi_2O_6$), and albite ($NaAlSi_3O_8$) but both have higher Na and lower Al. Pilot experiments of heating powdered jadeite at temperatures of 1200°C, 1400°C and 1600°C for different periods up to four hours were carried out to ascertain whether sodium was depleted relative to Si and Al. The analyses of glasses quenched from the different melts indicate that the Na_2O content of the quenched glasses is within 2 wt% of that in the original jadeite powder (Table 2, column 5), and there is no significant volatilization of sodium. It is therefore most unlikely that this NaAlSi glass was derived from a natural NaAlSi mineral with different porportions of these elements.

Conclusions

(i) The glass fillings in rubies and sapphires have a range of compositions, some of which correspond to mineral compositions. Others do not and are probably artificial and deliberately manufactured to 'enhance' the stone.

(ii) It is unlikely that any glass inclusions reported to date are natural volcanic glass, although sapphires in particular occur in geological environments where natural glass inclusions are a distinct possibility.

Acknowledgements

We would like to thank Miss F. Wall and Dr R. F. Symes for advice concerning the microprobe analyses and for taking the Microscan pictures, Mrs E. Brunton for carrying out a computer search of the literature, and Mr E.A. Jobbins for supplying pictures of sapphires from Montana and Nigeria. We had useful discussions with Dr A. Wilson (Laboratory of the Government Chemist) and with Mr T.S. Coldham.

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Solution coloration of smoky quartz

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Abstract

This paper discusses the possible coloration of smoky quartz by naturally occurring radioactive hydrothermal fluids. The smoky brown colour of the quartz crystals described here is confined to a surface layer only a few millimetres in thickness. The greatest depth of colour is concentrated around surface solution cavities and near-surface fluid inclusion chambers.

Introduction

While examining several hundred smoky quartz crystals imported from Minas Gerais, Brazil, it was noticed that a few dozen of the larger crystals, some as large as 20cm in longest dimension, showed an unusual outlined or shadowed, uneven smoky brown coloration. In these crystals the colour seemed to be confined to the outer surface with depth of colour extending into the crystal's surfaces a maximum of only 2.0mm. The colour was concentrated at crystal-face junctions and in and around solution pits, as shown in Figure 1, while the broad, flat rhombohedral and prism faces showed virtually no colour penetration. This gave the crystals an unusual type of skeletal phantom coloration. It has been well established that irradiation of colourless rock crystal quartz will produce smoky quartz (Rossman, 1981, and Nassau, 1984). It was therefore obvious that a source of radiation had played a major role in the colour enhancement of this material. But why the colour was distributed in the manner described above, rather than disseminated relatively evenly throughout these crystals as is usually the case, was still to be learned.

Microscopic examination

One of the crystals, measuring 9.5 × 7.8 × 4.1cm, was given to the author for a closer examination, to see if any evidence of the possible colouring mechanism could be discovered. Using a stereo zoom microscope it was observed that, without exception, wherever a near-surface fluid inclusion or cavity existed it was surrounded by a smoky brown halo or cloud. As illustrated in Figure 2, most of the near-surface cavities were very slightly open at the surface. The quartz had not grown sufficiently to seal them completely. Therefore, they contained no liquid, but only a gas phase.

However, a few of these cavities were sealed during growth and did contain both liquid and gas (Figure 3). A closer detail of this cavity and its two-phase contents is provided in Figure 4. The tip of this fluid inclusion, where the gas bubble is resting

Fig. 1. A large pit in quartz, measuring approximately 1cm in length, surrounded by a rim of smoky colour resulting from a radioactive hydrothermal solution.

Fig. 2. Near-surface cavity in the quartz crystal, very slightly open at the surface and now containing only a gas. Note the smoky brown cloud surrounding the cavity. 5x.

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Fig. 3. Two-phase fluid inclusion containing the once-radioactive liquid that caused the brown smoky quartz halo. 5x.

Fig. 4. Close detail of the two-phase inclusion shown in Figure 3. The bubble is free to move in its void. The solution was checked with a Geiger counter and is no longer detectably radioactive. 15x.

in the photomicrograph, appeared to be less than a tenth of a millimetre from the crystal's surface. Even a slight abrasion along that surface area could have caused this fluid inclusion to rupture. After judging the fragile nature of this inclusion, it was not at all surprising that liquid and gas fluid inclusions, in this near-surface zone of smoky coloration, were rare.

A probable mechanism

The phantom-like, surface confined, smoky brown colour displayed by these quartz crystals together with the way face junctions and solution pits are delineated suggests that the hydrothermal solution responsible for the last millimetre of crystal growth was radioactive. The radioactivity was probably the result of submicroscopic radioisotopes suspended in the silica-rich hydrothermal solution. The solution was not isotope-potent enough to produce a smoky brown colour throughout the crystals, so a surface-only colour alteration resulted. Although no reaction was expected, as a final testing step the crystal was checked for residual radiation using a Victoreen survey meter capable of detecting alpha, beta, or gamma radiation. The results of this radiation check were negative.

Concluding thoughts

No direct mention of radioactive hydrothermal solutions as colouring agents for natural smoky quartz could be found in the literature, nor have smoky quartz crystals of this type been described before. Nature is an excellent source of radiation. So, although this theory is plausible, it is still only a theory. Reader observations are welcome.

Acknowledgements

The author would like to thank Mr Rock H. Currier, of Jewel Tunnel Imports in Arcadia, California, for supplying the smoky quartz used in this study. Ruth Patchick deserves thanks for typing the manuscript.

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Notes from the Laboratory – 8

Kenneth Scarratt, F.G.A.

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

There can be no doubt that when a diamond is cut into a perfectly proportioned modern brilliant, whether the stone is coloured or colourless, the magnificent response this mineral can have to light is seen at its best. We should not assume though, that those diamonds which are not cut to produce this response, or were cut in an older style, are any less impressive. They have a beauty and a character of their own.

A large flat diamond was reported in this Journal in 1984 (Jobbins *et al.*, 1984). Of those who have seen this stone few would deny its historical interest, and even fewer would deny that in its own right it is a spectacular diamond. All those who have viewed the Crown Jewels in the Tower of London cannot fail to be stunned by the effect produced by thousands of old-cut diamonds.

The Laboratory was asked to examine another flat diamond in May 1986 and whilst this one did not have the size of that reported in 1984, it did have a recognizable colour. The diamond, surrounded by smaller old-cut diamonds, was impressively set in a heavy ring (Figure 1) which displayed its fancy blue colour effectively. When removed from the setting (Figure 2) the colour, which was still apparent through the table, could be seen to be quite deep when the stone was viewed edge on.

Like the 1984 flat stone, the high surface lustre of this stone gave it a character of its own and the fact that it was a distinct blue colour added to its impressive appearance.

Fig. 1. Large flat blue diamond set in a heavy ring.

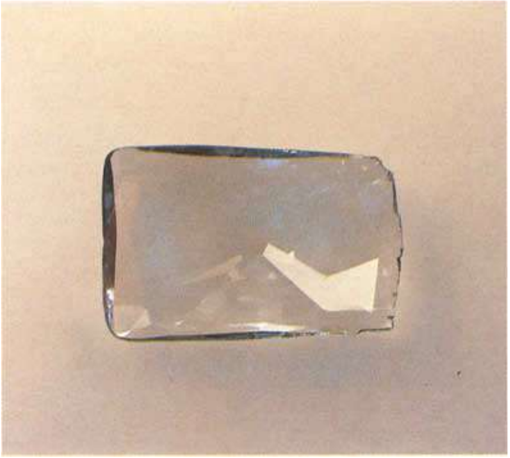

Fig. 2. The large flat blue diamond of Figure 1 after being removed from its setting.

The stone measured approximately 19.27–12.52 × 1.86 mm and weighed 4.36 cts. In clarity grading terms the stone, which had surface crazing and was chipped at the girdle (Figure 2), could be described as vs1.

The stone conducted electricity and was inert to long-wave ultraviolet, and only fluoresced a slight chalky colour under short-wave ultraviolet light. In common with other naturally coloured blue diamonds, this stone transmitted ultraviolet light down to 235.6 nm (Figure 3).

Today, as in the past, in producing a faceted diamond the cut chosen for a particular piece of

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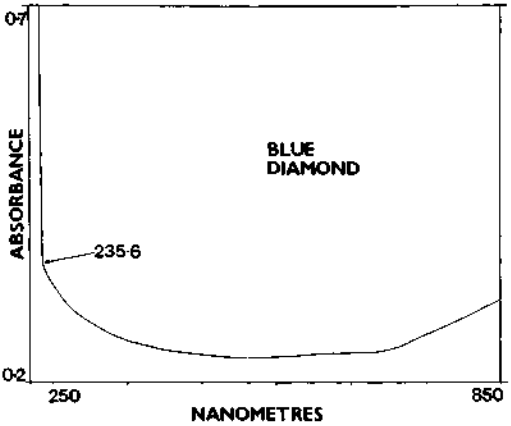

Fig. 3. The absorption curve of the blue diamond in Figures 1 and 2. The curve was obtained using a Pye Unicam PU8800/03 UV/visible spectrophotometer (Basil Anderson Model) with a speed of 0.5 nm/s and a bandwidth of 0.5 nm at room temperature. The path length was approximately 1.8 mm. The stone transmitted light down to 235.6 nm.

rough is the one which will maximize its potential both in terms of beauty and economics. This means that the vast majority of facted diamonds are cut in the modern round brilliant form or some fancy variation.

To the gemmologist who appreciates the unusual, not only in the form of a rare gemstone but also in the presentation of any gem material, it is a pleasure to see a diamond fashioned in an unconventional manner. These flat diamonds are unusual and this can also be said of another diamond we had the pleasure of examining recently. This was a very tastefully set stone cut in the style of a briolette (Figure 4).

Fig. 4. A tastefully set diamond cut in the style of a briolette.

* * *

Diamond in its natural state is an easily recognizable material, but even so the Laboratory has on many occasions had the unhappy task of having to inform the owners of large lots of colourless stones that what they have is topaz or quartz, and not a fortune in diamonds.

A short while ago there were rumours amongst the London diamond trade that synthetic cubic zirconia was being fashioned into octahedra and that the producers had even engraved 'trigons' on the faces. At about the same time we were asked to examine a parcel of rough stones which, it was said, were being offered to the trade as diamonds. If we were hoping to see the synthetic cubic zirconia 'crystals' our expectations were not realized. What was actually placed before us was a parcel of small pieces of quartz, each of which was coated with an adhesive containing numerous small squares of silver coloured foil (Figure 5)!

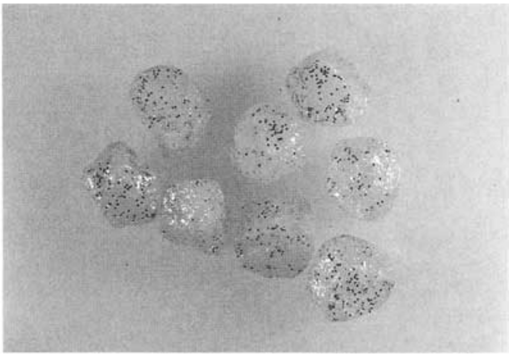

Fig. 5. 'Imitation diamond crystals' fashioned in quartz.

* * *

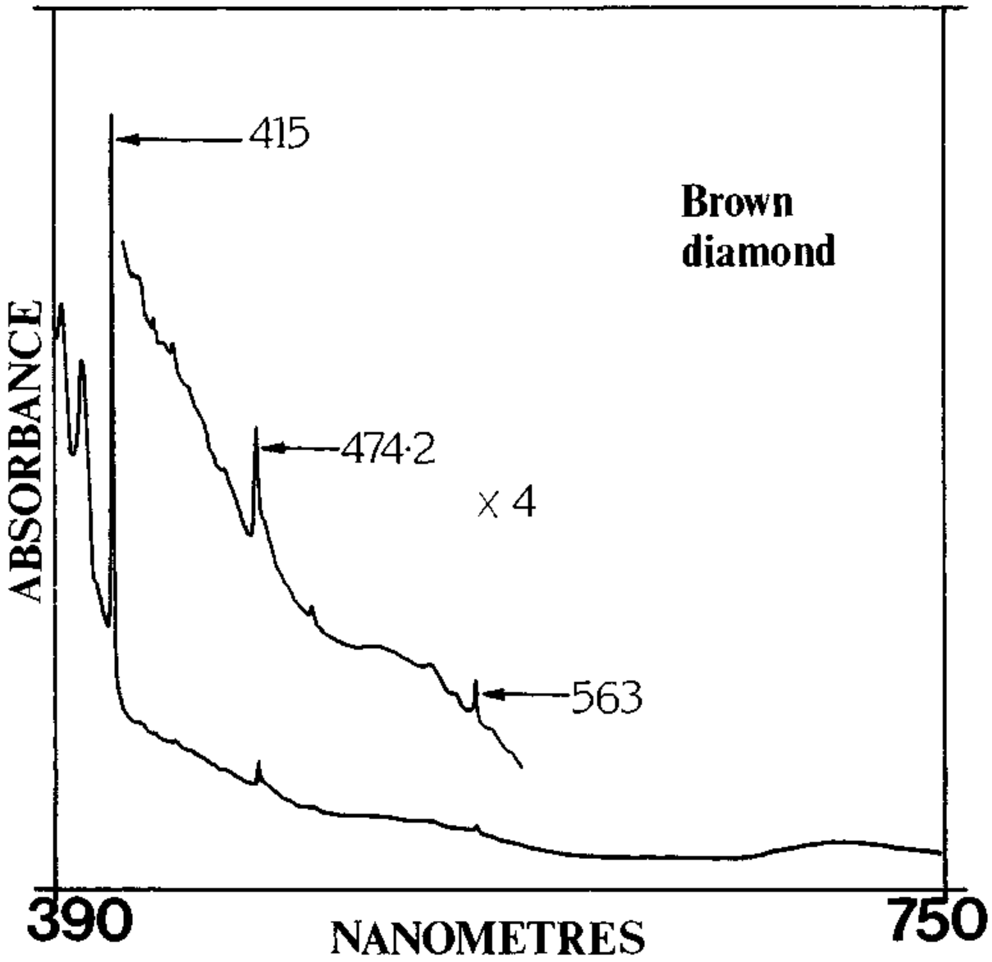

Fig. 6. The absorption curve of a brown diamond. The curve was obtained using a Pye Unicam PU8800/03 UV/visible spectrophotometer (Basil Anderson Model) with a speed of 0.5 nm/s and a bandwidth of 0.5 nm at approximately 120K. The path length was approximately 7 mm.

On rare occasions since 1977 we have noted the occurrence of a sharp fine absorption line in the area of 478 nm and a further group of three lines in the 560 nm region of the spectra of some brown diamonds. Owing to the proximity of the 'N2' band (at 120K, the N2 is at 477.2 nm) of the 'Cape series' spectrum, to the line seen in these stones, it is easy to mistake one for the other. When viewed with the hand spectroscope though, it will be seen that the N2 in the normal Cape series spectrum is much wider and is not as sharp as the line in the spectra of these brown stones.

At approximately 120K the wavelength of the line in the blue in the brown stones has varied between 474.2 nm and 474.9 nm but when recorded on a spectrophotometer the peak shape has been characteristic (Figure 6). The peak in each case is sharp and has a shoulder on its long-wave side. The wavelength of the main peak of the group in the green area has varied between 562.2 nm and 563 nm (Figure 6). The other two peaks have been at 554 and 544 nm.

In the past year we have examined three diamonds in which the colour changes from brown in artificial light to green in daylight. The spectra of these stones were recorded at 120K and each produced curves similar to that in Figure 6. However, one stone (Figure 9) recorded a spectrum (Figure 7) in which both the N2 and the '474' peaks were clearly present. In the hand spectroscope this combination is seen as a wide dark band with a sharp edge on its short-wave side.

For comparison purposes a normal Cape series spectrum (recorded at approximately 120K) of a

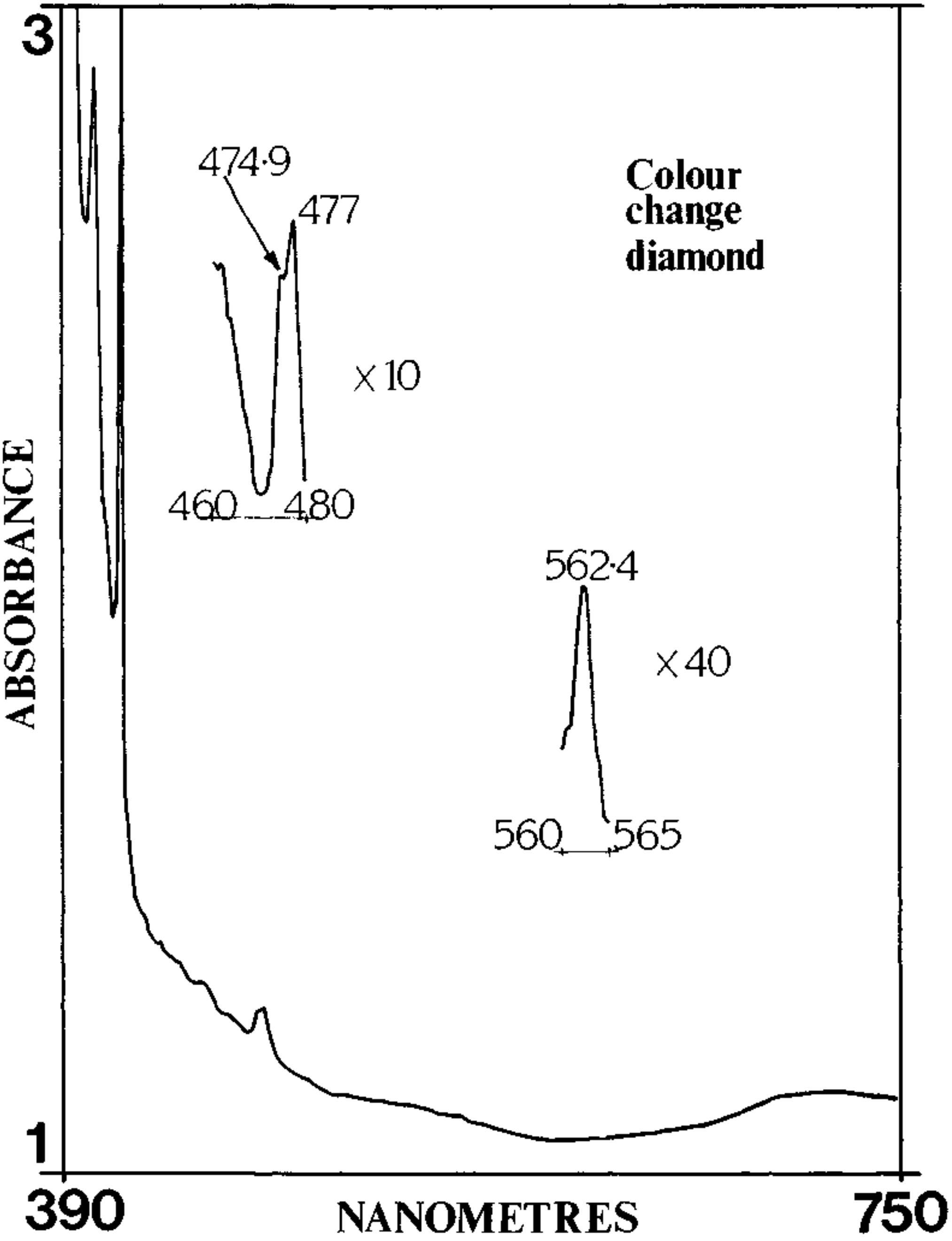

Fig. 7. The absorption curve of a diamond which changes colour from brown in artificial light to green in daylight. The curve was obtained using a Pye Unicam PU8800/03 UV/visible spectrophotometer (Basil Anderson Model) with a speed of 0.5 nm/s and a bandwidth of 0.5 nm at approximately 120K. The path was approximately 9.17 nm.

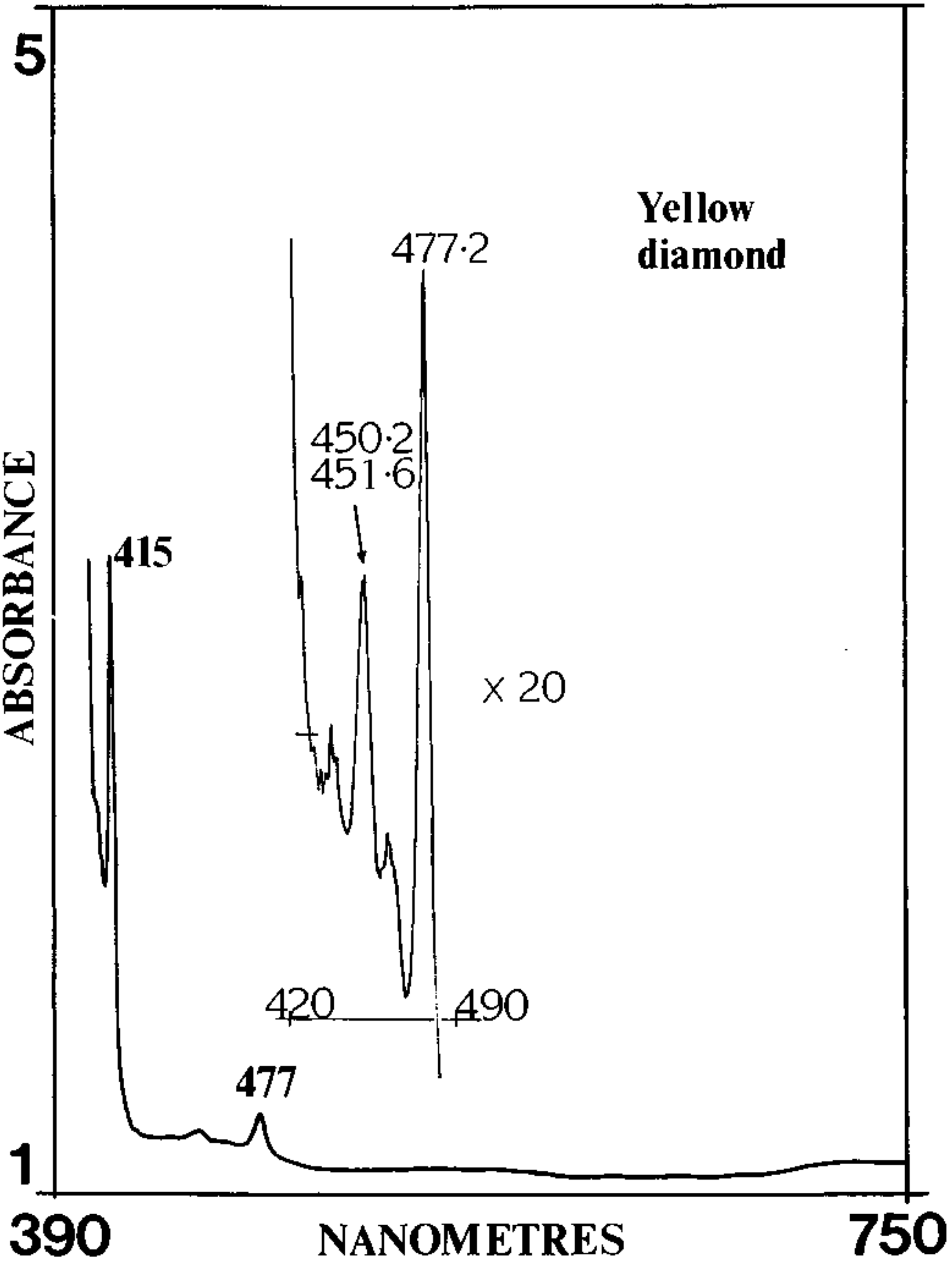

Fig. 8. The absorption curve of a Cape series yellow diamond. The curve was obtained using a Pye Unicam PU8800/03 UV/visible spectrophotometer (Basil Anderson Model) with a speed of 0.5 nm/s and a bandwidth of 0.5 nm at approximately 120K. The path length was approximately 6.8 mm.

Fig. 9. A diamond which changes colour from brown in artificial light to green in daylight.

yellow diamond is reproduced in Figure 8. It will be noted that at 120K a group of extra sharp peaks are seen in the spectrum of Cape series stones at 424.2, 430.2, 432.8, 435, 437 and 439.8 nm and that the peak at '451' is a doublet with peaks at 450.2 and 451.6 nm.

The reason for the 'colour change' in the stone in Figure 9 became clear following a microscopic examination which revealed that it contained large areas of dust-like cloud. The cloud fluoresced a bright yellow-green under ultraviolet light whilst the remainder of the stone fluoresced blue. This combined fluorescence was strong enough to change the colour of the stone from brown in artificial light to green in daylight.

* * *

The laser drilling of diamonds is carried out in order to reduce the visibility of black inclusions and thereby possibly improve the chances of the stone being saleable. There is very little, if any, chance of the clarity grade being improved by such treatment.

A diamond submitted for examination recently had seven drill holes present, each extending down to an inclusion or a cleavage area. However, the treatment had not been entirely successful. Whilst the drill holes were on target, in a few cases only a small area of the inclusion had been made less visible by conversion from black to white.

Figure 10 shows a very short laser hole in the stone extending from the table facet to a cleavage. The cleavage extends from a crown facet into the stone and at an angle with the table. Where the drill hole meets the cleavage there is a round white area, which is where the treatment has been effective, but otherwise it is still a mostly black cleavage. Figure 11 shows a similar result on a long black inclusion in the same stone.

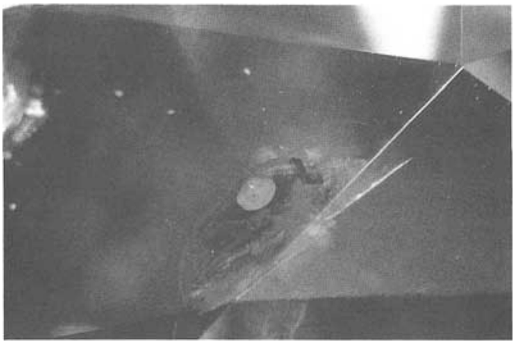

Fig. 10. A short laser hole in a diamond extending from a crown facet to a cleavage.

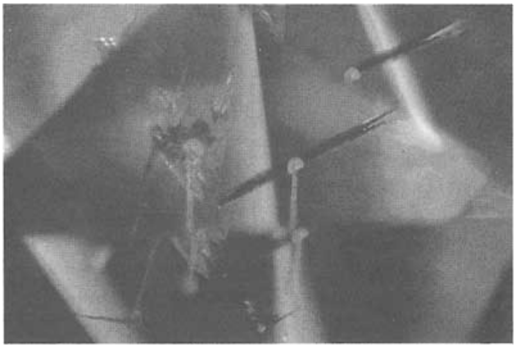

Fig. 11. A laser hole in a diamond extending down to a long black inclusion.

* * *

Some years ago a number of parcels were being offered for sale containing cabochons of a pink material which had a porcelain-like surface, and was said to be pink opal. In recent years very little has been seen of this material, however, some merchants have kept small amounts in stock.

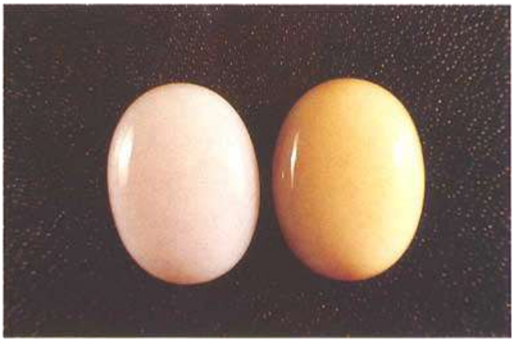

Fig. 12. Opal which has changed colour from pink to a much darker shade approaching orange.

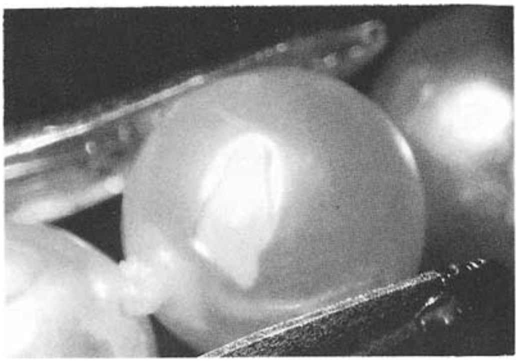

Fig. 13. Poor quality cultured pearls.

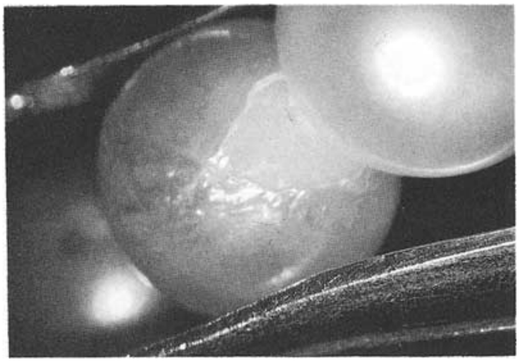

Fig. 14. Poor quality cultured pearls.

On a recent visit to one of these merchants we were informed that some of their stock of this material had changed from a light pink to a much darker shade which approaches orange (Figure 12). The stock had been stored in a safe and inside normal stone papers. At present the reason for this colour change is not known.

* * *

The quality of some cultured pearls being offered for sale to the public over the past few years falls short of that which hitherto has been an acceptable standard. It almost appears that because of the current increase in demand for cultured pearl necklaces, an 'anything goes' attitude is prevalent in some quarters.

Recently the Laboratory has been asked to examine rows of cultured pearls in which the nacre has either separated from the mother-of-pearl bead or is in the process of doing so. In some other cases (Figure 13) part of the mother-of-pearl bead has *never* been covered, or the nacre that is present is of very low quality (Figure 14). Following complaints from members of the public various Trading Standards Authorities are now investigating this problem.

Reference

Jobbins, E.A., Harding, R.R., Scarratt, K. 1984. A brief description of a spectacular 56.71 ct tabular diamond. *J. Gemm.*, **XIX**, 1, 1–7.

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The colour bar in the gemstone industry

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Abstract

The current general attitudes in the gemstone industry towards quantitative descriptions of the body colours of coloured diamonds and gemstones are discussed in some detail. Instruments and systems which are suitable for making such measurements are described. It is shown that practical and adequate procedures already exist and could be deployed at once if the industry wished to do so.

The body colours of a number of faceted gemstones were measured by means of a visual tristimulus colorimeter, using a new gemstone mounting technique developed by the author. From this experience and other considerations, there is evidence that an international agreement on gemstone colour grading could be reached more quickly if visual measurements were abandoned in favour of photoelectric ones.

Physical colour standards, such as painted chip collections, would still be required, but not for measurement. They would be needed to translate the incomprehensible CIE colour space notations produced by spectrocolorimeters into meangingful colour appearances.

Introduction

A previous article(1) presented a number of reasons for gemmologists to consider the adoption of a particular and internationally-used system of colour measurement for the numerical colour decription of faceted gemstones.

The arguments followed were similar to those given in earlier papers by Lewis (1952)(2,3,4,), who made the same plea to use this system without delay. Then (as now), suitable instrumentation was available for measuring these three numbers (CIE Tristimulus Colour Co-ordinates) for any diamond or coloured gemstone. His description of the CIE (1931) System, which has since been greatly extended [CIE 1976 (L*u*v*) colour space](5), still remains for the gemmologist one of the best accounts of this daunting subject.

This article outlines the use of visual comparison methods for gemmological colorimetry. It lists 17 obstacles which seem to be hindering the acceptance by the gemstone industry of gemstone colour measurement. A visual colorimeter designed by the author is described, together with the results of CIE measurements made by it on 38 faceted stones and 'windowed' rough. Proposals are made for taking the first steps towards establishing international standards for the quantitative description of gemstone body colour.

Colour grading charts

Colour is *what we see*. It does not exist without eyes to perceive the sensation. For this reason, it is those procedures which allow the direct visual comparison of pairs of colour stimuli which may be the most appealing, although not necessarily the most appropriate.

With these methods, an acceptable colour match can be made between the calibrated (reference) stimulus and that of the gemstone (test) stimulus. Three numbers taken from the matching reference stimulus then serve as a complete colour description of the gemstone. In principle, although perhaps not always in practice, these numbers can be transformed into CIE colour co-ordinates. The CIE values are much more universally understood than the miscellaneous sets of numbers produced by each of many systems which have so far been marketed. This is especially so if the CIE co-ordinates are expressed, not as the basic Tristimulus Co-ordinates (X,Y,Z), or as the chromaticity and luminance co-ordinates (x,y,Y), but as the dominant wavelength (λ_d), the percent excitation purity (p_e) and the metric lightness (L*). With only a little experience, these last-named co-ordinates permit a good mental image to be formed of what a colour will look like.

At the moment of writing, there are some five colour-grading chart systems being offered to gemmologists(6). They are mostly based on the long-established Munsell Colour Atlas(1,4,7,10,13,19,24). This atlas is a collection of over 1,500 colour-related paint 'chips', marketed as the 'Munsell Book of Colour'. Each chip is labelled with its own Munsell notation (H,V,C) relating to the CIE Illuminant 'C' (colour temperature=6775K). Tables or graphs (see Figure 1) are supplied which give the corresponding CIE co-ordinates, x,y,Y, which in turn can

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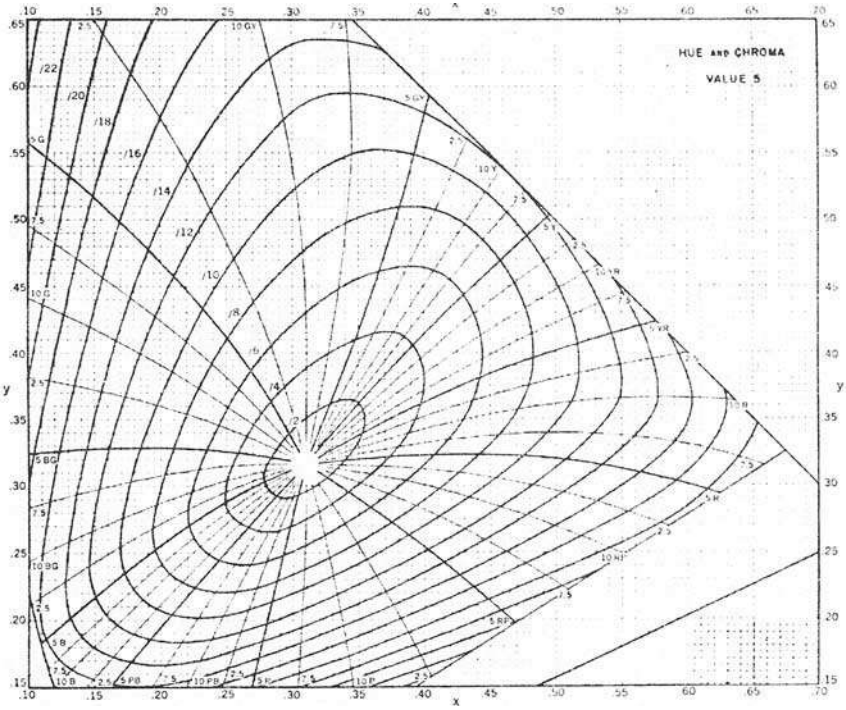

Fig. 1. Munsell loci of constant hue (H) and constant chroma (C) superimposed on a CIE (1931) chromaticity chart (x,y). For chart with value (V=5). CIE Source C.

be instantly converted into the more comprehensible numbers, λ_d, p_e and L*. A characteristic of the Munsell System is that the gaps between the calibrated chips have approximately equal colour spacings. Its most important feature is the prime position it holds amongst the world's colour scientists.

Trade objections

Resistance to the adoption of these relatively inexpensive chart systems by gemstone miners, dealers, jewellers and teachers is almost total. Academically-minded gemmologists and collectors are for the most part fairly sympathetic.

It is perhaps useful to list the main objections:–

1. The existing colour-grading charts do not compare like with like. A brilliant-type cut (no 'window') transparent stone has to be compared with a calibrated opaque, painted chip, or, less commonly, with a white-backed coloured acetate filter. In practice, matching is found to be confusing and awkward: this leads to poor accuracy.
2. There is much concern about the proliferation of notations, symbols, codes and numbers for each chart system. Each system has its own nomenclature, so that quantities generated by the use of one system cannot be instantly understood by the users of another. Cross-referencing is impossible.
3. There is also frustration about the multiplicity of terms used to describe the three precise and separable attributes of colour. They are referred to as metric hue (h_{uv}), metric chroma(C^*_{uv}) and metric lightness (L*) and are the three co-ordinates in the orthogonal colour space known as CIE 1976 (L*,u*,v*), often abbreviated to CIELUV$^{(5,8,15)}$. Examples of these common usages are:–

   Hue is the original Munsell term (H). It is also the term for metric hue (h_{uv}) in CIELUV space. It is the attribute of a visual sensation according to which an area appears to be similar to one, or to proportions of two, of the perceived colours red, orange, yellow, green, blue and purple. It is virtually equivalent to the CIE (1931) 'dominant wavelength' (λ_d), and corresponds to the 'farbton' (T) of the West German DIN 6164 System. It is often incorrectly referred to as 'shade' or 'colour'.

Chroma is the term for metric chroma (C^*_{uv}) in CIELUV space. It is associated with the CIE (1931) 'excitation purity' (p_e), the 'sättigung' (S) of DIN 6164 and the Munsell 'chroma' (C). It is the attribute of a visual sensation according to which an area appears to exhibit more or less chromatic colour. It has been variously described as 'saturation', 'colourfulness', 'intensity', 'vividness', 'vivacity', 'paleness', 'liveliness', 'purity', 'brightness', 'strength', 'cleanliness', 'grayness' and 'dullness'.

Lightness is the term for metric lightness (L^*) in CIELUV space. It is associated with the CIE (1931) 'luminous factor' (Y), the value (V) of Munsell and the 'dunkelstufe' (D) of DIN 6164. It is the attribute of a visual sensation according to which an area appears to reflect diffusely or transmit a greater or smaller fraction of incident light. It is often referred to as 'tone', and erroneously as 'brightness'.

4. The existing colour ranges, or 'gamuts', as they are called, are regarded as too restricted for gemstone grading. In general, gemstones have much more saturated hues than the colour charts provide. The more saturated paints are impermanent; they are therefore not included in the gamut of the long-established colour grading charts of Munsell.
5. Even with a set of over 1,500 chips, the colour spacings between chips are felt to be inconveniently large. The task of interpolating the gemstone's colour between a set of four or six chips is viewed as being both an uncertain and a fussy estimation. The CIE 'Standard Observer' can discern differences between some five million different colours when pairs of uniform fields are viewed side-by-side(7). This incredible, effortless feat of human vision explains why the steps between the chips in the available collections are regarded as too large.
6. There is much understandable unease about the varied and unreliable performance of the many different light sources used at present for stone-and-chart matches.
7. It is a strongly-held belief that two or more observers cannot agree about a given match or about the resulting colour numbers. Indeed there is a prevailing conviction that no colour-measuring procedure or apparatus will ever be able to yield an accurate and sensible statement about the body colour of a gemstone.
8. There is a widespread feeling that trained male colourists and women (either trained or untrained) possess much superior colour-matching abilities to those untrained males who have no colour vision defects.

Apart from these purely 'nuts-and-bolts' considerations, there are other aspects of colour grading (see below) which worry gemmologists.

9. The fear of possible misuse of gemstone certificates which include colour grading numbers. This includes the temptation to switch stones and certificates.
10. The high cost of non-subjective (i.e. non-visual) colour measuring equipment, such as spectrophotometers and photoelectric colorimeters.
11. The dread of a market collapse in high-quality coloured stones. Memories are still fresh of the massive slump in diamond prices, largely caused by the vigorous sales promotions of investment firms using price-linked colour-grading certificates.
12. An aversion to any national or international agreement which would allocate specially-defined volumes or zones in a given CIE colour space to certain groups of stones such as rubies, emeralds and sapphires. From this, it is believed, would surely follow the setting-up of plus-and-minus limiting tolerances for each of the co-ordinates λ_d, p_e and L^* for the most commercially-valuable or aesthetically-preferred stones.
13. Having set out upon this course, miners, dealers and jewellers would be fearful of another problem. They would expect to encounter difficulties in disposing from their inventories many of the larger number of stones which would necessarily be now excluded from the preferred zones. They feel that a new generation of colour-educated buyers would probably resist purchasing goods which were 'out-of-specification'.
14. Those gem cutters who aim for maximum weight and clarity, rather than optimum colour, would scarcely welcome any such convulsive changes in their traditional ways of working.
15. The use of many related sets of master (colour-calibrated) stones is now an internationally accepted practice for diamonds of the Cape series. Although costly, the reason that this is practicable is because the colour range is not three-dimensional (λ_d,p_e, L^*) as with diamond fancies and coloured stones, but is virtually one-dimensional (p_e). All the colours embraced by the 11 commercially-important GIA colour grades, D to N, have a constant λ_d of 576 nm.

The most yellow of these, N, has the incredibly low p_e value of 5.0%!⁽⁹⁾ As few as seven master stones are considered sufficient to cover this tiny gamut. This would hardly be possible with coloured stones, as the sheer economics would preclude such large collections.

Nevertheless, many dealers do indeed possess sizeable ranges of their specialist coloured stones. They would be likely to rebel against changes which would threaten the trading advantage which the possession of such 'standards' would endow.

16. It would appear to be advantageous to jewellers, valuers, auction houses, insurers and insurance brokers to arrange to have CIE colour measurements made routinely on their higher quality gemstones when they become their temporary custodians. This practice would almost certainly confer total legal protection to themselves and their clients in the event of losses, price disputes or allegations of stone- or certificate-switching, colour fading or various chicaneries and deceits. Let it be supposed that a single valuable emerald has been lost from its setting and has no similar companions to help judge its colour. How can the jeweller supplying the replacement, which itself will be either poorer or finer in colour, negotiate a solution satisfactory to the owner, the valuer, insurer and himself? As litigation is now a major growth industry, one would imagine that prior colour measurement would be the answer.

One would imagine wrongly. As an American gemmologist friend with a taste for Goldwynisms put it, "They are agog with indifference". He reports sadly that the cost of measurement and the fuss of sending goods back and forth to an accredited laboratory is thought to be hardly worth the degree of protection gained.

A final obstacle which does not worry gemmologists, but which does worry the author is this:–

17. Many gemmologists, especially those involved with jewellery, have strongly-developed artistic temperaments. Like the archetypal easel painter, they have little patience with 'finicky measurements' and are prone to feel that an analytical approach to a quantitative colour selection of stones is nonsensical.

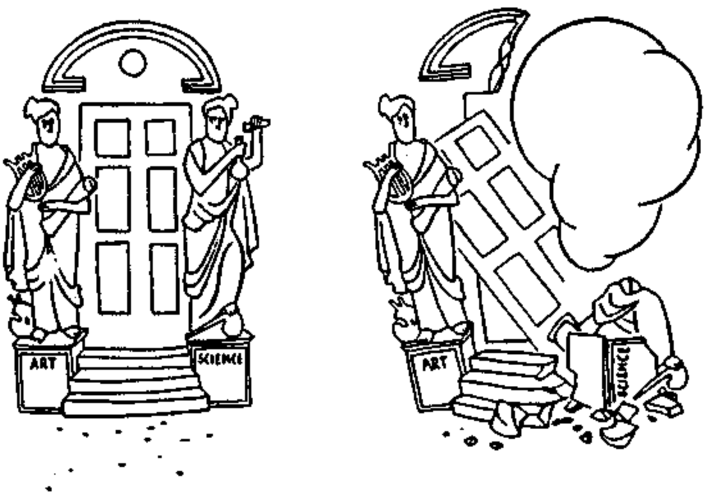

Fig. 2. The archetypal artist's view of the archetypal scientist.

Most successful artists possess only a rudimentary scientific grasp of colour production and the simpler mechanisms of perception; almost none have any knowledge of colour measurement. If reproached about this, they will offer a scornful retort, such as "I know my own colours (meaning colorants, dyes or pigments), so I don't need to paint by numbers, thank you". Their general feeling about science is fairly well summed up in the cartoon in Figure 2.

A brave attempt was made some years ago by an extremely talented artist and teacher, Joy Turner Luke ⁽¹⁰⁾, to coax and cajole her fellow artists into learning something about colour science. She suggested several novel ways by which they might perhaps gain inspiration and fresh insight into their work. From all accounts it was not a great success. The poet Keats has encapsulated this curious sentiment that the appreciation and savouring of beautiful objects is diminished if even the smallest attempts are made to describe their nature:–

> Do not all charms fly
> At the mere touch of cold philosophy?*
> There was an awful rainbow once in heaven:
> We know her woof, her texture: she is given
> In the dull catalogue of common things.
> Philosophy will clip an Angel's wings,
> Conquer all mysteries by rule and line,
> Empty the haunted air, and gnomèd mine –
> Unweave a rainbow.
> Lamia, II, page 472.

As an unashamed, hard-core, card-carrying physicist, the author is both puzzled and irritated by these views. He cannot believe that knowledge has to be paid for by the loss of wonder. Gübelin's magnum opus 'The internal world of gemstones'(11) provides the most beautiful and elegant proof of the absurdity of the Keatsian view.

Commercial perspectives in colour control

The vital question which must be posed is this. Is the gemstone industry unique in its apparent hostility to colour grading, with respect to other successful enterprises who have been compelled to use high-quality colour control procedures for industry-wide standardisation?

The answer to this question is an unequivocal yes.

Since the beginning of the 1950s, the worldwide penetration of colour into the manufacturing and marketing processes has been truly massive and will continue to increase. No consumer product, commercial package, sales promotion or entertainment activity is now without its colourful message.

Most industries now require means for rigorously controlling the colour appearance of their products. These are organizations which supply such diverse commodities as paints and coloured coatings, clothing and furnishing textiles, dyed leatherware, plastics, paper and packaging materials, printing inks and photographic films, artistic and architectural products, coating phosphors for television sets and fluorescent light tubes, anodised-and-dyed deposits on metals, dental protheses, coloured glasses, pottery and ceramics, skin and hair cosmetics, industrial mineral oils, waxes and resins, foodstuffs, flowers, beverages and pharmaceuticals.

It is therefore not surprising to discover that there now exists a large variety of instrumental means for predicting, formulating and monitoring the precise amounts of colorants to be added to various matrices to achieve the desired colour of the final product. Or to accept or reject the natural products of the forests, fields, mines and seas. All such assessments make use of any one of the several colour spaces associated with the CIE Tristimulus Colour System.

The earliest commercial method of colour control originated in the textile dyehouse. Here, a textile swatch of three dyed yarns was supplied to the dyer. One was the colour to be aimed at; the other two represented the limiting colours. Finished goods lying outside this colour bracket were returned by the customer. Unfortunately, the dyehouse soon discovered that this kind of simple quality control was no longer able to meet the wishes of their customers. Some of the most complex and sophisticated arrangements now in use consist of spectrophotometers linked on-line to large-memory computers. Their success in trimming the skilled labour force and in reducing the proportion of rejected dyehouse products vastly compensated for the high capital costs.

In all these cases, the suppliers saw no need to change from their simple colour controls to the much more rigorous and costly ones. As with all competitive market forces, it was the customers who were the driving force. It was only after the customers' needs were satisfied that the suppliers discovered the benefits. The paint industry has been by far the quickest to have risen to the challenge; manufacturers can now paint to within incredibly narrow colour tolerances.

A recent survey of colour grading issues has been given by Rouse(12). As a teacher at the Asian Institute of Gemmological Sciences in Bangkok, Thailand, his views carry much authority in a country which is one of the world's most important gemstone producers and traders. His concluding paragraph is worth quoting:–

'Colour grading should be viewed as a valuable tool for creating a communication system where none exists; as a means to standardize the colour stone industry, and as a vehicle to generate confidence and sales in an industry that needs both. Dealers, therefore, should not be alarmed at the emerging systems of colour grading. Given the proper framework, they can open up a new era for the gemstone industry: an era of colour communication standardization which will result in an

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* Science was an unfamiliar word in the time of Keats. It was then better known as natural philosophy.

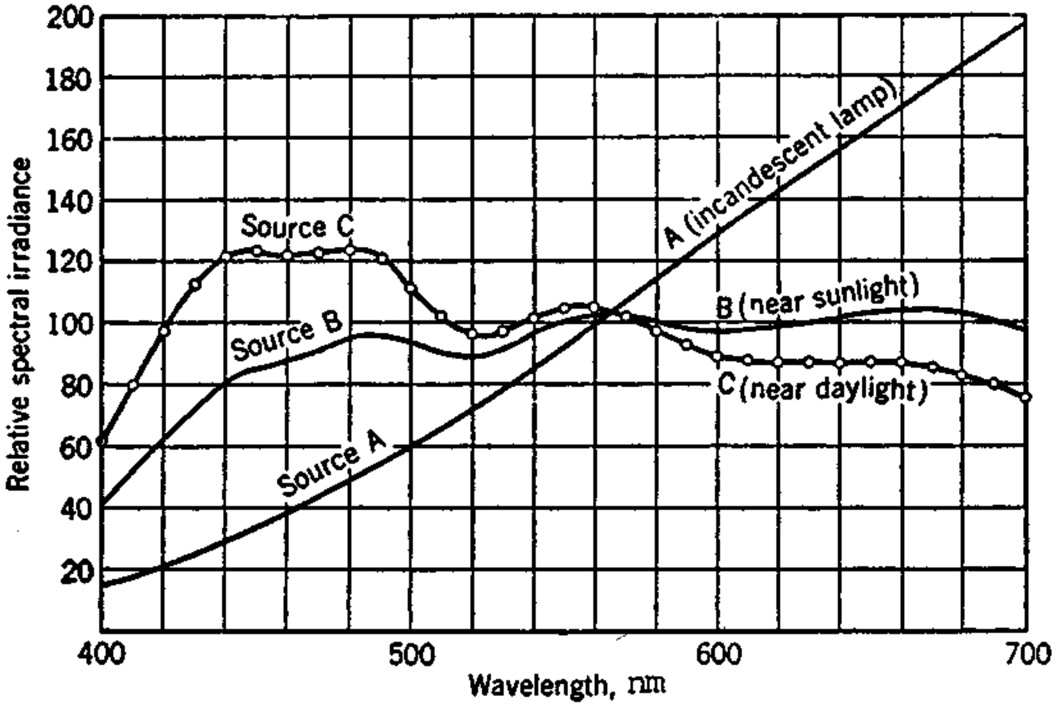

Fig. 3. Relative spectral energies from standard CIE Sources, A, B and C.

upgraded cutting industry, a new public confidence in gemstones, and a thriving marketplace for dealers.'

Methods and instruments for gemstone colorimetry

Apart from the colour-matching charts and colour sample collections, there are two other fundamentally different methods currently used in gemstone colorimetry. They are termed 'visual tristimulus colorimetry' and 'photoelectric colorimetry'.

These devices, whilst much more costly, have many important advantages over the colour reference charts. They can embrace a larger colour gamut; they require no awkward interpolations since the reference colours are stepless; they possess built-in, or can produce, CIE-approved light sources and viewing arrangements; they have no need of sets of calibrated reference gemstones, and they yield less subjective and more accurate and realistic measurements of a gemstone's body colour.

Visual CIE Tristimulus colorimeters. These instruments depend on the visual comparison of two coloured object surfaces (or of transparent bodies) or their optically-manipulated images. One of these is the gemstone under test. The other is that of the calibrated reference standard. The CIE conditions of viewing for colorimetry in general are quite rigorous. They are:–

a. The two structureless comparison fields must be separated by a sharp dividing line.
b. This bi-partite field of view must be restricted so as to have an angular subtense not greater than 4°.
c. The white light illuminating the pair of objects must conform to one of only three light sources approved by the CIE. These are described as Source A(S_A), Source B(S_B) and Source C(S_C). Their relative power emissions as a variation with wavelength are shown in the graph of Figure 3. It can be seen from this that S_C has a much higher proportion of violet-blue light ($\lambda = 400$ to 480 nm) to red light ($\lambda = 630$ to 700 nm) than S_A (see Appendix 1 for more details).
d. The illuminating and viewing geometries must conform to any one of four specified arrangements.

When the above conditions are fulfilled, observers with normal colour vision show an extremely high sensitivity to minute colour differences. There are usually few serious discrepancies in field matches between different observers who have passed a colour vision test.

Further details of the CIE requirements are outlined in various publications(7,13,14,15).

Photoelectric colorimeters. These instruments should be of particular interest to those who prefer their colour measurements to be undertaken by a dispassionate machine. Their use would remove all the eight 'nuts-and-bolts' objections already mentioned. The devices are so contrived that an individual's colour-measuring decisions are taken over by a hypothetical 'eye', so that even a colour-defective operator can produce accurate measurements.

This mathematical ideal eye is the creation of the CIE and is termed the 'CIE Standard Observer'. It consists of a table of numbers which represents a statistical account of the visual colour responses of some 52 actual colour-normal observers. These numbers are called 'CIE colour-matching functions' or distribution coefficients, $\bar{x}_\lambda,\bar{y}_\lambda,\bar{z}_\lambda$. They are shown plotted against their wavelengths in Figure 4. These curves are really the basic data of the CIE system and in effect define how the 'standard observer' sees any given colour. All else in the CIE system can be derived from them, including the extremely useful chromaticity diagrams(1,5,7,15,16).

The contrivance which makes use of these curves is the recording spectrocolorimeter which is the most fundamental of several of these psychophysical, non-subjective instruments. Its purpose is to break down first the component spectral energies of the light received from the coloured object, whether it be from a reflecting surface or from a transparent body. The instrument used by research gemmologists to carry out this task is called a spectrophotometer. A diagram of its usual form, operating in the transmission mode, is shown in Figure 5. The results of an operating run made by it on a faceted Thai ruby is presented as the print-out reproduced in Figure 6. Such a graph contains all the basic information needed to build up a complete picture of the gemstone's colour *under any specified kind of illumination*.

Table 1: Colour appearance systems and colour atlases

Name of colour-order system and atlas	Country of origin	Year of introduction	Colour space notation	Number of colour samples	Approx. cost (1986)	References
CIE Tristimulus Colour System	International	1931	X,Y,Z,	none	—	1,3,4,13,14,19
Munsell Book of Color*	USA	1943	H,V,C	1566	£700	1,4,7,10,13, 19,24
DIN-6164 Colour Chart	W. Germany	1960	T,S,D	585	£150	13,19
ISCC-NBS Centroid Colors	USA	1964	H,V,C	251	£30	1,20,21
Munsell Limit Color Cascade	USA	1974	H,V,C	816	£40	Tintometer Ltd.
CIE 1976 (L*u'v') Colour Space	International	1976	L*,u',v'	none	—	5,8,15,16
CIE 1976 (L*u*v*). Known as 'CIELUV'	International	1976	L*,u*,v*	none	—	1,5,8,15,16
OSA Uniform Color Scale	USA	1977	L,j,g	558	Unknown	22
Natural Colour System. Known as 'NCS'	Sweden	1979	s,c,ø	1412	£140	23
SVF Formula Colour Space	Norway	1986	Vy,F_1,F_2	none	—	24

* The Munsell Color Notation was first published by A. Munsell in 1905 and the first Atlas of the Munsell Colour System was made commercially available in 1915. However, it was not until 1943 that a new renotated Munsell Book of Color was linked to the CIE (1931) system, as indeed are all the other systems and atlases listed above.

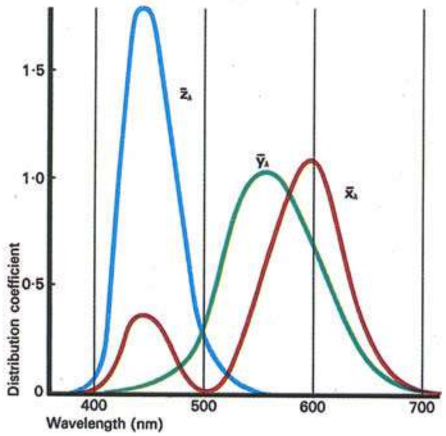

Fig. 4. CIE colour matching functions for an equal-energy white light (CIE Illuminant E).

This is accomplished by mathematically combining the three fundamental elements needed to produce the CIE tristimulus colour values, X,Y,Z(13,14,16). These three elements which are essential in producing the sensation of colour, listed together with their numerical expressions, are:–

1. The light source. This is expressed as the spectral power distribution of the chosen CIE standard or non-standard illuminant. It is important to appreciate that actual CIE *sources* are not required here, only illuminants (see Appendix 1).
2. The object's colouring characteristics. This is expressed as the percent transmittance (or reflectance) of the object with respect to wavelength (λ) and is obtained by means of the spectrophotometer (see Figure 6).
3. The 'eye' of the CIE 'Standard Observer'. This is expressed as the CIE distribution coefficients $\bar{x}_\lambda,\bar{y}_\lambda,\bar{z}_\lambda$ (see Figure 4).

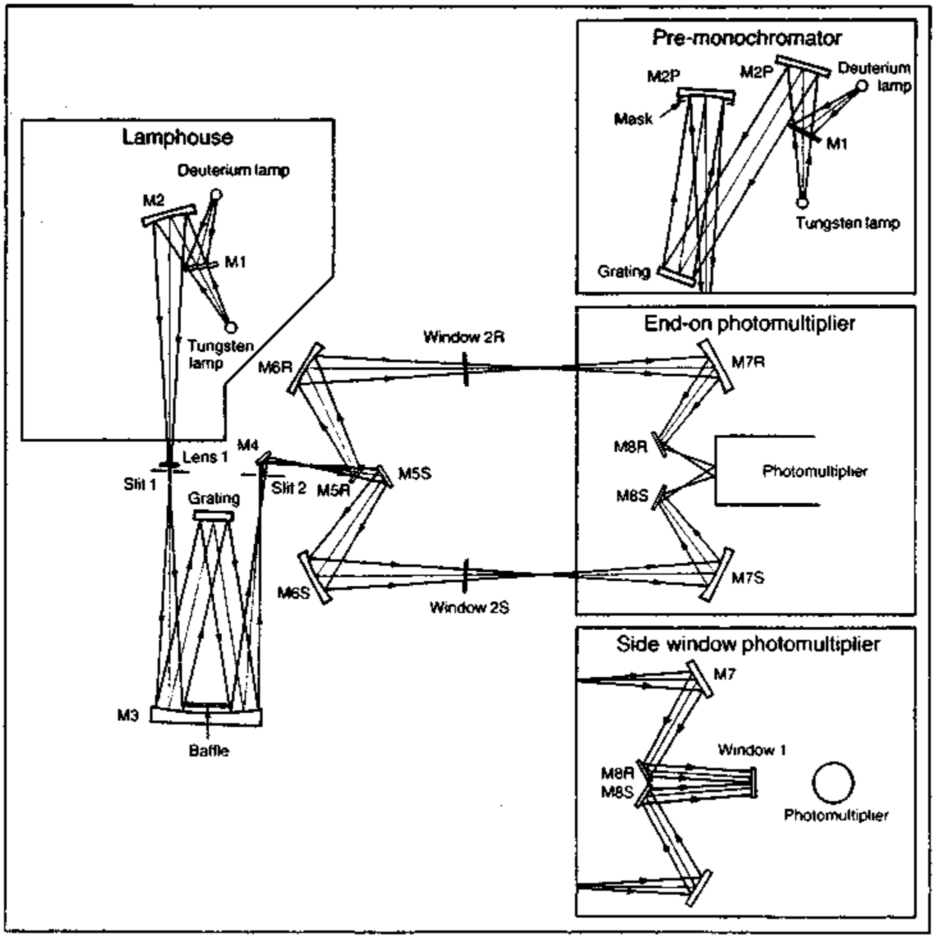

Fig. 5. Optical design details of the Pye Unicam (PU8800/03) UV-visible spectrophotometer (Basil Anderson model).

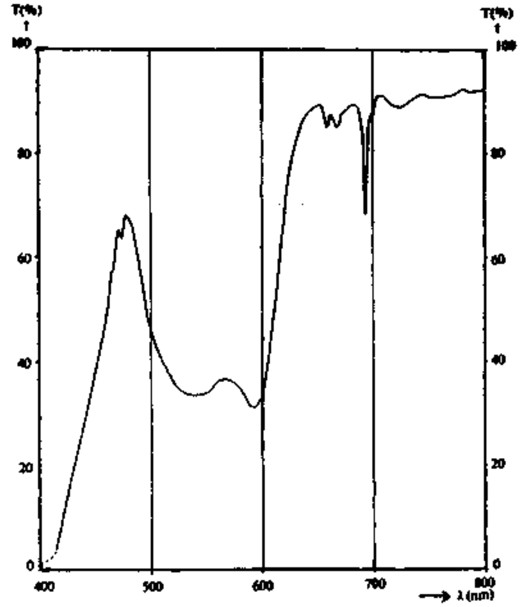

Fig. 6. Results of a spectrophotometer transmission scan through the visible region. The specimen was a faceted Thai ruby immersed in a cell filled with methylene iodide (di-iodomethane). Reference No. 38.

A microcomputer is attached 'on-line' to the spectrophotometer; the combination now becomes a spectrocolorimeter. All the relevant CIE data and computing instructions are stored in the memory. Once the object's colour characteristics have been measured and transferred to the microcomputer, the instrument automatically delivers the X,Y,Z co-ordinates for the selected light source.

Up to this point, only a spectrum and three colour co-ordinates have appeared in the VDU of this 'black box'. As colour is something which is seen, some means must therefore be provided for visualising the actual colour appearance which these raw, quite incomprehensible numbers represent. To this end, the microcomputer can be programmed to transform the X,Y,Z, co-ordinates into those of the many colour-appearance spaces and three-dimensional systems now in current use. With the exception of the CIE system itself and that of the SVF notation, the perceptual colour order systems shown in Table 1 have material colour standards associated with them. These are in the form of collections of systematically-ordered painted or printed colour samples or chips.

Each colour-space system has its own virtues and shortcomings, so that a suitable one must be selected for the purpose in hand. Useful guidance is given by Judd and Wyszecki(13), Wright(17) and Tonnquist(18).

Photoelectric tristimulus colorimeters. These operate on a quite different principle from that of the spectrocolorimeter. They are devices which automatically evaluate the CIE tristimulus values of a given sample without making use of the human eye.

In practice, the sample is suitably positioned so as to receive white light from a stabilised source. The light passing from the sample, either by transmission or reflection, is conducted to specially-designed red, green and blue filters. Photocells lying behind them are used to measure their transmitted light intensities. The combinations of the spectral characteristics of the light source, the filters and the photosensors are so chosen that their separate responses match exactly those of the 'Standard Observer' curves of Figure 4. A white reference sample is used to balance the photocurrents of the sensors so that the three readings obtained on a test sample are directly proportional to its X,Y,Z values.

To produce such a device which is reliable, flexible in use, accurate and of a low cost, is a very tall order indeed. Since the first attempt was made in 1915(27), enormous efforts have been made in trying to attain this goal. The degree to which commercial instruments have been successful in duplicating the desired distribution coefficients has varied greatly from one to another. Maintenance of the calibration is especially difficult. As only one kind of illuminant is possible, alexandrite effects cannot be measured. In no manner can even the best be compared in accuracy with that of the spectrocolorimeter.

An attempt to use this kind of colorimeter for gemstone colorimetry has recently been described(25,26), but no results have yet been reported.

Existing visual CIE tristimulus gemstone colorimeters

Returning to these types of instruments, so far only two have been developed for gemstone colorimetry. They are the GIA 'ColorMaster' and the Nelson-Lovibond Gemstone Colorimeter.

The GIA ColorMaster. This instrument uses the principle of additive coloured lights (red, green, blue) for generating a colour-matching field and comparing this with the body colour of a gemstone. It does this by flooding a colourless translucent gemstone representation with a mixture of red, green and blue lights. The relative intensities of these lights can be controlled and the resulting colour-matching photocell values presented as digital readouts. The device is illustrated in Figure 7.

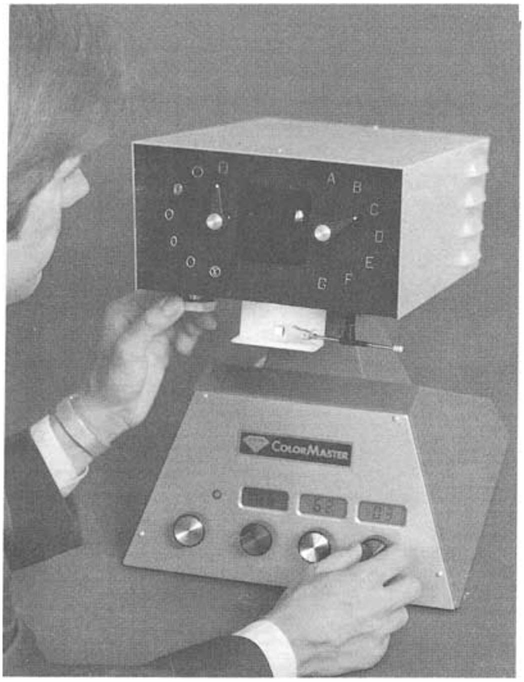

Fig. 7. The 'GEM' ColorMaster of the GIA.

In the patent declaration of the invention[28], its stated main purpose was to enable two jewellers to exchange by telephone a numerical description of the colour appearance of a selected gemstone. For this to happen, both jewellers were obliged to possess identically-calibrated ColorMasters, one to analyse and one to synthesize. In an effort to surmount this limitation, the manufacturers supplied instructions for transforming these ColorMaster readings into CIE co-ordinates, x,y,Y, for either 'tungsten' or 'daylight' viewing. However, as none of the four CIE requirements are even remotely fulfilled, such co-ordinates have no scientific validity.

A recent article on a proposed new classification scheme for gem-quality garnets[29] presented a CIE chromaticity diagram showing plots for 202 garnets. Apart from possessing no basis in colour science, the diagram also possessed no achromatic ('white') plot! Thus one is unable to learn whether an S_A or S_C light source was used, if indeed it were possible to achieve either with this apparatus.* This unfortunate omission means that the values of x and y cannot be transformed into the more comprehensible colour-appearance quantities, λ_d and p_e. Even

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* An earlier article[30] places the neutral point used as $x=0.3604$; $y=0.3483$. This corresponds to a light source having the properties of a reddish-purple S_R.

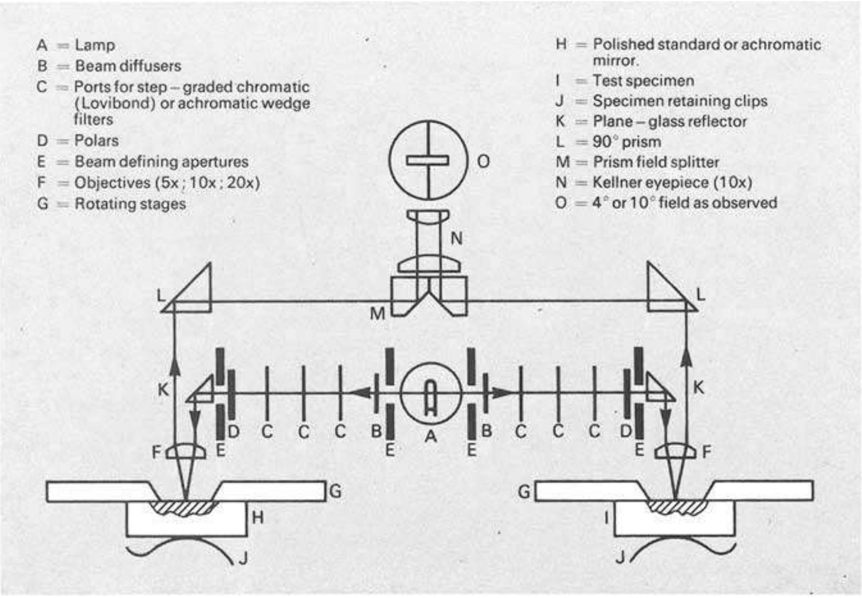

Fig. 8. Illuminating and imaging beam paths in the Nelson-Lovibond visual tristimulus microcolorimeter. Specular reflection mode.

those numbers do not provide all the information needed to convey the full colour appearances. The third necessary co-ordinate, Y, was also omitted. As these multiple errors have been compounded by describing the diagram contents as having a 'tone level 5', whatever that might mean, this item in an otherwise superb contribution should not go undeplored.

Happily, most of the many users of the Color-Master seem to have decided not to use the CIE conversion formulae. The main uses in the U.S.A. appear to be that of a jewellery sales promotional aid, a component of the new computer-trading networks for gemstone exchanges and as a rather expensive colour educational tool for trainee gemmologists. A frank and informative discussion of the instrument and its use has been given by Federman$^{(31)}$.

The Nelson-Lovibond Gemstone Colorimeter. This device uses the principle of subtractive coloured lights (cyan, magenta, yellow) for producing a colour-matching field. The Lovibond Tintometer instrument and its derivatives have had a long and successful history in their many industrial applications. Their construction and use are well documented$^{(7,13)}$, so there is no need for further descriptions.

Some 10 years ago, with the kind co-operation of Tintometer Ltd, the author used the basic heart of the system, the calibrated glasses, to produce an apparatus for the rapid identification of any of approximately 300 metallic ore minerals$^{(32,33)}$. This was done by measuring the specular colour of a minute area on the polished section of a polycrystalline ore. It was the first visual tristimulus colorimeter to yield the CIE co-ordinates, x,y,Y for the Sources, S_A and S_C for coloured areas down to 30 micrometres diameter. This could be done for both the reflection and transmission modes. The illuminating and imaging beam paths for this microcolorimeter, shown in the specular reflection mode, are illustrated in Figure 8.

The instrument was then modified to measure not the specular, but the diffusely reflecting light from similarly minute areas. For example, it was found possible to measure the colours of the individual paint layers on automobile body finishes. The up-ended and polished multiple-layered paint fragments from say a hit-and-run accident could easily be measured, and numbers rather than words, fed into a central police computer data base. Another successful application was the colour measurement of certain groups of flower pigments. The colour of an area of only about four plant cells across could be measured before chemical deterioration took place$^{(34)}$.

Encouraged by these and other successes, the author decided to grasp the gemstone nettle. The general difficulties which Lewis predicted$^{(4)}$ soon became apparent, but the greatest problem was to find the only acceptable way to guide the measuring light beams into and out of the gemstone.

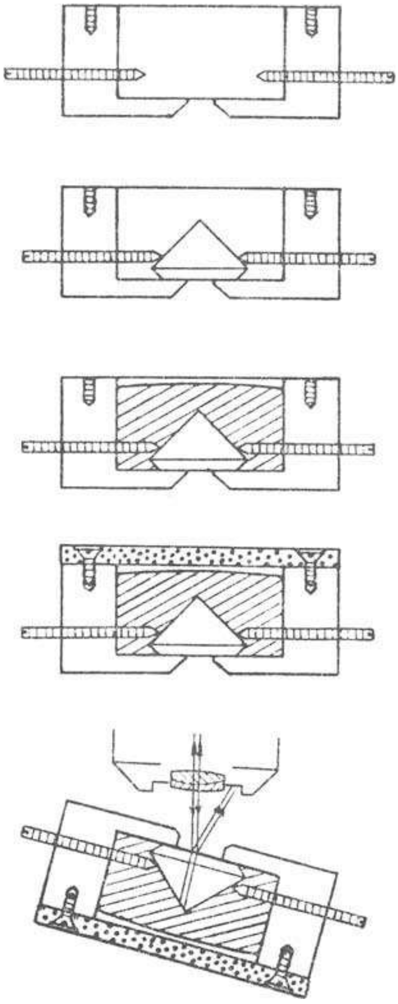

Fig. 9. Mounting and illuminating-viewing details of the Nelson FMIR gemstone mounting technique.

A physicist would probably describe a brilliant-type cut gemstone as 'a wavelength-dispersive, off-axis, retroreflector'. This means that for the stone to perform its task, the light striking or entering the crown should be returned to the eye of the beholder, bringing with it any 'fire' but not returning any desaturating external specular reflections. After much pondering and experimenting the author stumbled on a rather neat way of doing this,

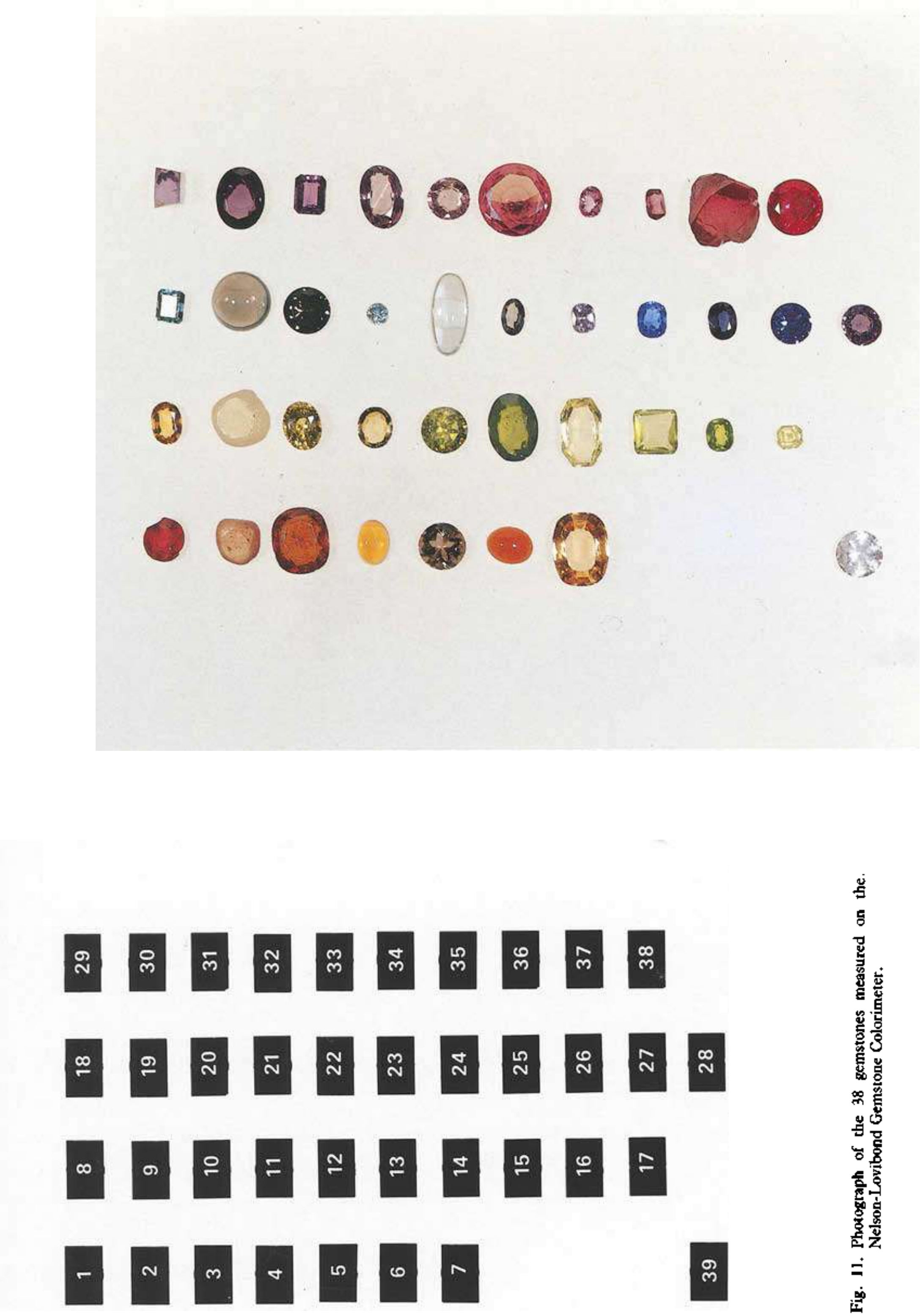

Fig. 11. Photograph of the 38 gemstones measured on the Nelson-Lovibond Gemstone Colorimeter.

Table 2: CIE Tristimulus Colour Co-ordinates of 38 gemstones measured with the Nelson-Lovibond gemstone colorimeter

CIE source A (x=0.4475; y=0.4074) Colour space,x,y,L*

Stone No.	Gemstone	Origin	Weight	Polar Co-ordinates			Colour Classification	Dominant Wavelength range λ_d (nm)
			Carats	λ_d (nm)	p_e	L*		
1	Spinel	Burma	3.45	635.0	75.7	31.2	Red	700 to 630
2	Garnet rough	Kenya	6.03	620.0	33.9	56.6	Orange	630 to 590
3	Garnet, hessonite	Sri Lanka	8.65	611.0	92.6	26.4		
4	Fire opal	Mexico	1.98	604.5	92.5	45.2		
5	Quartz, smoky	Switzerland	3.86	599.5	26.4	42.3		
6	Cornelian	India	2.11	596.0	54.6	42.6		
7	Topaz	Brazil	10.21	590.5	54.2	86.5		
8	Amethyst, H.T.; citrine simulant	Brazil	1.76	589.0	90.0	73.4	Yellow	590 to 570
9	Rutile, synthetic	Linde, USA	8.65	586.0	26.1	61.6		
10	Zircon, normal density	Sri Lanka	5.96	585.0	67.8	64.2		
11	Chrysoberyl	Sri Lanka	1.95	583.2	59.8	78.9		
12	Sphalerite	Mexico	5.45	581.8	75.0	39.9		
13	Zircon, low density	Sri Lanka	7.44	578.0	78.3	33.4		
14	Beryl	Madagascar	4.78	576.5	25.7	95.7		
15	Peridot	Zabargad	3.87	571.5	48.9	69.2		
16	Demantoid	USSR	1.60	561.0	59.4	55.4	Yellow-green	570 to 550
17	Tsavorite	Kenya	0.88	552.1	28.7	50.4		
—	None		—	—	—	—	Green	550 to 510
18	Emerald, synthetic	Linde, USA	1.35	505.0	49.6	49.9	Blue-green	510 to 480
19	Spinel, synthetic, simulated tourmaline	Unknown	10.00	499.2	18.8	31.6		
20	Spinel, synthetic, simulated tourmaline	Unknown	3.77	493.5	35.6	11.3		
21	Zircon	Cambodia	0.67	492.3	20.3	47.0		
22	Spinel, synthetic, aquamarine simulant	Unknown	8.92	489.0	24.4	83.3		
23	Spinel	Sri Lanka	1.08	481.1	7.8	55.6		
24	Tanzanite	Tanzania	0.73	480.4	17.9	65.7		
25	Spinel, synthetic, sapphire simulant	Unknown	2.81	480.0	65.9	32.3		
26	Sapphire	Australia	1.55	479.3	59.0	19.6	Blue	480 to 450
27	Glass, sapphire simulant	Unknown	2.06	474.0	73.6	28.6		
28	Spinel	Sri Lanka	3.80	472.0	24.3	26.4		
—	None			—	—	—	Violet	450 to 400
29	Tanzanite, oriented cube, 'C' axis	Tanzania	5.73	C577.8	29.5	31.9	Violet-purple	C579 to C575
30	Spinel	Sri Lanka	6.54	C571.8	44.3	13.8	Mid-purple	C575 to C555
31	Amethyst	Tanzania	2.01	C567.1	48.5	43.5		
32	Amethyst	Thailand	5.08	C561.5	19.8	61.0		
33	Spinel	Sri Lanka	3.00	C554.5	17.6	49.0	Red-purple	C555 to C504
34	Sapphire, alexandrite simulant	Unknown	13.69	C535.5	35.6	47.2		
35	Ruby, pink	Sri Lanka	1.30	C521.0	31.2	60.5		
36	Almandine	Sri Lanka	0.90	C511.0	51.8	32.3		
37	Almandine, rough	Kenya	20.03	C509.0	64.8	28.4		
38	Ruby, synthetic	Unknown	7.23	C504.5	76.6	32.5		
39	Spinel, synthetic (Reference)	Unknown	4.27	None	0.0	100.0	Colourless	—

Note: C579.0=400 nm; C503.9=700 nm

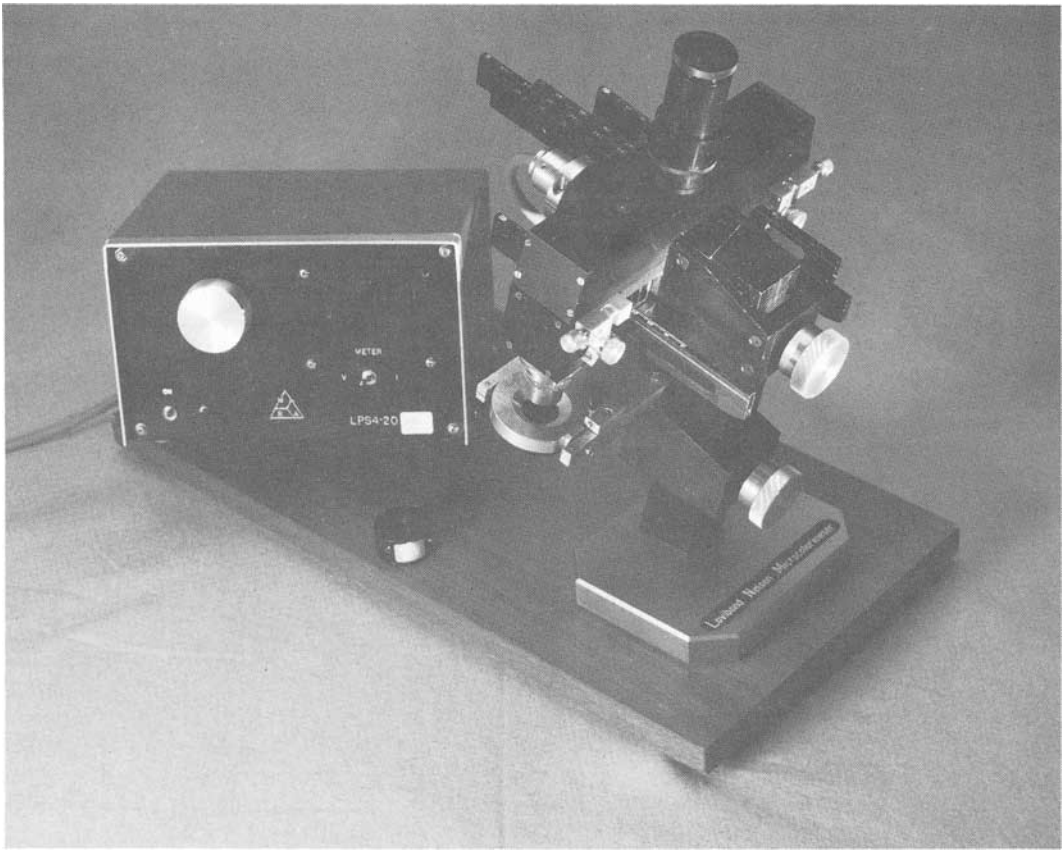

Fig. 10. The Nelson-Lovibond Gemstone Colorimeter. Five colour-matching slides containing the calibrated Lovibond filter glasses can be seen inserted into the beam paths. A constant-intensity CIE Source A is maintained by the mains-stabilised power supply. A FMIR mount can be seen beneath this.

but excluding the 'fire'. The method, which he has termed 'frustrated multiple internal reflection' (FMIR) is best explained by way of Figure 9.

The stone, of any shape or size, is placed in the empty metal cell. The cell has four loosely-fitting screws which serve to centre and hold the stone in position. A thick silicone rubber monomer suspension of a pure-white pigment such as barium sulphate, or the anatase form of titania, is poured into the cell so that it entirely surrounds the stone, except for the table facet. The gentlest of pressures on the screws is enough to prevent leakage through the cell's bevelled aperture. When the silicone rubber has polymerised, through the prior addition of several drops of curing liquid, a lid is screwed on top of the cell to prevent any disturbance of the gelled but flexible rubber.

The cell is now inverted and placed on one of the tilting substages of the colorimeter shown in Figure 10. The cell is tilted at an angle just sufficient to direct the specular reflection from the table facet so that it does not enter the objective lens and is trapped in the objective's annulus (see Figure 9).

In operation, the well-defined and directed light beam, descending from the microscope objective, enters the mounted stone. Here it is deflected slightly by refraction and passes through the stone until it meets the interface between the stone and the white rubber. As the flexible rubber is in direct optical (i.e. 'wetted') contact with the stone, the normal internal total reflection does not take place (i.e. it is frustrated). Instead, the light enters the white rubber near to the culet and is diffused. This diffuse patch of light is able to return back along the original beam path and is collected by the objective. The collected light is then delivered to the comparison eyepiece. Here, it is joined with a similar structureless patch of white light received from a colourless reference stone. This stone has been mounted in an identical manner to that of the test stone and held on the other tilting substage. In this manner, the total ray-path length is much the same as that met with in the normal viewing aspect of a gemstone.

The matching procedure itself can be better seen from Figures 8 and 10. Before the white light reaches the eyepiece, it is intercepted by the calibrated coloured Lovibond glass filters. These are mounted in nine metal slides, each bearing 10 filters. A colour match in the eyepiece is achieved by sliding into the beam path the appropriate combinations of pairs of the Lovibond chromatic filters (magenta plus yellow; yellow plus cyan; cyan plus magenta) together with neutral (achromatic) density wedges. The subsequent procedures for converting the matching Lovibond glass numbers and the visual optical density readings into the CIE co-ordinates, x,y,Y are thoroughly dealt with in Reference 7.

The colorimeter was used to obtain the CIE co-ordinates for S_A of 38 coloured stones, mostly faceted, but some as cabochon-cut and some as rough pebbles with a polished window. They are shown in Figure 11. They were mounted using a proprietary pure-white preparation known as 'Silcoset 105'. A colourless, brilliant-cut synthetic spinel was used as the white, neutral reference stone (Stone No 39). The results are presented in Table 2, with the measured x,y,Y Cartesian co-ordinates converted into the λ_d, p_e, L^* colour-appearance polar coordinates. The stones are also shown in Figure 12 positioned within this colour space and occupying the point positions representing their body colours. The envelope of optimal colours, known as the MacAdam limits(13,19) is shown in Figure 13 as a Perspex model of the same S_A colour space. The boundaries of this model represent the maximum possible value of L^* for a given chromaticity (x,y), assuming that the objects do not fluoresce. All the colours of the gemstones are seen to lie within this most interesting and useful colour volume. A chromaticity chart projection of it is given in Figure 14.

When these modifications and measurements were first described(35), the author naively believed that as gemstones were usually displayed sold and worn under tungsten lighting conditions, S_A would be the ideal source. He learned later that traders insisted upon a daylight source or its (non-CIE) simulant. (See Appendix 1). An attempt was then made to convert the instrument's S_A source to S_C by means of a Davis-Gibson liquid filter(14,19), but it proved to be much too absorbing to cope with stones of low L^*. Rather than design a more luminous and complex optical system, it was decided to abandon further marketing of the colorimeter for gemstone use. However, the invention of the 'FMIR' mounting technique during this period has since been put to good use in the construction of a low-cost spectrocolorimeter. This is now in the preproduction stage.

The FMIR mount†

The considerable advantages of the FMIR mounting technique are worth listing:–

1. The microscopical examination of the gemstone's illuminated surface and interior allows the user to detect the presence of both surface and internal imperfections. This makes it possible to move the cell across the substage so as to keep these scattering or obscuring centres well out of the narrow beam path. False results are more likely to ensue when a stone's table facet is applied blindly to an instrument's entrance port.
2. The microscopic control also allows the incident light beam to be directed as closely as possible to the culet. It ensures that the total chromophore path length is virtually the same as that encountered in everyday viewing. A coloured stone is judged by the buyer only when it is table face up as in gem-set jewellery. This is not the situation with conventional transmitted light spectrophotometry. Here, the shorter ray path options are few because gemstones are designed as retroreflectors. Figure 15 illustrates the fact that the only practicable pathway through most stones is by an entry through a crown facet and an exit through a nearly parallel pavilion facet.
3. Other means for collecting radiation from faceted gemstones for spectrophotometry have been proposed. The integrating sphere is one such technique, but Collins(37) has shown that this is not without its own colour-distorting perils. In another, the stone is supported on a clamp in a liquid immersion cell, using an optically-compatible liquid. This has been employed for investigating both visible(38) and infrared(39) spectra.

   The FMIR technique is free from the various constraints imposed by these methods. It should also be able to cope with ultraviolet measurements.
4. In the above 'crown facet ⟷ pavilion facet' beam paths, incident polarised light is often used in academic studies for isolating pleochroic colours. Polarised light has absolutely no place in colour grading work as human vision cannot detect it without the use of an analysing polar. If

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† The author has decided not to exercise his patent rights on this invention. If gemmologists or other designers of spectrocolorimeters find it useful, they may feel free to use it. If they do so, all that is wished for is that due reference be made to this article.

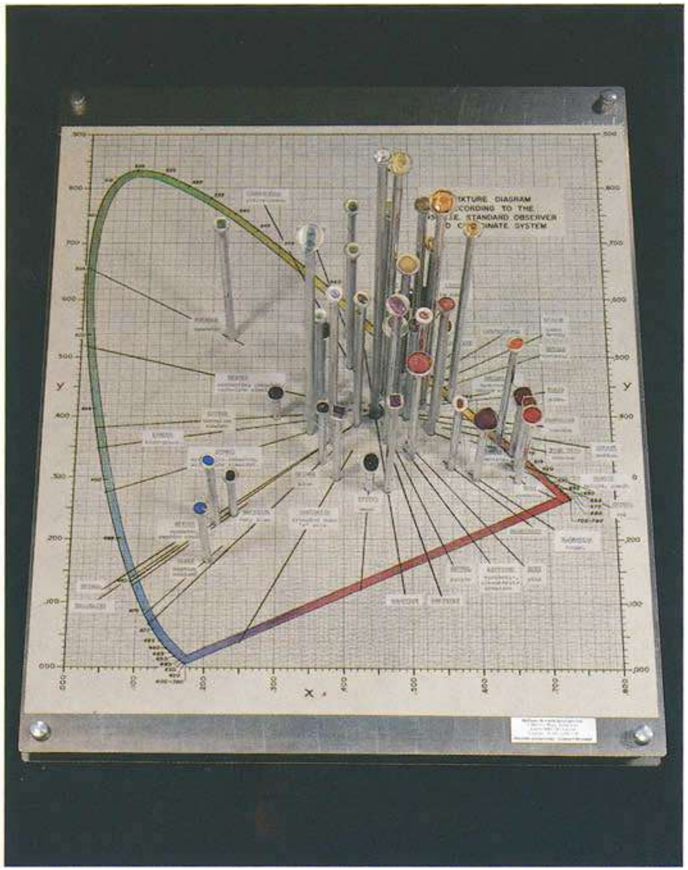

Fig. 12. The 38 measured gemstones arranged to show their colour point locations within the CIE colour space, x,y,L*. CIE Source A. The topmost stone is that of the colourless white spinel used as the white (neutral) reference standard ($p_e=0.0$). Its co-ordinates are x=0.4475; y=0.4070; L*=100.0.

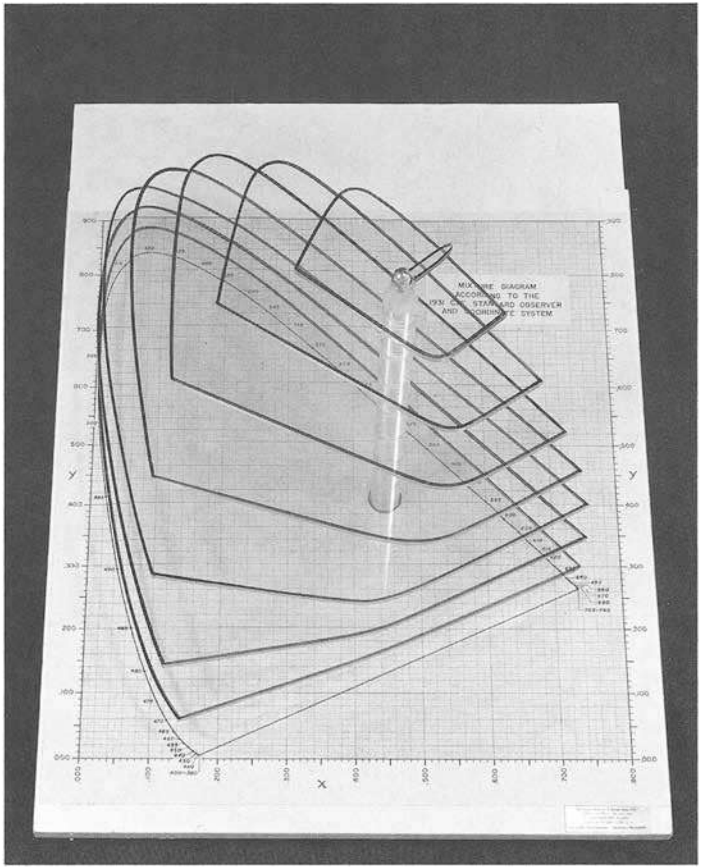

Fig. 13. A perspex model of the MacAdam Limits (optimal colours) for x,y,L* colour space. CIE Source A.

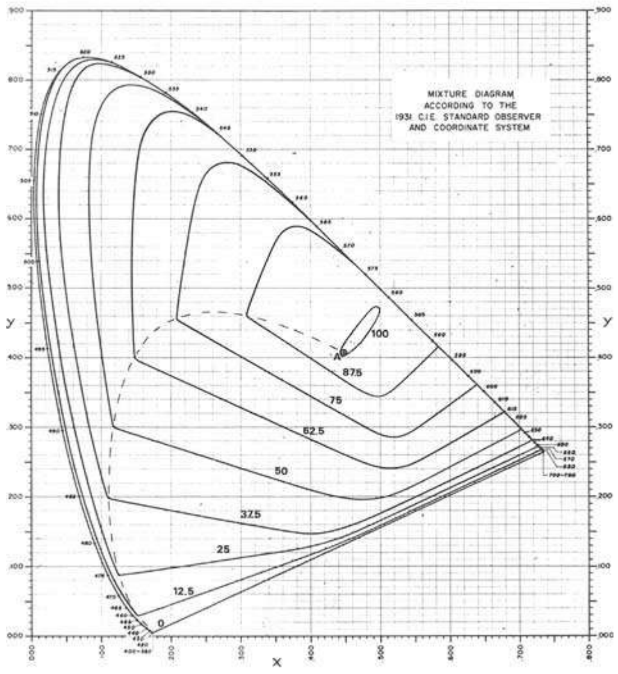

Fig. 14. Chromaticity loci of optimal colours.

pleochroic colours are present in the 'trans-reflected' or 'remitted' beams from FMIR mounts, the eye itself or the photosensor will mix these colours quite effectively.

5. The technique eliminates falsely enhanced hue and saturation measurements arising from stray dispersion effects. Dispersion 'fire' is quenched by the frustration of all multiple internal total reflections. Also, the removal of all specular surface reflections and all internal reflections means that desaturation of the observed body colour cannot occur.
6. The absence of a bulky metallic gemstone support ensures the absence of disturbing scattering effects.

   The four small metallic points of contact in the FMIR mount are virtually invisible. Indeed, it was found possible to measure a gemstone set in a gold finger-ring which had been invested with the white silicone rubber.
7. The size and shape of the stone is unimportant. All that is required is a single polished flat face having a diameter slightly greater than that of the cell's aperture of 2.5 mm. This could be helpful in assessing the potential of costly gem mineral rough before commencing faceting.
8. There is a useful by-product of the technique. After measurement, the stone is easily parted from the mounting, using only the fingers. The two parts of the separated mount are fitted together and secured with plasticine. This now becomes a mould. If this is filled with a two-part epoxy cement, preferably mixed with a little flake aluminium powder, a positive replica is obtained. This constitutes a faithful, permanent, geometrical record of the girdle and all the pavilion facets. Using an optical goniometer, the author found an exact correspondence between the interfacial angles of an emerald's pavilion facets and those of its aluminium-pigmented epoxy casting.
9. Within the recommendations laid down by the CIE for the illuminating and viewing conditions, it must be said that this technique does not comply strictly with any of the four specified arrangements. The two which most closely approach it are termed the 0°/45° and 45°/0° geometries whereas the FMIR mount would be

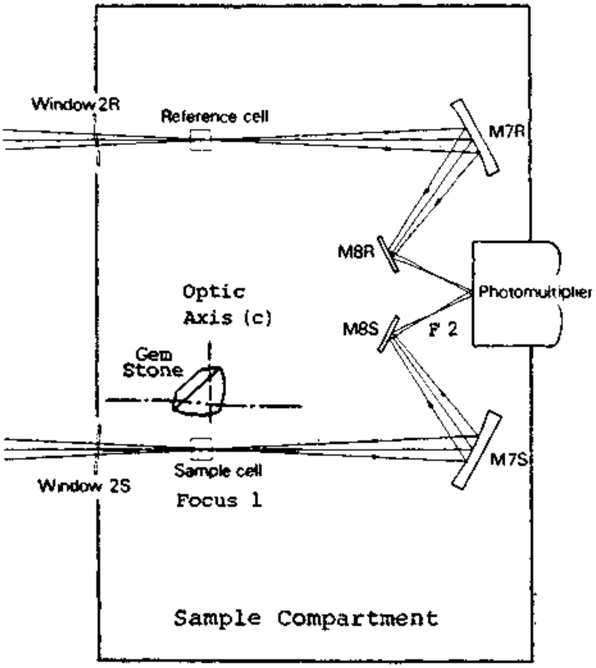

Fig. 15.
The sample compartment of a spectrophotometer showing the only possible transmitted light beam path in air through a well-cut faceted stone. The position of the stone is shown at the first focus (Focus 1) of the incident beam. An alternative position for small stones is at the second beam focus (F2). Reference 36.

described as an approximate 45°/45° geometry. To see if the FMIR mount gave comparable results, three of the 12 tiles of the second series of the Ceramic Colour Standards(40) were measured using a 45° tilt angle and S_A source. The chosen tiles were Deep Blue (No 1), New Yellow (No 4) and Bright Red (No 6). Good, acceptable agreements were obtained.

Discussion

From the views expressed and the instrumentation described here, there are several conclusions which can be drawn which are almost self-evident.

It is clear that the tools needed to characterise numerically the body colour of a gemstone are already in place. When any of the currently available spectrophotometers are linked to a suitable sampling arrangement, such as the microscope/FMIR mount unit or some similar device, together with a computer, then this combination becomes the tool par excellence, the gemstone spectrocolorimeter. Photoelectric tristimulus colorimeters should be regarded with caution.

The existing spectrophotometers were designed mainly for biological and health-care laboratories. As they represent only one component of a gemstone spectrocolorimeter, they are unnecessarily elaborate and therefore costly (about £25,000 with ancillaries). With the imminent appearance of a new generation of gemstone spectrocolorimeters, designed purely for gemstone colorimetry, prices will fall dramatically. For example, it is envisaged that a complete unit, yielding CIE values of X, Y, Z; x, y; λ_d, p_e; u', v'; L^*, u^*, v^* for the Illuminants A, C and D65, will cost about £3,500 and be in production within 18 months.

In practice, the obscure CIE numbers from spectrocolorimeters require transforming into actual colour-appearance samples. Although some of the gemstone colour-grading charts (Appendix 3) are no doubt useful, the low-price alternative forms of the American Munsell and the Swedish Natural Colour chart systems are easily the best choices. Curiously, both contain more of the saturated colours than their costlier parent systems. The little-known Munsell Limit Colour Cascade costs £40 as against £700. The NCS Index costs £47 against £140. (Table 1).

It is an open question as to which is the preferable colour collection. The Munsell atlas has sold over 50,000 units and this guarantees it a durable future. Although the NCS atlas is only but two years old, it has the greater advantage of having a simple, valid, numerical 'language' by which it can call to mind and describe the perceptions of colour and colour combinations. Because of the low costs, both can be tested together, so that experience alone can decide which is best for use in gemstone colorimetry.

The only reason to refer to the Universal Color Language[20,21] is to demonstrate its clumsiness and imprecision. As in a previous plea[1], it is to be hoped that the desire to employ numbers rather than words will prevail in gemmological colorimetry.

In spite of the existence of suitable hardware, almost impenetrable barriers still exist in the trade to the ready acceptance of gemstone colour measurement. Most of the reasons which prop up these barriers have been touched upon here.

Nevertheless, there is evidence of the beginning of some activity towards their removal. An 'International Gemstone Standards Committee' has been inaugurated which is concerning itself with colour grading issues. Several conferences and seminars have recently been held which dealt with this topic, although rather cautiously. Interest seems to be the greatest in America where gemstone computer networks are proliferating. South East- and Far East- Asian countries are following closely behind, but both apathy and hostility still prevail in the European marketplace. Rouse's rousing clarion call has not been heard there.

It is highly probable that it will be the international buyers and customers, as always, who will ultimately cause the barriers to come down.

Appendix 1

Light sources

The terms 'CIE Illuminant' and 'CIE Source' have caused much misunderstanding. To draw the crucial distinction, the CIE sanctions the use of four standard *illuminants* for colorimetry[14]. Three are described as 'standard light *sources*' and directions are specified for their production. The first, S_A, represents an incandescent tungsten lamp operating at a colour temperature of 2855K. The second and third sources, S_B and S_C, are produced by filtration of the source S_A through rigorously specified liquid filters. They are intended to simulate 'direct noon sunlight' (correlated colour temperature of 4875K) and 'north noon diffuse daylight' (correlated colour temperature of 6775K) respectively. All are relatively easy to produce[1,7,13,14]. (See Figure 3).

The fourth standard illuminant, D65, is not a real source. It consists simply of a numerical table of the spectral power distribution representing a particular phase of daylight having a correlated colour temperature of 6500K. It is used in conjunction with spectrophotometers to calculate the CIE Tristimulus co-ordinates of object colours, and plays no part whatever in practical visual colorimetry.

Other non-standard illuminants simulating other phases of daylight are sanctioned. These cover a correlated colour temperature range of 4000K to 25000K (e.g. D55, D75 . . .). Because of serious practical obstacles, the CIE is highly unlikely in the foreseeable future to recommend the use of an actual light source as a simulant to any of the 'D' series of illuminants. Indeed, it has even withdrawn its recommendation for the use of 'S_B'.

A good example of this common misapprehension is given in the CIBJO publication 'Rules for the Diamond Trade' (1980). Article 3(3) requires that the stones must be colour-graded ". . . under normalized artificial light equivalent to approximately 5500° Kelvin (D55)". As Article 3(6) states that "Photometric measurements have no determinative value", it is difficult to see how these conflicting requirements can be reconciled.

Appendix 2

Comments on 'Trade objections'

As with objections (1) to (5), that of (6) requires little further comment. It is enough to repeat the necessity of using only S_A or S_C light sources; those employing gas discharge lamps must be avoided at all costs.

Given an almost universal non-compliance in gemmology with one or more of the CIE requirements, the views relating to objection (7) are not unexpected. In addition, there is the possibility that the two fields may exhibit 'metamerism'[7,13,19], a colour phenomenon related to the alexandrite effect. It can be present when there is a good colour match under a given light source, but a poor match when using a different source. This situation could arise when fairly saturated purple stones are being examined. Adherence to the use of a single stated CIE source would eliminate this problem.

The feelings expressed under objection (8) spring from a misconception and have no scientific basis. Female colorists are undoubtedly more aware or more conscious of colour sensations than those males who have no colour vision defects. However, it has been found that both groups possess the same colour discriminatory abilities, which is an entirely different matter.

This misconception has arisen because of the fact that 8.1% of the male population have colour vision defects against only 0.4% for the female population. Expressed differently, it means that for every female who has defective colour vision, there are 20 males similarly affected. Thus it would be prudent for the gemstone industry to require those of its male members who are active in the marketing of diamonds and coloured stones to submit to a colour vision check. Normal colour vision can be assumed if an observer is able to pass one of the established and well-conducted colour vision tests, such as those using the Ishihara Charts, the Farnsworth D15 Test or the Lovibond Colour Vision Analyser(7). Those whose colour vision is sufficiently abnormal to be a handicap should not be encouraged to work in situations where critical colour judgements have to be made.

Appendix 3

Commercially-available charts currently used for the colour grading of coloured gemstones

Colour Chart	Supplier
GIA Color Grading Manual	Gemological Institute of America, 1660 Stewart Street, P.O. Box 2110, Santa Monica, California 90406, USA
Gem Dialogue	Kassoy, 32 West 47th Street, New York, N.Y. 10036, USA
Gem Color Manual	Gemlab Research and Technology Group, Box 69024, Vancouver, British Columbia, V5K 4W3, Canada
Gem Color Guide	Gemological Technology Inc., Costa Mesa, California, USA
AGL Color Scan	American Gemological Laboratories, Inc., 645 Fifth Avenue, New York, N.Y. 10022, USA

Note: See also the CIE-linked colour-appearance systems listed in Table 1.

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Spectrophotometric measurements of faceted rubies: critical review of an immersion technique

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Referring to the paper 'Spectrophotometric measurements of faceted rubies' by A. Banerjee, J. Himmer and H.-W. Schrader (*J. Gemm.*, 1985, **XIX**, 6, 489–93) and to the abstract of this article by C.M. Stockton (Gems & Gemology, 1985, **XXI**, 3, 182) and in reply to the Letter to the Editor by Banerjee and Schrader (*J. Gemm.*, 1986, **20**, 2, 135–6), four critical notes must be added to the discussion. For this purpose, a transmittance diagram of two faceted Burma rubies is used to compare the immersion spectra published by Banerjee *et al.* (one of them, Figure 3, shown here as curve A) with a spectrum recorded in air by G. Bosshart (curve B).

1) Banerjee *et al.* (1985) intended to demonstrate immersion in methylene iodide as an advantageous general technique for getting straylight-free absorption diagrams of faceted gemstones in the 400 to 800 nm range. While, for the visible area, we do not negate the feasibility of good-quality absorption spectra of faceted gemstones immersed in certain colourless, light-stable heavy liquids, the two published ruby curves (Figures 3 and 4, pages 492 and 493) do not prove the advantages of the method and should not be termed 'clean spectral diagrams' (Stockton, 1985): both spectra are misleading in part. They show a strange additional transmission peak roughly where the slender chromium absorption band is positioned in any undisturbed ruby diagram (see curve B). The phantom transmission in curve A is an unexplained artefact most likely caused by the methylene iodide immersion technique.

In addition, Figures 3 and 4 are insufficiently resolved: the chromium doublets at 475/476 nm and at 693/694 nm in fact are wide singlets. The alert spectroscopist also notes that the abscissa in Figure 3 (here as curve A) is in error by at least +40 nm. This would be the transmittance diagram of a greenish or colour-changing corundum and not of a ruby.

2) It is not correct to state that absorption curves of faceted gemstones in air in general are negatively affected by 'refraction and reflection of the light beam' and 'cannot be easily reproduced'. Recording in air is successfully done by an increasing number of gemmological laboratories around the world (for the sake of comparability, however, preferably in the absorbance and not in the transmittance mode). In fact, a skilled operator is able to record detailed and fully polarized absorption spectra in air, all the way down to 280 nm and unpolarized curves even down to 200 nm.

3) Immersion techniques require a set of wide, fairly expensive UV silica glass cells and are cumbersome in terms of fine adjustments of the stone in the light beam. Immersion does not eliminate scattering effects caused by condensed tiny inclusions nor by strong internal growth inhomogeneities and fluorescence.

According to the authors' experience, immersion does not even improve the UV/Visible spectra of cut stones with inferior polish, nor of rough stones, in an obvious manner.

4) Among the *liquids* a gemmologist usually knows, methylene iodide is the least suited for immersion. It is not entirely colourless and it reacts to light and heat by darkening. Transmission ends at approximately 440 nm at best (and thus is completely inappropriate for UV spectra of rubies). Dispersion of light into the spectral colours is high (a problem encountered in immersion microscopy of inclusions also). Like other heavy liquids, it has a strong and unpleasant odour, is expensive and not totally harmless with respect to toxicity. The only property of methylene iodide which is advantageous for the recording of gemstones like rubies, is its high refractive index (n_D 1.734 at 23°C).

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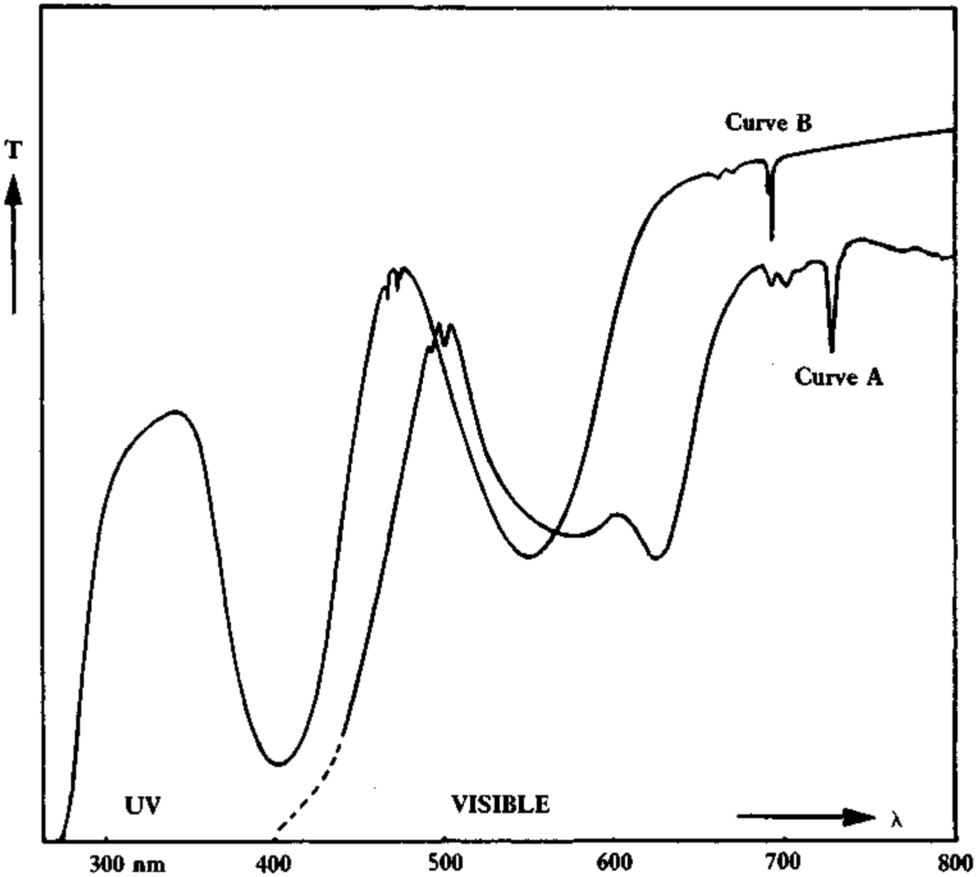

Comparative transmittance spectra of two faceted rubies from Burma, recorded at ambient temperature in methylene iodide immersion by Banerjee *et al.* (1985), Curve A, and in air by G. Bosshart, Curve B.

Bromoform has better transmittance (down to 350 nm) but a markedly lower refractive index (n_D 1.590 at 23°C).

Perchloroethylene (C_2Cl_4), a colourless liquid of medium refractive index (n_D 1.505 at 23°C) and of lower toxicity than carbon tetra-chloride (therefore used in dry cleaning), can be considered as an option for extraordinary cases, since it transmits at least to 300 nm and is stable.

Own immersion experiments dating back to 1974 and correspondence of one of the authors (GB) with the late B.W. Anderson as early as January 1978, showed distilled water to be that 'very useful dream liquid' with the most favourable combination of properties. It is colourless, transmits to at least 240 (210) nm, is stable to light, ultraviolet radiation and heat (during recording and storage), has low dispersion, is universally available, cheap, non-toxic, odourless and non-fluorescent. The low refractive index (n_D 1.329 at 23°C), however, even disqualifies this liquid as an ideal immersion medium.

Conclusion

From our own observations, we therefore conclude that immersion is an unnecessary complication during absorbance measurements on rough and cut gemstones and especially is of no advantage for the recording of UV spectra of faceted rubies.

Experience in properly positioning the stones, varying from specimen to specimen in the degree of difficulties presented by the external and internal properties, efficiently replaces the need for immersion techniques.

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J. Gemm., 1986, 20, 4

Some low cost accessories

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Abstract

In an attempt to save money the following devices were constructed with wood at a total cost of approximately £2.00. None are claimed to be original ideas.

Gemstone holder for the refractometer

This holder is easily constructed given the use of normal carpentry tools. It consists of a piece of ¾in. thick blockboard, 2in. long by 1⅛in. wide, with a 3/16in. hole in the centre. It is important that the long sides are exactly parallel. The two cheek pieces, either side, are 4mm plywood, 2⅜in. by 2in. Cut outs are made by holding both in a vice, and using a 1⅛in. wood bit and a coping saw. The width apart is governed by the dimensions of the table of the refractometer. The sides are glued and pinned to the base, and, if necessary, dressed with a plane. A 3/16in. flat-headed brass machine screw 2¾in. long with two 3/16in. hexagonal nuts to fit, a small piece of aluminium sheet bored and filed to a point, and a small blob of Blu-Tack, complete the assembly. Lines at 45° intervals are drawn on the top surface as an aid to the determination of refractive indices. The machine screw is inserted upwards as shown in Figure 1. Blu-Tack is quite effective in controlling the gemstone while it is on the prism of the refractometer. Total cost 50 pence.

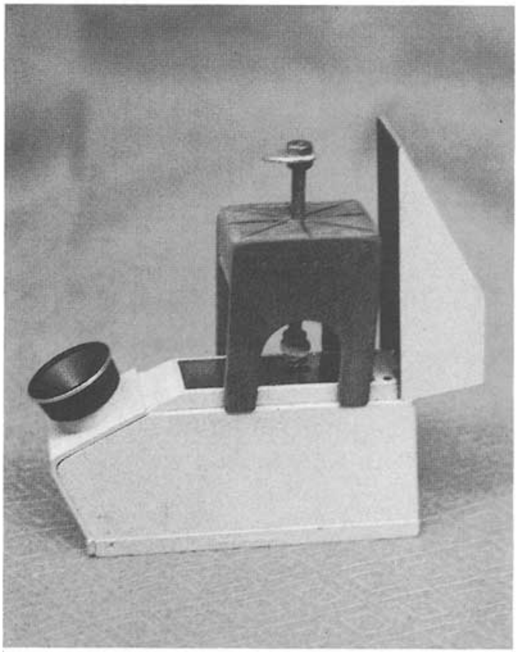

Fig. 1. Gemstone holder for the refractometer.

Holder for heavy liquid bottles

Spilt methelyne iodide and bromoform, besides being obnoxious and smelly, are also quite effective paint removers, so a holder for the heavy liquid bottles was devised. It was made from a piece of scrap wood, 2½in. by 2½in. by 8in. long. The bottles are 1in. in diameter by 2¼in. high. The holes, bored into the wood, should be 1⅛in. in diameter and 1¾in. deep. Six holes were drilled to take the normal range of four specific gravity testing liquids plus extra bottles of specialized dilutions. The finished holder is shown in Figure 2; cost 25 pence.

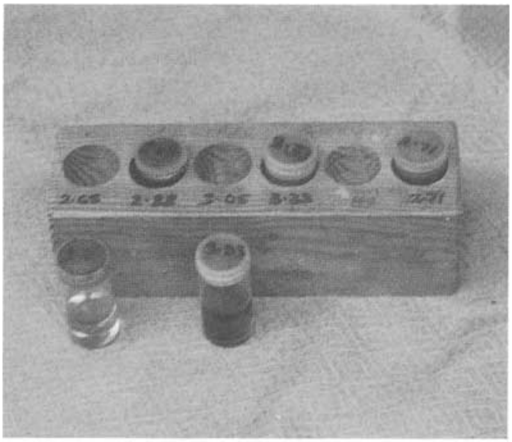

Fig. 2. Holder for heavy liquid bottles.

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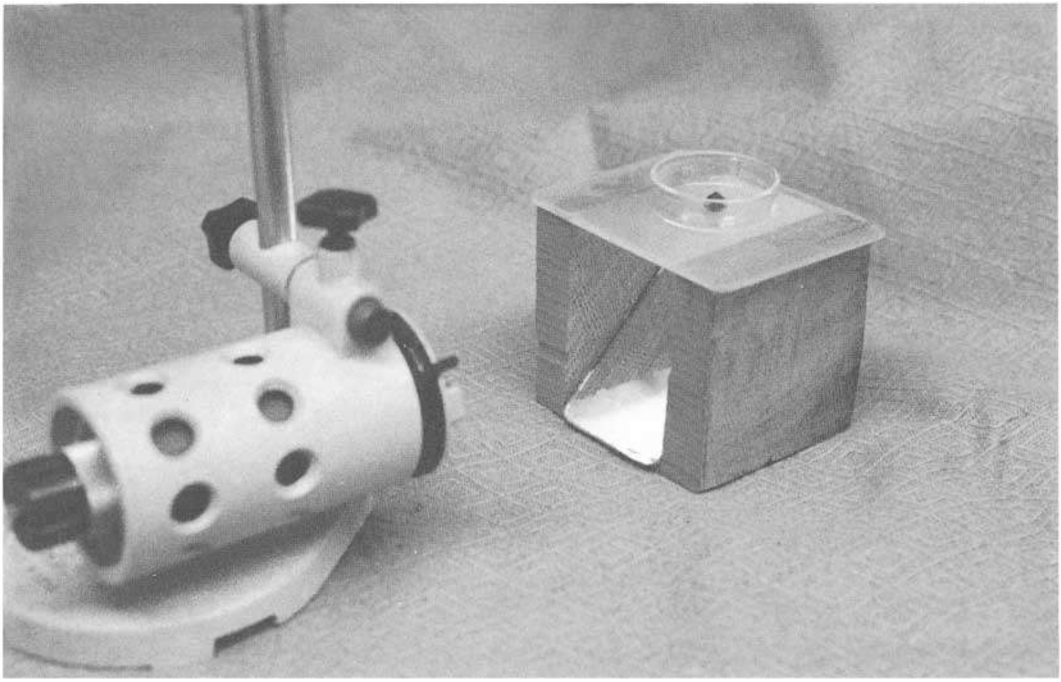

Fig. 3. Angled mirror device for immersion contrast.

Angled mirror device for immersion contrast

This is also easily constructed. It consists of a block of wood 3in. × 3in. × 4in. long, a mirror and a piece of ground glass. Holding the wood in a vice, two diagonal cuts are made with a tenon saw, corner to corner, 2in. apart (the width of the mirror). The 45° slope is obtained by removing the wood with a sharp chisel. The mirror, purchased from Woolworths, was originally too large, and was cut to size with a diamond saw, but a glass cutter would work equally well. It should be 2in. wide by 4¼in. long. It is glued to the inside diagonal of the wood with Evostik, or any other good adhesive. The ground glass top 4in. × 3in. is made by rubbing together two pieces of window glass with silicon carbide 260 grit and water, until an acceptable degree of opacity is obtained. The sharp corners are reduced with 'Wet and Dry' paper or on grinding wheels. It is glued into place, as shown in Figure 3; cost £1.00.

If interested persons are dubious about their technical ability to construct these accessories, an approach to a local joiner asking him to make them in his spare time would keep down the cost.

* * *

The Editor would be pleased to receive contributions from other readers who feel that they have made inexpensive accessories for use in gem testing.

[Manuscript received 6 May 1986.]

The Gem-trak gemstone identifier – a test report

Peter Read, C.Eng., F.G.A.

There are many thermal conductivity testers on the market which can distinguish diamond from its various simulants, but until recently only two of these have been capable of identifying any other gemstone. The reason for this becomes clear when the design requirements for both types of thermal tester are examined.

In the case of the diamond/diamond simulant instrument, it is only necessary to discriminate between diamond (with a thermal conductivity ranging from 1,000–2,600 W/m/degree C) and corundum (which, compared with diamond, has the next highest conductivity of 40 W/m/degree C). Because of the large difference in these two thermal conductivities, the design problems involved in the production of a suitable thermal tester are relatively simple.

In contrast, it is considerably more difficult to identify non-diamond gems by this method as their thermal conductivities span the very much smaller range from glass at 1.0 W/m/degree C to sapphire/ruby at 40 W/m/degree C.

The first commercial instrument specifically to cover both diamond and the non-diamond gems

The Omnitest 'Gem-trak' thermal conductivity gemstone identifier.

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was the Gemtek 'Gemmologist' in 1983(1). This was followed in 1984 by the 'Alpha-test'(2). Both instruments used a technique which measured the time taken for the heated probe test tip to fall between two preset temperature levels. This time interval was displayed as a direct analogue indication of the gem's thermal conductivity (a low reading indicating a high conductivity).

The 'Alpha-test' instrument represented a significant improvement on the earlier 'Gemmologist' in that the temperature of its probe tip was automatically stabilized. In addition, its digital display was automatically zeroed each time a new test was initiated.

The operating constraints, which were necessary because of the very small differences between the thermal conductivities of the non-diamond gems, remained the same, however, for both instruments. This meant that the testers had to be operated in a draught-free environment having an ambient temperature between 18 and 25° C (64–77° F), the gem under test had to be at body temperature, and the probe tip had to be applied at right-angles to the test surface with just enough pressure to cause the tip to retract by 3mm. To users who were more familiar with the less rigorous test requirements of the simpler diamond/diamond simulant tester, these operating constraints proved troublesome.

In April 1986, a third generation thermal gemstone tester was introduced. This new instrument, the 'Gem-trak', uses the same basic measuring technique as its two predecessors (indeed, the probe together with the principal gemstone readings and the sapphire/emerald calibration adjustments appear to be identical to those of the 'Alpha-test').

The 'Gem-trak' gemstone identifier is housed in a stylish electronic-type instrument case whose carrying handle can be used as a stand to tilt the unit at a convenient operating angle. In comparison to the 'Alpha-test', one practical improvement is a test probe that can be disconnected from its control box by means of a plug/socket on the front panel. This facilitates the replacement of a damaged probe.

During tests on diamonds and a range of other gems, the 'Gem-tek' produced consistent readings within the ranges quoted in the operating manual (as with the 'Alpha-test', it was found that high zircons produced much lower readings than low zircons – 52 compared with 400). Repetitive tests on the same gemstone were essential to establish a valid reading, and some users of this type of instrument have complained of the time taken between tests for the probe tip temperature to stabilize and the 'Ready' lamp to light (approximately 10–15 seconds depending on the conductivity of the gem).

While acknowledging the technical ingenuity incorporated in the design of instruments such as the 'Gem-trak', it should be remembered that (as with the reflectivity method of gem identification) there are several stones which cannot be positively identified because they have similar thermal conductivities). Bearing this in mind, the 'Gem-trak' is mainly suitable for the identification of diamonds, diamond simulants and a limited range of non-diamond gems (particularly where the latter are small and are mounted so that they cannot be checked on either a refractometer or a reflectivity meter).

The 'Gem-trak' is manufactured and distributed by Omnitest Ltd., Highcliffe House, 411–413 Lymington Road, Highcliffe, Dorset BH23 5EN.

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Gemmological Abstracts

Adrian, J. 1986. Geology as an aid to gemmology in New South Wales. *Australian Gemmologist*, **16**, 2, 80.

Abstract advocating changes in gemmology in line with changes in geological thinking. R.K.M.

Baker, C.R. 1986. The hardness of Australian diamonds. *Australian Gemmologist*, **16**, 1, 11–12.

Investigates the generally held belief that Australian diamonds are harder to cut than those from other sources because of inclusions, twinning, type of crystal, etc. Stones from the new Argyle AK1 pipe, which is a lamprolite and not a kimberlite, are affected in this way. R.K.M.

Balfour, I. 1986. Famous diamonds of the world, XXV. The 'Sancy'. *Indiaqua*, **43** (1986/1). 127–32, illus.

Although there have been at least three diamonds known as the 'Sancy', the one which is now recognized as the authentic stone is a pear-shaped briolette weighing 55.23 ct and is displayed in the Louvre, Paris.

It is possible that Nicolas de Sancy acquired the stone during his travels in the Far East, but the author admits that the 'Sancy' has probably the most confused history of all the famous diamonds. Among the stone's owners were James I, Cardinal Mazarin, Marie Antoinette, the Russian Prince Demidoff, the Maharaja of Patiala, and Lady Astor. In 1978 the 'Sancy' was re-sold for a reputed $1,000,000 and is now on view in the Louvre Museum, Paris. P.G.R.

Barton, M.D. 1986. Phase equilibria and thermodynamic properties of minerals in the $BeO–Al_2O_3–SiO_2–H_2O$ (BASH) system, with petrologic applications. *American Mineralogist*, **71**, 277–300, 12 figs.

Phase relations and thermodynamic properties of behoite, bertrandite, beryl, bromellite, chrysoberyl, euclase and phenakite are quantitatively evaluated from new measurements with data from the literature. M.O'D.

Beattie, R., Brown, G. 1986. Facetable bowenite. *Australian Gemmologist*, **16**, 1, 25–6, 5 figs in colour.

A translucent yellowish-green bowenite of 0.84 ct was cut from New Zealand material. RI 1.560–1.562. SG 2.59. H 5–6. R.K.M.

Beesley, C.R. 1986. Pakistan's emeralds. *Jewelers' Circular Keystone*, **157**, 2, 358365, 9 figs in colour.

An outline of the mining of emerald from a number of sites in Pakistan. M.O'D.

Beran, A., Zemann, J. 1986. The pleochroism of a gem-quality enstatite in the region of the OH stretching frequency, with a stereochemical interpretation. *TMPM Tschermaks Mineralogische und Petrografische Mitteilungen*, **35**, 19–25, 3 figs.

The enstatite examined was almost colourless and of gem quality, of a few millimetres in size. Two sharp absorption bands were seen at 3410 and $3510 cm^{-1}$ and these were attributed to OH stretching vibrations. The absorption coefficients were larger parallel to the direction of the silicate chains so that the OH dipoles must be oriented approximately parallel to [001]. A stereochemical interpretation of the incorporation of the OH groups into the structure is given. M.O'D.

Birdsall, M.C. 1986. Lightning Ridge, black opal capital of Australia. *Lapidary Journal*, **40**, 3, 26–32, 5 figs in colour.

A general history of the Lightning Ridge opal fields. M.O'D.

Brown, G. 1986. Presidium DiaMeter. *Australian Gemmologist*, **16**, 1, 17, 2 figs.

A slide-rule type gauge which is said to be useful, with limitations, for comparing weight/diameter of brilliant-cut diamonds. R.K.M.

Brown, G. 1986. Letter. *Australian Gemmologist*, **16**, 1, 18.

Quotes Dr Birch's microprobe analysis of the Hart's Range aventurine feldspar from Koppio, discussed in *Australian Gemmologist*, 1984, 15, 8, 263–74, defining it as a potassium aluminium silicate, with sodium and barium described as a minimum microcline with bulk composition of about $Or_{88}Ab_{12}$. R.K.M.

Brown, G. 1986. Australian gem feldspars. *Australian Gemmologist*, **16**, 2, 81.

Abstract calling attention to andesine-labradorite from the Hogarth Range, NSW, and to an anorthoclase-cryptoperthite antiperthite from Moonstone Hill, N. Queensland, which have gem potentials. R.K.M.

Brown G., Snow, J., Taylor, B. 1986. The Gemlusta GL500P reflectometer. *Australian Gemmologist*, 16, 1, 9–10, 1 fig.

A further version of earlier Gemlusta instruments, this one had additional facilities. Not all claims made by the maker could be substantiated. R.K.M.

Campbell, I. 1986. On the subject of gemstone treatments. *South African Gemologist*, 2, 1, 11–13.

Yellow sapphire and the nomenclature to be used for treated stones are discussed. M.O'D.

Cassedanne, J. 1986. La kunzite au Bresil. (Kunzite in Brazil.) *Revue de Gemmologie*, 87, 5–8, 10 figs (8 in colour).

Various sites for kunzite in Brazil are described and mapped. A list of known sites is given and there is a short bibliography. M.O'D.

Chikayama, A. 1986. Gemstones in China – especially jade and similar stones. *Australian Gemmologist*, **16**, 2, 60–3, 1 map.

A brief account concerned with nephrite and with other ornamental minerals used by the Chinese carver. R.K.M.

Dahanayake, K., Ranasinghe, A.P. 1985. Geology and mineralogy of gemming terrains of Sri Lanka. *Bulletin of the Geological Society of Finland*, **57**, 1–2, 139–49, 5 figs.

Gem recovery in Sri Lanka is carried out in river valleys and on hill slopes underlain by high grade Precambrian metasediments. Corundum is the most important of the gem minerals found and occurs in assemblages which also contain garnet, spinel, topaz, tourmaline and zircon. These assemblages may be residual, alluvial or eluvial deposits. Gem minerals are derived from garnetiferous gneisses, granulites and charnockites and their formation is attributed to a desilification process under conditions of high temperature and pressure, since the charnockites in particular are poor in quartz though rich in corundum, hypersthene and sillimanite. M.O'D.

DeVries, R.C., Fleischer, J.F. 1986. Synthesis of jadeite for jewellery. Wahroongai News, 20, 6, 8–11, 1 fig. A reprint from General Electric Technical Information No. 84, CRD282 November 1984*.

Explains the difficult experimental method of synthesis from a powdered glass which is sintered at high temperatures and at pressures equivalent to those used in diamond synthesis. Some lamination of the product occurred. Reconstitution of natural jadeite from its powder was also achieved. An optional lower pressure method is mooted. R.K.M.

Flamini, A., Gastaldi, L., Viticoli, S. 1986. Crystal growth and characterization of beryl doped with transition metal ions. *Materials Research Bulletin*, 21, 1–6, 6 figs.

The growth of beryl crystals containing the transition metal ions Cr^{3+}, Fe^{3+}, Fe^{2+} and Mn^{2+}, from a flux of $Li_2Mo_2O_7$ is described together with notes on the characterization of the crystals. M.O'D.

Fryer, C.W. (Ed.), Crowningshield, R., Hurwit, K.N., Kane, R.E. 1986. Gem Trade Lab notes. *Gems Gemol.*, **22**, 1, 46–53, 24 figs in colour.

An alexandrite of fine colour had coarse silk of unusual type; calcite marble and magnesite bead necklaces were identified; a fine danburite, thought to be the first from Sri Lanka, resembled very fine yellow sapphire. An alphabet of letters cut by laser from diamond is illustrated and would have been impossible to make by conventional cutting methods; three ekanites examined in the past year were all hazy with inclusions and were highly radioactive; a tarnished or coated emerald gave an RI of 1.48 on the coated area but normal Zambian emerald readings where cleaned; glass microspheres were found at Nogales, Arizona, possibly connected with the Winslow meteoric crater; an amphibole ring was tentatively identified as magnesian hastingsite, a hornblende; white quartzite, dyed blue to imitate lapis lazuli was distinguished by higher RI and dye concentrations; a large oolitic opal had chalcedony matrix; several tissue nucleated salt-water cultured pearls seen recently in which drilling has attempted to eliminate evidence of tissue nucleation, the salt-water version seems to be new; freshwater bead-nucleated pearls were found to have pre-drilled nuclei, making insertion into the less accessible mussel body simpler; four 'padparadscha' sapphires cut from a 1126 ct crystal

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* Abstracted in *J. Gemm.*, 1985, **XIX**, 7, 633.

discussed in *Gems Gemol.*, Spring 1983 issue, were examined, one stone of 16.92 ct had been heat treated to an unnatural orange colour altering its fluorescence and absorption; yttrium aluminium gallium garnets of a deep vanadium green colour were found to have reddish-brown flux melt inclusions and wispy veils, a marked absorption similar to green YAG, RI 1.885, SG 5.05. All are described and illustrated. R.K.M.

FRYER, C.W. (Ed.), CROWNINGSHIELD, R., HURWIT, K.N., KANE, R.E. 1986. Gem Trade Lab notes. *Gems Gemol.*, 22, 2, 108–13, 14 figs in colour.

A devitrified cobalt glass imitation of black onyx from Hong Kong tested and identified. Green glass cabochons represented as natural showed devitrification and a large bubble suggesting artificial origin. Dyed and wax-sealed lapis lazuli beads showed patchy red fluorescence under long-wave UV in some beads while others showed normal chalky green expected in natural coloured lapis lazuli, swab tests defeated by paraffin wax seal, Chelsea filter gave brownish-red colour brighter than expected in natural coloured lapis.

A shaped bead necklace had been veneered with opal, using black adhesive to give superficial appearance of black opal. Green opal cabochons with black dendrites resembled green grossularite garnet. Raised area around drill-hole of a cultured pearl was due to the erosion by skin acids of all surface unprotected by the mount. Mantle-tissue nucleated freshwater pearls had large drill holes intended to remove tell-tale 'voids', but X-ray fluorescence revealed them as cultivated – sometimes used to replace natural pearls in old jewellery.

Two opaque black cabochons with sharp reddish-brown 'eyes' were found to be a massive fibrous form of rutile which has not previously been reported. 'Cobalt-blue' spinels, reportedly from Okkampitiya in Sri Lanka, were tested, RI 1.720, inert to UV, very little anomalous birefringence, absorption bands as 434, 460 and 480 nm were diagnostic. An opaque greenish-blue carving was identified as paraffin-wax treated Chinese turquoise. RI 1.58 was due to wax. Black wax used to simulate matrix.

All stones are illustrated. R.K.M.

FRYER, C.W., KOIVULA, J.I. 1986. An examination of four important gems. *Gems Gemol.*, 22, 2, 99–102, 5 figs in colour.

The star of Bombay sapphire (182 ct), the Portuguese Diamond (127.01 ct) and the two large diamonds of Marie Antoinette's earrings (approx. 19 and 13 ct), all supplied by Harry Winston Inc., were examined gemmologically. R.K.M.

FUMEY, P. 1986. Étude des émeraudes synthètiques. (Study of synthetic emeralds.) *Revue de Gemmologie*, 87, 19–20.

A brief summary of the methods by which synthetic emeralds are produced. M.O'D.

GÜBELIN, E. 1986 Deux nouveaux produits artificiels sur le marché des pierres précieuses: le rubis synthètique 'Ramaura' et le gallo-aluminate d'yttrium. (Two new artificial products on the gem market: Ramaura synthetic ruby and yttrium gallium aluminate.) *Revue de Gemmologie*, 87, 15–16, 14 figs in colour.

Describes the physical and optical properties of yttrium gallium aluminate with photographs of characteristic inclusions. M.O'D.

GÜBELIN, E. 1986. Opal from Mexico. *Australian Gemmologist*, 16, 2, 45–51, 14 figs in colour.

An excellent account of the great variety of opals found in the mountainous regions, the richest area being the State of Queretaro. Dr Gübelin illustrates and lists many minerals included in these opals. R.K.M.

GÜBELIN, E., WEIBEL, M., WOENSDREGT, C.F. 1986. Some unusual sillimanite cat's-eyes. *Gems Gemol.*, 22, 2, 96–8, 3 figs (1 in colour).

Some blackish sillimanite cabochons with sharp chatoyant streaks are claimed to be Sri Lankan. Under SEM examination about 0.5% of Fe_2O_3 was found. RI 1.660–1.680, SG 3.257. R.K.M.

GUNAWARDENE, M., RUPASINGHE, M.S. 1986. The Elahera gem field in central Sri Lanka. *Gems Gemol.*, 22, 2, 80–95, 19 figs in colour.

This has been an active gem centre for centuries, but modern exploitation began in the 1950s and became large scale in the late 1970s. Mining is by open pit and gem gravels are extracted by pick and chunkel shovel. Corundum in a great variety of shades is found together with spinel, garnets, chrysoberyl (alexandrite and cat's-eyes), zircon and sinhalite. R.K.M.

HARDER, H., 1986. Naturliche kobaltblaue Spinelle von Ratnapura, Sri Lanka. (Natural cobalt blue spinel from Ratnapura, Sri Lanka.) *Neues Jahrbach für Mineralogie, Monatshefte*, 3, 971–100.

Natural Co-bearing spinels have recently been found in the gem gravels of Paradise mining area, NE of Ratnapura, Sri Lanka. XRF partial analysis of a sapphire-blue spinel gave Co 0.09, Ni 0.04, Fe 0.29, Mn 0.01, Cr 0.025, V 0.035, Ti 0.01, Zn 0.001, Ca 0.1, K 0.2, Ga 0.01%; the presence of Ga may be useful in distinguishing natural from synthetic Co-bearing spinels. The natural blue spinels have *n* 1.715–1.720, SG 3.58–3.61. R.A.H.

Harder, H., Schneider, A. 1986. Isomorpher Einbau von Eisen und Titan zur Erklärung der blauen Farbe von Rutilund Spinellhaltigen seidig weißen Korunden nach einer Wärmbehandlung. (Isomorphic inclusion of iron and titanium as an explanation of the blue colour of rutile and spinel-bearing silky white corundums after heat treatment.) *Neues Jahrbuch für Mineralogie, Monatshefte*, 5, 209–18.

In natural sapphires the blue colour is due to electron transition between Fe^{2+} anf Fe^{3+}, whereas in synthetic sapphires the Fe^{2+}/Ti^{4+} electron transition is responsible. The matrix of rutile-bearing silky/milky natural corundum crystals is poor in Ti and Fe, but in the samples studied Fe also occurs in inclusions of ceylonite (spinel). Samples of this rutile-bearing corundum on heating to 1600°C for 30 minutes are changed to a fine sapphire blue caused by the Fe^{2+}/Ti^{4+} electron transition now possible in the corundum lattice. The sum of transition elements Fe and Ti in the corundum was almost tripled by such heat treatment. R.A.H.

Heilmann, G., Henn, U. 1986. On the origin of blue sapphire from Elahera, Sri Lanka. *Australian Gemmologist*, **16**, 1, 2–4, 6 figs in colour.

An examination of chemistry and inclusions verifies that the sapphires have eroded from garnetiferous gneiss rocks of the Highland Group. R.K.M.

Heylmun, E.B. 1986. Opal from Magdalena. *Lapidary Journal*, **40**, 3, 49–53, 6 figs (3 in colour).

Magdalena is an important location for opal in the state of Jalisco, Mexico. Various mines in the area are described. M.O'D.

Holmes, I. 1986. Fireworks at midnight. *Lapidary Journal*. **40**, 3, 20–4, 1 fig. in colour.

A short review of the opal found in Indonesia; many are a pronounced black and have a fine play of colour. A pinpoint pattern of colour is characteristic. M.O'D.

Katz, M.B. 1986. Review of the geology of gemstones in Sri Lanka. *Australian Gemmologist*, **16**, 2, 52–6, 1 map.

A concise geological account concerned largely with theories of origin. R.K.M.

Keller, A.S., Keller, P.C. 1986. The sapphires of Mingxi, Fujian Province, China. *Gems Gemol.*, **22**, 1, 41–5, 6 figs in colour.

Research and exploration of this remote sapphire source suggests that the occurrence is similar to those in New South Wales. The corundum is alluvial or eluvial and is mined by hand from the stream bed. Sapphires vary from yellowish green through green to very dark blue. Heat treatment has so far done little to improve the colour. There is potential for increased production. R.K.M.

Keller, P.C., Wan, G-D. 1986. The Changma diamond district, Mengyin, Shandong Province, China. *Gems Gemol.*, **22**, 1, 14–23, 13 figs in colour.

Diamond bearing areas are known in Shandong, Hubai, Liaoning and Hunan Provinces, and at Changma, in Shandong, kimberlites exhibit great potential. Mining is by terraced open cast pit which from the illustrations is of vast size. Victory No. 1 pipe gives about one carat per ton, with around 20% of gem quality which are faceted at the State-owned Shanghai Diamond Factory, or at the Beijing Diamond factory, a collective venture. Rough is also imported from Antwerp. Chinese production is in its infancy when compared with other sources.

Changma diamonds tend to be yellowish, but some very large crystals have been found and some fine whites, fancy yellows and browns were seen. R.K.M.

Keller, P.C., Wang, F. 1986. A survey of the gemstone resources of China. *Gems Gemol.*, **22**, 1, 3–13, 10 figs in colour.

A general overview of deposits of amber from Fushun coalfield; cinnabar from Wanshanchang; corundum from Fujian and Hainan Island; diamond from Sichuan, Xinjiang Uygur and Yunnan; garnet from Jiangsu, including pyrope, grossular, demantoid, rhodolite and spessartine; nephrite from Kunlun mountains and other places. Altay Mountains yield most expected pegmatite gem minerals including large beryl crystals of industrial quality. Gemmy peridot is found in basalt lava in Hebei Province, and fine turquoise in Hubei and Shaanxi Provinces. Many other species are found and China can be expected to become a source of many gems. R.K.M.

Kelly, S.M. 1986. Bowesite – a new lapidary material from Australia. *Australian Gemmologist*, **16**, 1, 5–8, 6 figs in colour, 1 map.

This is an attractively patterned green rock mixture of diopside, epidote, grossularite, actinolite, plagioclase, quartz, sphene, iron oxide and calcite in varying amounts. RI 1.57, SG 2.78 to 3.10. Opaque, light green to dark rich green and near black. Volcanic detritus product suitable for carving. R.K.M.

Kemp, D.E. 1986. Whitby jet. *Lapidary Journal*, **40**, 2, 37–41, 4 figs.

A short useful account of the occurrence and fashioning of jet from Whitby, Yorkshire, England. M.O'D.

Koivula, J.I., Fryer, C.W. 1986. The gemmological characteristics of Chinese peridot. *Gems Gemol.*, **22**, 1, 38–40, 7 figs in colour.

Six peridot nodules were available for this report and three of these were faceted to stones of various sizes, light to dark yellowish-green in colour. RI 1.653–1.689, SG 3.36, with typical peridot absorption. Inert to UV light. Hardness approaches 7. Inclusions plentiful and typical of alkali basalt material and similar to those found in Arizona peridot. R.K.M.

Koivula, J.I., Misiorowski, E. 1986. Gem News. *Gems Gemol.*, **22**, 1, 54–5, 2 figs in colour.

Diamonds. India: New deposits reported from Tanna and Chatarpur districts. Japan: Largest synthetic industrial diamond crystal (3.50 ct) claimed by National Research Institute at Tsukuba. South Africa: Pyrope with diamond inclusions (reversing the normal order) has been found. Sri Lanka: Geological Survey are drilling to locate possible diamond occurrences.

Coloured stones. Dr Kurt Nassau says that heating to 200°C for an hour will determine colour stability in gems, but should not be used for yellow sapphires which will lose colour under this test. Pala International has begun dredging in Sri Lanka, output is cut in California. Two strongly particoloured Sri Lankan sapphires in yellow and blue were seen from Mr Ben Hoo of Singapore.

Synthetics. Adachi Shin Industrial Co. Ltd of Japan are producing a 'water-melon' synthetic beryl with a heavily zoned pink core surrounded by a green 'rind'. Dopants appear to be manganese and chromium. Other colours have been grown by what is said to be a new method. R.K.M.

Koivula, J.I., Misiorowski, E. 1986. Gem news. *Gems Gemol.*, **22**, 2, 114–16, 3 figs in colour.

Among many fine natural gems at the Tucson show cat's-eye kunzite, covellite, lepidolite cabochons, magnesite dyed to imitate turquoise, pectolite, 'rainbow' moonstone, spurrite and two taaffeite crystals (one of 46.17 ct is largest on record) were seen, as well as many other rarities.

A 2.12 ct purple twinned spinel from a private collection showed two separate six-rayed stars. A rock crystal quartz had been cut skilfully to reflect a single vertical acicular tourmaline crystal inclusion in a perfect wheel formation. A fine emerald crystal from the Sams collection at the Houston Museum of Natural Science is also illustrated. R.K.M.

Kovac, D. 1986. Minerals and gemstones of Pakistan. *Australian Gemmologist*, **16**, 2, 57–9.

Gemstone mining is a young industry in Pakistan but its origins are ancient and its potential is great. Emerald is the most important gem and is mined in the Swat valley, near Mingora. Ruby comes next in importance and is from the Hunza valley high in the Karakoram ranges. Other gems are topaz, aquamarine, chrome diopside, kunzite, garnets, spinel, tourmaline and various ornamental chalcedonies. R.K.M.

Landais, E. 1986. Le trésor de la 'Voûte verte' de Dresde. (The treasure of the 'Green Vaults' at Dresden.) *Revue de Gemmologie*, 87, 4.

A brief summary of the contents of the Green Vaults at Dresden, German Democratic Republic. M.O'D.

Livstrand, U. 1986. Black pearls of Manihi. *Lapidary Journal*, **40**, 2, 26–34, 5 figs in colour.

An account of pearl fishing at Manihi in the Tuamotu Archipelago in the South Pacific. M.O'D.

London, D. 1986. Formation of tourmaline-rich gem pockets in miarolitic pegmatites. *American Mineralogist*, **71**, 396–405, 6 figs.

Pocket development in tourmaline-rich, miarolitic, rare-element pegmatites occurs between approximately 475 and 425°C and between 2800 and 2400 bars. This observation arises from the examination of fluid inclusions in spodumene, beryl, tourmaline and quartz from the miarolitic pegmatites of Afghanistan. It is possible that the formation of gem pockets may depend upon the timing of tourmaline crystallization since an alkali borate component is removed from the residual pegmatic melt when it is formed so that other alkali alumino-silicate and oxide-forming minerals are deposited and a large amount of H_2O exsolved. If crystallization of tourmaline is inhibited until a late stage of pegmatite consolidation the liberated H_2O may form pegmatite pockets. M.O'D.

Medoff, R.S. 1986. Value added: selecting organic gemstone material. *Lapidary Journal*, **40**, 2, 42–9, 4 figs in colour.

A guide to the purchase of amber, coral, pearl and other organic ornamental materials. M.O'D.

Moon, A.R., Phillips, M.R. 1984. The physics of asterism in sapphire. *Schweizerische mineralogische und petrographische Mitteilungen*, **64**, 329–34, 5 figs.

The star in asteriated sapphire arises from the incoherent superposition of reflected Fraunhofer diffraction patterns which arise when light is scattered from precipitates strictly oriented within the host. Long, thin precipitates give sharper stars than shorter, wider ones. M.O'D.

Nassau, K. 1986. Green glass made of Mount Saint Helen's ash? *Gems Gemol.*, 22, 2, 103–4, 2 figs in colour.

A green glass, said to have been made from the volcanic ash of this eruption, was analysed and compared with a black glass made from known St Helen's ash. They differed significantly and the green glass must contain only a small proportion of that ash, if any. R.K.M.

Newsome, D. 1984/85. Colors and spectral distributions of fluorescent minerals. Part III. *Journal of the Fluorescent Mineral Society*, **13**, 2–28, 13 figs.

The gem species benitoite and scheelite are among the minerals whose luminescence is discussed. M.O'D.

Niedermayr, G. 1986. Mineral localities in Austria. *Mineralogical Record*, **17**, 2, 105–10, 8 figs (6 in colour).

Beryl, including emerald and aquamarine, epidote, apatite, amethyst, euclase, scheelite, datolite, sphene and garnet, are among the minerals of gemmological interest described. M.O'D.

O'Donoghue, M. 1986. Gems and gemmology. *Watchmaker, Jeweller and Silversmith*, May 1986, 54–7, 3 figs in colour.

Topics considered this month include determination of the source of rubies, gemmology in Italy, examination preparation courses, trips to field areas of gem interest, sugilite, synthetic diamond and how to tackle examinations in gemmology. (Author's abstract.) M.O'D.

O'Donoghue, M. 1986. Gems and gemmology. *Watchmaker, Jeweller and Silversmith*, June 1986, 58–60.

Synthetic gem diamond, Lechleitner solid synthetics, coloured and faceted strontium titanate, YAG, GGG and $YAlO_3$ and the writing of Pliny on beryl, are among the topics discussed this month. (Author's abstract.) M.O'D.

O'Donoghue, M. 1986. Gems and gemmology. *Watchmaker, Jeweller and Silversmith*, July 1986, 39–42, 1 fig.

This month the topics discussed include the varieties of chrysoberyl, hints for students taking gemmological examinations, with particular reference to the available literature, reviews of the first three Butterworth gem books and details of rare stones and synthetics, including pink-orange sapphire and gemstones from China. (Author's abstract.) M.O'D.

O'Donoghue, M. 1986. Industrial review – gemstones. *Britannica Book of the Year* – 1986, 274.

1985 saw little change in the world gem markets and arguments over whether or not treatment should be disclosed were still unresolved. Details of the country of origin for major stones are increasingly being requested by buyers in the saleroom.

The Internal Revenue Service in the United States has cracked down on the practice of making tax-shelter donations of gemstones to major collections whose acquisitions have declined as a result. Indian production of cut diamonds threatened to undercut traditional sources and the Israeli industry in particular could be affected. The Aredor field in Guinea was producing diamonds, 95% of which are said to be of gem quality. (Author's abstract.) M.O'D.

Partlow, D.P., Cohen, A.J. 1986. Optical studies of biaxial Al-related color centers in smoky quartz. *American Mineralogist*, **71**, 589–98, 7 figs.

Three absorption bands associated with trapped hole centres develop when quartz containing trivalent Al in a substitutional trivalent Si site is subjected to ionizing radiation. Studies of the directional anisotropy of two of the bands in the quartz basal plane show that they may interchange orientations from crystal to crystal in major rhombohedral growth. M.O'D.

Ponahlo, J., Koroschetz, T. 1986. Quantitative cathodoluminescence of gemstones. *Australian Gemmologist*, **16**, 2, 64–71, 13 figs (9 in colour).

A detailed account of this method of gemmological testing between natural and synthetic stones. [In 1976 the GIA found that this method of testing could produce colour changes and damage in some stones.] R.K.M.

Pough, F.H. 1986. Gem treatment: pearl. *Lapidary Journal*, **40**, 3, 16–18.

A short review of the various methods by which the appearance of pearl can be improved. M.O'D.

Ringsrud, R. 1986. The Coscuez mine: a major source of Colombian emeralds. *Gems Gemol.*, **22**, 2, 67–79, 11 figs in colour.

Coscuez, a small mine high in the Andes about 10 km from Muzo, is second most productive in Colombia, its emeralds being sold as Muzo stones. They are found in calcite veins in distorted Lower Cretaceous carbonaceous shales. Mined by adit tunnelling and latterly by bulldozer and dynamite to expose calcite which is then worked by hand pick. Locals poach tailings. RI 1.574–1.580, SG 2.68–2.71, pink to red under emerald filter, inclusions mainly part-healed fractures with fewer three phase cavities than in Muzo stones. R.K.M.

Rossman, G.R. Mattson, S.M. 1986. Yellow, Mn-rich elbaite with Mn-Ti intervalence charge transfer. *American Mineralogist*, **71**, 599–602, 3 figs.

Yellowish-green to yellowish-brown Mn-rich tourmaline from Zambia and Nepal owes its colour to an Fe^{2+}–Ti^{4+} (brown) and Mn^{2+}–Ti^{4+} (yellowish-green) intervalence charge transfer. A band at 325 nm is caused by a Mn–Ti interaction and is especially well developed in the Zambian material. M.O'D.

Rotstein, A.H. 1986. Fossil ivory, stable and usable. *Lapidary Journal*, **40**, 2, 35–6, 3 figs.

A solution is offered to the problem of cracking as found in mammoth and walrus ivories which are stabilized by an undescribed process. M.O'D.

Sheils, K.C. 1986. Ultraviolet recovery. *Lapidary Journal*, **40**, 3, 36–40, 1 fig.

Ultraviolet light is used to find opal at the Coober Pedy field in South Australia. Orange-fluorescing gypsum has been found to be a guide to localities for good quality opal. M.O'D.

Shigley, J.E., Kampf, A.R., Rossman, G.R. 1986. New data on painite. *Mineralogical Magazine*, 50, 267–70, 3 figs.

The third painite specimen to be found turned up in 1979 in a parcel of rough Burmese gem quality spinel. Composition echoed that of the type crystal but trace amounts of Fe, Cr, V, Ti, Na and Hf were also found. The colour is believed to arise from the presence of Cr^{3+} and V^{3+} as optical absorption spectra of these elements were observed. M.O'D.

Smith, J.V. 1985. Can Yogo sapphire firm survive? *Jewelers' Circular-Keystone*, **156**, 13, 146–52, 3 figs in colour.

Describes the current financial troubles of Intergem Inc., owner of the main source for Montana blue sapphires. M.O'D.

Smith, J.V. 1986. Gem synthetics: options and outlook. *Jewelers' Circular-Keystone*, **157**, 4, 206–24, 28 figs (25 in colour).

A review of the present part played by synthetic gemstones in the jewellery trade, their method of manufacture and ways to identify them. Photographs of inclusions complete the article. M.O'D.

Stern, L.A., Brown, G.E., Bird, D.K., Jahns, R.H. Foord, E.E., Shigley, J.E., Spaulding, L.B. 1986. Mineralogy and geochemical evolution of the Little Three pegmatite-aplite layered intrusive, Ramona, California. *American Mineralogist*, **71**, 406–27, 7 figs.

The Little Three pegmatite is a celebrated source of spessartine, tourmaline and topaz. Several layered pegmatite-aplite intrusives exposed at the mine show closely associated fine-grained to giant-textured mineral assemblages thought to have co-evolved from a hydrous aluminosilicate residual melt with an exsolved supercritical vapour phase. M.O'D.

Swanson, S.E., Fenn, P.M. 1986. Quartz crystallization in igenous rocks. *American Mineralogist*, **71**, 331–42, 12 figs.

The transition from euhedral to dendritic growth in quartz depends upon the degree of undercooling and does not have any particular relationship to bulk composition, water content of the melt or pressure. M.O'D.

Thomas, L.H. 1986. Elusive in Louisiana. *Lapidary Journal*, **40**, 3, 54–6.

A location for precious opal near Leesville in south-west Louisiana is described. The material has been reported to be an opalescent sandstone consisting of irregular particles of quartzite from 0.1 mm to 1 mm in size; these are cemented by pieces of precious fire opal. M.O'D.

Thomas, S.A., Lee, H.W. 1986. Gemstone carving in China: winds of change. *Gems Gemol.*, **22**, 1, 24–34, 11 figs (5 in colour).

Traces the history of stone carving from Paleolithic times, through Sung, Ming and Ch'ing Dynasties to Emperor Ch'ien Lung who encouraged the art by establishing workshops in the Imperial Palace at Beijing and importing Moslem gem carvers. Jadeite first used in 1784. Today the industry is being encouraged in many ways and power tools are replacing many, but not all, of the foot-treadle lathes, with diamond dust used for polishing. R.K.M.

Tombs, G.A., Sechos, B. 1986. Examination of surface features of Argyle diamonds from Western Australia. *Australian Gemmologist*, **16**, 2, 41–4, 9 figs in colour.

Diamonds from the Kimberly, Western Australia, area occur in potassium-rich lamprolite pipes and not in kimberlites, and it is suggested that the alkali has attacked the contained diamonds which tend to be highly misshapen, etched and corroded. Some etch-pits on octahedral faces are hexagonal rather than the normal trigon shape and it may be that growth and etch conditions have combined. Garnet inclusions have been found. R.K.M.

VAHLDIEK, B.W. 1976. Bernstein aus den eozänen Braukohlen von Helmstedt (Budesrepublik Deutschland, Niedersachsen) Stratigraphie und Ausbildung. (Amber from the Eocene brown coal of Helmstedt (Lower Saxony, Federal Republic of Germany) stratigraphy and formation.) *Aufschluss*, 37, 165–77, 3 figs (1 in colour).

Amber from an Eocene lignite at Helmstedt is described and details of its stratigraphical relationships and formation given. M.O'D.

VANCE, B. 1986. The angel of Yowah. *Lapidary Journal*, **40**, 3, 33–4, 2 figs in colour.

Describes a specimen of opal found in the Yowah Valley of central Queensland and thought to resemble the figure of an angel. The stone weighs 1280 ct. M.O'D.

WANG, F. 1986. A gemmological study of turquoise in China. *Gems Gemol.*, **22**, 1, 35–7, 4 figs in colour.

Turquoise of a quality to compare with material from other countries is mined in Hubei Province. Colour ranges from sky-blue to bluish-green depending upon the amount of ferrous iron present, with constants within the normal range for the species, and the expected absorption. R.K.M.

WILSON, M.M. 1986. Expeditions. Big sky sapphires. *Lapidary Journal*, **40**, 1, 26–36, 6 figs in colour.

An interesting account of the sapphire mines of Montana, USA. M.O'D.

WILSON, W.E. 1986. What's new in minerals? *Mineralogical Record*. **17**, 2, 147–52, 10 figs (6 in colour).

Describes specimens seen at the Detroit and Munich mineral shows. Items of gemmological interest include cobaltian calcite from Mupine, Shaba province, Zaire; golden topaz from near Mimosa, Espirito Santo, Brazil; aquamarine from Lavra da Invreja, Marambainha, Minas Gerais, Brazil; elbaite crystal groups from the Genipapo mine, Aracuai, Minas Gerais, and more tourmaline specimens from the well-established localities of the Cruzeiro mine (water-melon crystals) and Itinga (olive-green crystals with brownish-green or yellow terminations). M.O'D.

ZEITNER, J.C. 1986. Opal in the United States. *Lapidary Journal*, **40**, 3, 42–8, 6 figs in colour.

Opal from Idaho, Nevada, California, New Mexico, Oregon and Texas is described. M.O'D.

ZWAAN, P.C. 1986. Gem minerals from the Embilipitiya and Kataragama areas of Sri Lanka. *Australian Gemmologist*, **16**, 2, 35–40, 5 figs.

An account of two comparatively new gem areas where deposits are thought to be eluvial rather than alluvial. Crystals are often euhedral and well formed. The first locality is noted for rarer gems like brown to colourless enstatite, cordierite and kornerupine. Kataragama lacks these but has corundum, spinel, almandine, hessonite and tourmaline. Apatite, brown sphene, actinolite, diopside and hiddenite are also reported. R.K.M.

New artificial diamond developments in Japan. 1986. *Production Engineering Research Association*, PERA-OTIS 86/5549. Unpaged.

More than one Japanese firm is working on the production of artificial diamond; Sumitomo Chemical claim to be able to produce a low cost mass production method for stones up to 1 ct in size and are also developing smaller stones (about 0.5 mm) for use as semiconductor heat sinks. Offprints of several papers from a variety of journals accompany this report. M.O'D.

Book Reviews

Andergassen, W. 1982. *Il diamante oggi*. (The diamond today.) Paleani Editrice, Rome. pp.278. Illus. in black-and-white and in colour. Price on application.

This book provides an excellent introductory text on the diamond from its formation, recovery, history, fashioning, testing, grading and simulation. The most prominent feature is a set of coloured photographs of diamond surfaces showing their features in interference colours. Grading is explained and questions are posed in some of the chapters. There is a glossary and a short bibliography.

M.O'D.

Anderson, B.W. 1983. *Gemmologia practica*. (Practical gemmology.) Traduzione di Carlo Trossarelli. Istituto Gemmologica Italiano, Milan. pp.xvi, 551. Illus. in black-and-white. Price on application.

This is a well-produced and somewhat enlarged translation of the 9th edition of *Gem testing* (1980)*. Additions include extra illustrations and improved tables (those in the original were a disappointment).

M.O'D.

Christiansen, E.H., Sheridan, M.F., Burt, D.M. 1986. *The geology and geochemistry of Cenozoic topaz rhyolites from the western United States*. Geological Society of America, Boulder, Colo. Special Paper 205. pp.82. Price on application.

Cenozoic topaz-bearing rhyolites rich in silica are found widely distributed across the western United States and Mexico. They are enriched in fluorine and the topaz was formed in post-magmatic vapour-phase alteration. Details of the various deposits are given with maps and diagrams. M.O'D.

Cipriani, C. 1986. *The Macdonald encyclopedia of precious stones*. Macdonald, London. pp.384. Illus. in colour. £7.95.

Translated from the Italian, this book is a handy guide to a large number of gem materials and contains a good deal of information which is carefully put together and which will be useful for students. The system used to find particular species (colour depictions in diagrammatic form in the text margins) appears a little complicated but this does not matter and they are not really needed. The arrangement appears to be in order of importance but this is quite sensible in so small a book. The quality of the reproductions is high, though the spessartine looks too yellow. M.O'D.

Farn, A.E. 1986. *Pearls: natural, cultured and imitation*. Butterworths, London. pp.150. Illus. in black-and-white and in colour. £25.00.

Of all the members of the new series of Butterworths Gem Books this is to me the most welcome. Not only has there been a dearth of serious literature on pearls (and on ornamental organic materials in general) but in this instance the only possible author has arisen to take up pen and responsibility so that readers can be assured that use of the book really will enhance their knowledge of the material, which is once more gaining in popularity after years of comparative neglect. Mr Farn cut his teeth on pearls (perhaps literally) and no one living knows more about them. The book follows the pattern set for the series in having a section of colour photographs in the centre and in providing adequate references at the back. There is also a glossary. After a general introduction which ends with a list of pearl occurrences, Mr Farn goes on to discuss how pearls come to be formed. He lists some theories held in antiquity (flashes of lightning is one of them) and enlarges on the charming notion that pearls are formed from dewdrops, concluding regretfully that they are not. There are, in fact, several possible causes of pearl formation; grains of sand are now known to be a very rare cause but parasitic intrusions are more likely agents. A chapter on the history of pearls (i.e. the recorded use of pearls in early times) is followed by an outline of the structure and anatomy of the pearl oyster. Here there are some excellent and necessary

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* Reviewed in *J. Gemm.*, 1980, XVII, 3, 193.

diagrams accompanied by a description of how the oyster works. The next chapter outlines the places where pearls have been found and good-sized clear maps are provided. A good deal of history is included in this quite long chapter (which also covers freshwater pearls) and this is lucidly introduced.

Cultured pearls form the subject of the next section of the book. Here again the history of the processes used are recounted and readers should be clear when they have read the section exactly what processes have been used in the past and which ones are likely to be in use now. Testing of pearls comes naturally at this point and the section contains useful diagrams and photographs.

Lastly the subject of imitation pearls is introduced, followed by notes on pearl pricing (the complicated method of arriving at the price of good quality pearls at least is still in use); a pot-pourri on the staining and other treatment of pearls and famous pearls. An excellent summary of a difficult subject – my only criticism is that (in my copy at least) the binding is flimsy, one gathering coming out on first handling of the book. M.O'D.

GAUTIER, G. 1983. *Cartier, the legend.* Arlington Books, London. pp.253. Illus. in black-and-white and in colour. £19.95.

The story of the various branches of the firm of Cartier is recounted from 1808 to the present day. Many photographs of Cartier products are included with the well-written text. The original French text was entitled *Rue de la Paix* and was published in 1980 by Juillard, Paris. M.O'D.

KALDIS, E. (Ed.) 1985. *Crystal growth of electronic materials.* North-Holland, Amsterdam. pp.x, 384. Illus. in black-and-white. Dfl 235.00.

This volume which is full of features relevant to the growth of gem-quality crystals, covers the lectures given at the 5th International Summer School on Crystal Growth and Materials Research (ISSCG–5) held at Davos in September 1983. It provides useful updates on techniques of crystal growth and gives details of materials composition which were unsuspected before.

An introductory section gives an overview of fundamental aspects of crystal growth which would be useful for anyone approaching the topic for the first time and subsequent sections deal with the growth of substances of extreme dimensions, with growth from high and low temperatures and with the growth of silicon. Growth of III–V compounds, miscellaneous materials and crystal characterization complete the book. Those with an interest in the growth of such materials as YAG, GGG and corundum will find interesting points on the conditions needed for the growth of the best quality crystals. The growth atmosphere is particularly important.

Each chapter is provided with extensive references and readers are recommended to consult the book where possible; even if many of the details are hard to understand it is always useful to know why certain materials are grown and why some cost more than others. M.O'D.

LEONE, E., CUMO, C. 1985. *Gemme naturali e artificiali.* (Natural and artificial gems.) Editrice Elleci, Valenza. pp.575. Illus. in black-and-white and in colour. L.90 000.

This large book is intended to cover all the varieties of minerals that can be used ornamentally. It begins with a description of the principles behind the classic tests and an account of the causes of colour. There are short sections on gemstone occurrence and on inclusions and how they arise. Diamond begins the long account of the gemstones themselves and there are some excellent colour photographs illustrating luminescence and the polishing process. The first-class colour pictures follow the text through the book; there are some fine black-and-white ones, too, particularly illustrating emerald and its synthetic and composite counterparts. There is a fairly short bibliography and identification tables.

For the Italian reader this provides an excellent introduction to gemmology and the language does not seriously impede the English reader from finding out a good deal about the subject. M.O'D.

MAY, E. 1979. *Jade for beginners.* Times Books International. Singapore. Illus. in black-and-white and in colour. pp.57. Price on application.

A short but well-written guide to the jade minerals as used in ornament. The use of jade in the past is discussed with particular reference to China. M.O'D.

MILLER, R.McG. 1985. *Departmental report on the mining and production of diamonds at CDM 1945 to 1983.* Namibian Department of Economic Affairs and the Geological Survey, Windhoek. pp.28. R3.50.

This report was commissioned to refute long-standing arguments that CDM (Consolidated Diamond Mines) were increasing diamond production in contravention of the Halbscheid Agreement. It was alleged that high-grade ore was mined in preference to low-grade ore and that over-burden and waste were dumped on top of diamondiferous gravel. Statistics are used in the refutation as are day-by-day accounts of the actual production.

M.O'D.

Medenbach, O., Wilk, H. 1986. *The magic of minerals.* Springer-Verlag, Berlin. pp.204. Illus. in colour. DM128.

A translation by John Sampson White of *Zauberwelt der Mineralien*, 1977*. M.O'D.

Menzhausen, J. (Text.) 1983. *The Green Vault.* An introduction. The State Art Collections in Dresden, Dresden. pp.119. Illus. in colour. 15M.

Though much of the area of the Green Vaults was destroyed by bombing in 1945, some of the contents were in safe keeping and in fact much of the total stock was eventually brought back to the City and will in due course be rearranged in some of the rooms which were unaffected by the raid and by later vicissitudes in other countries. This attractively illustrated guide depicts many artefacts of gemmological interest, mostly from the period and illustrating the style known as Dresden Baroque. As always with books from the German Democratic Republic, the price is amazingly low. M.O'D.

Mitchell, R.S. 1985. *Dictionary of rocks.* Van Nostrand Reinhold, New York. pp.xi, 228. Illus. in black-and-white and in colour. £32.95.

This most useful reference book forms a companion to the author's *Mineral names – what do they mean?* (Van Nostrand Reinhold, 1979)†. Rocks are arranged alphabetically and some related materials are also included. These are migmatites, tektites, impactites and major meteorite types. Cave rocks and formations, organic resins, ambers, bitumens and major coal varieties can also be found. On the gem and ornamental material side, a number of gem-rock terms are included and many local and trade names are explained as well as non-English terms often found in English-language publications. Some terms not found in the main alphabetical section can be found in the glossary; these include structural and textural terms often used in petrology and microscopic petrography. The origins of rock names have been investigated and as many as possible are explained; where names relate to individuals brief biographies are given. A section of coloured pictures provides a welcome break in the text.

The author claims that this is the first book of its kind and I have no evidence of any other one as comprehensive as this. M.O'D.

Rouse, J.D. 1986. *Garnet.* Butterworths, London pp.x, 134. Illus. in black-and-white and in colour. £22.00.

Forming part of the Butterworths Gem Books series, this is a well-presented study of the gem varieties of the garnet group of minerals. The history of use of garnet is discussed first, with references to classical and later authors and this section which, like those following, contains a list of references, is succeeded by a chapter on garnet chemistry, physical properties, colour and classification. A table giving the main characteristics of each gem variety of garnet is included and will prove useful as a quick reference guide for students.

Each garnet variety is now discussed in turn following the order pyrope, almandine, spessartine (given here as spessartite), grossular and andradite. Intermediate (rhodolite) garnets are treated between the almandine and spessartine sections and rarer varieties (yellow andradite, uvarovite) are discussed in the andradite chapter.

The contents of these chapters cover the members of the family exhaustively and major locations are shown on maps. A section of colour pictures depicts inclusions in garnet.

This is an excellent book and I was particularly pleased to see the number of references appended to each chapter. M.O'D.

Samsonov, J.P. Turingue, A.P. 1984. (Gems of the USSR.) Nedra, Moscow, pp.335. Illus. in black-and-white and in colour. 4r. 50c (In Russian.)

This is a well-produced survey written with the general supervision of an Academician (V. I. Smirnov) and thus amounts to an official guide. Occupying so large an area the USSR contains examples of almost every variety of gem mineral and the range of these minerals can be seen in the important collections in Moscow and Leningrad which have been drawn upon for the illustrations to this book. Some years ago I was able to examine some of the gem specimens in the reserve collections of the A.E. Fersman Mineralogical Museum in Moscow and some of the stones seen on that occasion are represented here.

The book begins by introducing and classifying gem minerals and then explains how they are formed. Gems suitable for collecting are described and there is a chapter on gemstone synthesis; this section also contains details of gem testing practices. Later chapters describe the manufacture of ornamental pieces and jewellery.

The last chapter is one of the most interesting; it explains how gemstone deposits are evaluated and how they may best be worked; it also describes the operation of Western gem markets and gives some

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* Reviewed in *J. Gemm.*, 1979, **XVI**, 7, 488.

† Reviewed in *J. Gemm.*, 1980, **XVII**, 2, 136.

ideas on the way in which similar industries might be developed in the USSR. There is a short bibliography and an index of gemstone deposits. There are many good quality colour pictures and even for those with no Russian these make the book well worth getting. As always with Soviet books, the price is within the reach of all; a sensible policy which we could well copy. M.O'D.

SCHMETZER, K. 1986. *Naturliche und synthetische Rubine*. (Natural and synthetic rubies.) Schweizerbart'sche Verlagsbuchhandlung, Stuttgart. pp.vi, 131. Illus. in black-and-white and in colour. DM38.

In a major survey of ruby, Dr Schmetzer begins with a discussion of the mineralogy and crystallography of corundum with a table showing the chemical composition of rubies from eleven localities. The growth methods and composition of synthetic rubies follows.

The next part of the book (which is not divided into chapters which can easily be distinguished from one another) covers inclusions and continues virtually to the end. The accompanying coloured and black-and-white photographs are superb and the book is worth buying for these alone. There is an extensive bibliography preceded by notes on fluorescence and fluorescence spectroscopy. The book is up-to-date and includes notes on Knischka and Lechleitner ruby and it is to be hoped that further works on other stones, of a similar standard, will be forthcoming. M.O'D.

SCHÜTT, R.-W. 1984. *Die Entdeckung des Isomorphismus*. (The discovery of isomorphism.) Gerstenberg Verlag, Hildesheim. pp.324. DM68.

This study of the gradual recognition of the phenomenon of isomorphism in mineralogy and chemistry forms part of the series *Arbor scientiarum*, taking the number IX of Reihe A, *Abhandlungen*. Much of the text is given over to the work of Haüy and his contemporaries and particular reference is made to isomorphism in emerald and other beryls, apatite, calcite, calcite and aragonite, diamond and graphite; the mechanism of crystallization and the concepts of 'masse chimique' and 'melange chimique' are also discussed before the study turns to the work of Mitscherlich and Berzelius. There is a comprehensive bibliography and the study is an invaluable guide to early thoughts on the formation of minerals. M.O'D.

SINKANKAS, J. 1985. *Gem Cutting*. 3rd edn. Van Nostrand Reinhold, New York. pp.xvii, 365. £51.20.

First published in 1955, this familiar tall book is still the best account of the fashioning of gem materials in English. Over the years the general presentation has not varied much; the author makes the point in his preface to the current edition that one of the few notable developments in faceting is the widespread use of diamond polishing agents for almost all types of work from the original rough to the finished piece. There has been a large increase in the number of substances which can be cut, particularly man-made ones and details of these are given in a large section at the end of the book. As always with John Sinkankas, the style is enviably lucid and the diagrams unmatchable. M.O'D.

VOYNICK, S.M. 1985. *The great American sapphire*. Mountain Press Publishing Co., Missoula, Mont. pp.xi, 199. Illus. in black-and-white and in colour. US$9.95.

This is a well-written and interesting account of the discovery and marketing of the sapphires from Yogo, Montana, USA. The first sapphires were recognized as such in the 1860s and mining has suffered many vicissitudes up to the present. Though the account of the mining operations forms the main part of the book, there are many gemmological asides and an account of the effects of heat treating corundum in general. The author has consulted many sources and it would have been pleasing to have had a bibliography in a book which is otherwise well worth reading and very reasonably priced. M.O'D.

ZANCANELLA, R. 1980. *Il diamante: manuale pratico*. (The diamond: a practical manual.) Istituto Gemmologico Italiano, Milan, pp.195. Illus. in black-and-white and in colour. Price on application.

This is a useful and well-produced book dealing primarily with diamond grading and cutting, though there is also a good deal of introductory information on the properties of diamond. Particularly useful are the coloured diagrams which illustrate how a stone is polished to give the best optical effects. Final chapters describe how stones are tested and there is a short bibliography.

For those interested in the path of light through a diamond this book gives outstanding diagrams and the labelling of the diagrams with figures giving various sets of proportions are also valuable as a guide for those unfamiliar with the importance for the final stone of adherence to sets of proportions. M.O'D.

Proceedings of the Gemmological Association of Great Britain and Association Notices

OBITUARY

HENRY JAMES BLACKBURN WHEELER

It is with very deep regret that we report the death, from a heart attack on 5 June 1986, shortly after returning from holiday in China and Hong Kong, of Mr H.J.B. Wheeler, former Secretary of the Gemmological Association and of the National Association of Goldsmiths.

Harry and Rene Wheeler

Harry Wheeler served the two Associations all his working life, joining them as a shorthand-typist at the age of 16 in 1934. He first attended gemmology classes at the old centre at Chelsea Polytechnic in 1939, but war disrupted that effort and it was not until after some six years with the Royal Army Service Corps, which took him to many places including North Africa and Sicily, that he was able once more to take up these studies. He passed the Diploma examination with Distinction in 1947, a year which produced two Tully Medallists and eleven distinctions out of a total of 22 successful students. Harry was an excellent gemmologist.

With two associations to serve, Mr Wheeler emulated his predecessor, Mr Gordon Andrews, in his efficient approach to these and other responsibilities. The two men had worked together for so long that the transition could only be smooth, with a minimum of reorganization. In both capacities he had a broad and total understanding of the problems involved. Over the years the scope and coverage of the associations had grown enormously, due largely to the collaborative efforts of Andrews and Wheeler in the near thirty years since the end of the war and to the quiet efficiency of Harry himself when he was eventually alone at the secretarial helm.

Harry Wheeler was an excellent and popular speaker who enjoyed the challenge of conferences and award ceremonies which brought successful students each year from many parts of the world. His relations with staff were meticulous and fair. He expected work to be done well, but showed appreciation of effort at all times.

He was a Freeman of the Worshipful Company of Goldsmiths, a Freeman of the City of London, an Honorary Fellow of the Canadian Gemmological Association, a Honorary Member of the Gemmological Association of All Japan and, since retiring in 1982, a Vice-President of our own Gemmological Association. Already a widely travelled man, he used that retirement to journey even further afield and was an excellent ambassador for Britain's gemmologists. His hobby was bowling, something requiring a different skill but rather similar concentration to that which served him so well in his long career.

A director of Gemmological Instruments Ltd, with his brother, Douglas Wheeler, who served the two associations for a similar length of time, and others, Harry was influential in fostering the introduction of new and improved instruments and in furthering the development of correspondence teaching at all levels.

Those of us who knew him well will remember him for his ability to grasp and understand detail, and his innate shrewdness in all things requiring judgement.

Harry is survived by his wife Rene, two sons and a daughter and six grandchildren, to whom our most sincere condolences are expressed. His wife was a familiar and popular figure at GA (and NAG) events and gave Harry and the Associations very active support throughout his career. One son is employed in the gem stone trade. It is a well-known platitude to say that a death brings an era to an end, but in the case of Harry J. Wheeler the feeling of loss is tempered only by the three years since he dropped out of active participation in Trade affairs. His delightful personality is still fresh in memory and will be greatly missed by all who knew him.

* * *

PATRICIA MARGARET STATHAM died peacefully in Derby on 13 August 1986 in her sixty-fifth year.

Pat Statham gained a B.Sc. degree at Reading University. She joined the Department of Health in Scotland for a short time, but then transferred to the Geological Survey in Edinburgh. Her work there was mainly on fossils but on her transfer in 1956 to the (then) Geological Survey and Museum in London she worked with E.A. Jobbins on minerals and gemstones. This very successful partnership continued for some 23 years until her retiral in 1979. Her first task in London, requiring meticulous application, was the rearrangement, on crystal chemistry lines, of the mineral collection of some 80 000 specimens. One of the responsibilities of a curatorial mineralogist is dealing with enquiries. She answered many thousands on minerals, gemstones and hardstone carvings, and became one of a dying breed of specimen mineralogists who could identify the species and locality of a considerable range of mineral specimens at sight. She was the epitome of down-to-earth reliability, intensely loyal and unassuming.

She gained her F.G.A. in 1969 and with her superb attention to detail became an excellent proof reader of gemmological and mineralogical texts. The new Guide '*Gemstones in the Geological Museum*' was jointly revised by Pat Statham and E.A. Jobbins and appeared under her authorship. She helped with the Index of Volume XIX of this *Journal* only a few months before her death from lung cancer.

Devotion to duty, as exemplified by Pat Statham, is not so common a trait today.

* * *

Mr H.J. Korevaar, F.G.A. (D.1972), Zwanenlaan, Netherlands, died on 30 June 1985.

Mr M.D.S. Lewis, Brighton, died on 8 July 1986. Mr Lewis gained his Diploma and the Tully Medal in 1944, and was the first recipient of the Research Diploma of the Gemmological Assocation in 1945. A full obituary will appear in the January 1987 issue of the *Journal*.

GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to Mr Leslie Cole, F.G.A., for a set of hand-held weighing balances in the original wooden box.

CON LENAN

Secretary 1982–1986

Con Lenan will relinquish his post as Secretary of the Gemmological Association on 1 November 1986 to take up an appointment as Marketing Director of the London Commodity Exchange. We thank him for his significant contribution to the progress of the GA and particularly for his efforts in refurbishing and polishing the Association's image.

NEWS OF FELLOWS

Mr M.J. O'Donoghue, M.A., F.G.S., F.G.A., has been appointed Editor of the Newsletter of the Geological Information Group of the Geological Society and to membership of the Geological Society's Library Committee.

Messrs O'Donoghue and Read, with Mr R. Huddlestone, conducted a one-day course for Preliminary Examination candidates at 100 Hatton Garden, London E.C.1, from 17–19 June 1986.

MEMBERS' MEETINGS

London

On 16 September 1986 at the Flett Theatre, Geological Museum, Exhibition Road, South Kensington, London S.W.7, Mr Ken Scarratt, F.G.A., Director of the Gem Testing Laboratory of Great Britain, gave an illustrated talk entitled 'Happenings at the Lab'.

Midlands Branch

On 19 September 1986 at Dr Johnson House, Bull Street, Birmingham, Mr A. Hodgkinson, F.G.A., gave a talk entitled 'New sources of gemstones and new synthetics'.

North West Branch

On 19 June 1986 at Church House, Hanover Street, Liverpool 1, Mr D. Durham gave a talk entitled 'From rough to finished gem'.

On 18 September 1986 at Church House, Mr A. Hodgkinson, F.G.A., gave a talk entitled 'New sources of gemstones and new synthetics'.

COUNCIL MEETINGS

At the meeting of the Council held on 26 August 1986 at Saint Dunstan's House, Carey Lane, London EC2V 8AB, Mr Jonathan P. Brown, Barrister-at-Law, F.G.A., was appointed successor to Mr Con Lenan as Secretary of the Association (see p.202).

At the meeting of the Council held on 16 September 1986 at the Royal Automobile Club, 89 Pall Mall, London S.W.1, the business transacted included the formal appointment of Mr J.R.H. Chisholm, M.A., F.G.A., as Consultant Editor. A list of members elected will appear in the January 1987 issue of the *Journal*.

NEW GEMMOLOGY COURSE

On 31 August 1986 at the International Watch, Jewellery and Silver Trades Fair, Earls Court, London, a champagne reception was held to mark the official launching of the New Gemmology Course (Preliminary section).

GEMMOLOGICAL ASSOCIATION INAUGURAL DINNER, NEW YORK CITY

The Inaugural Dinner of the Gemmological Association of Great Britain in the United States was held on 9 June 1986 in New York City, where approximately 60 people gathered at the New York Athletic Club. People from various parts of the country were present and the Gemmological Association was honoured to have among its guests recognized leaders of the gemmological profession and representatives of the nation's leading gem trade associations. Guests were welcomed by Dorothy Gibson, F.G.A. (Tully Medallist, 1984), and the speaker was David Callaghan, F.G.A., Chairman of the Gemmological Association, who, of course, was already well-known to many of the guests. All enjoyed his talk on the Association and also on jewellery.

The Gemmological Association plans to hold similar dinner meetings in different parts of the United States when the Chairman or other Officers of the Association are in the country.

SEMINAR ON GEOLOGICAL AND MINERALOGICAL LITERATURE

The Science Reference and Information Service will be holding a one-day seminar on the use of geological and mineralogical literature on 3 December 1986. It is intended for those dealing professionally with the extensive literature of the earth sciences for librarians and research workers and anyone who needs to become familiar with the very large amount of information now available on such topics as prospecting, mineral testing, details of new minerals and of particular rock and mineral groups such as ores and gemstones. The needs of the oil and mining industries will also be covered.

The seminar will be held at the Science Reference and Information Service, 25 Southampton Buildings, Chancery Lane, London WC2A 1AW. The price of the seminar is £43.50 (plus VAT) to include lunch and refreshments.

Application forms can be obtained from Marketing and Public Relations Section, Science Reference and Information Service, 25 Southampton Buildings, London WC2A 1AW. Telephone 01-405 8721, ext. 3427.

GEMOLOGICAL INSTITUTE OF AMERICA

The Institute has announced the appointment of Bill Boyajian as acting President following the resignation of Glenn Nord to take up another appointment.

EXAMINATIONS 1987

The examination dates for 1987 are as follows:

Gem Diamond Examination:
    Monday 8 June.
Examinations in Gemmology:
    Preliminary: Theory, Monday 29 June.
    Diploma:
    Theory, Tuesday, 30 June.
    Practical, Wednesday, 1 July (the practical examination may also be held on Thursday 2 July and Friday 3 July)

The last date for receipt of examination entry forms is 31 March.

Letter to the Editor

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

Dear Sir,

I read with sadness Mr Morgan's obituary for Mr F.S.H. Tisdall whom I first encountered as a student in the mid 1960s. This sounds strange when we realize that he actually took his Diploma with Distinction in 1936 (not '35).

It is not generally known that this quite remarkable man, feeling that his gemmology might perhaps have rusted a little, actually applied for permission to sit the GA examinations, which he had already passed so brilliantly, a second time. It was not possible to allow this but the Council did not prevent him from working through the entire two years of the correspondence course again. I undertook to be his instructor and must admit that he gave me quite a run for my money. He had a shrewd and enquiring mind which he exercised to the full, and our exchanges were very lively at times.

Later, when I had an office in Holborn from 1967 to 1979, he would turn up from time to time, often quite unheralded, and start further discussions even before he was properly through the door. A man of considerable character in more senses than one. I have not heard him described as a Midland's Robert Webster but, having known the latter extremely well, I can confirm that they were alike in many ways.

Yours etc.,
Keith Mitchell

11 August 1986
21 Bark Hart Road, Orpington, Kent.

CORRIGENDA

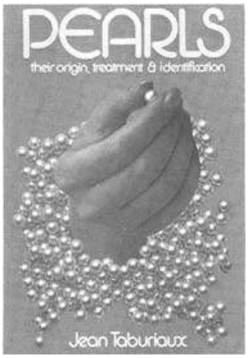
In *J. Gemm.*, 1985, **XIX** (7), on p.620, Table 3, last column: for 'Add 0.0006' read 'Subtract 0.0017'; for 'Subtract 0.0004' read 'Add 0.0010'; for 'Subtract 0.0007' read 'Add 0.0015'; and for 'Subtract 0.0008' read 'Add 0.0020'

On p.152 above, in the caption to Figure 21, for 'Figure 21' given in brackets throughout the caption, read 'Figure 20'

On p.173 above in fig. 2 (c) the crown angles were omitted. The values to be inserted on the four curves are 24°, 30°, 34.5° and 37°, reading from the lowest curve upwards.

On p.196 above, 1st column, in line 12 from foot, for 'cemetary' read 'cemetery'

On p.199 above, 1st column, last heading, for 'America' read 'Africa'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Genesis

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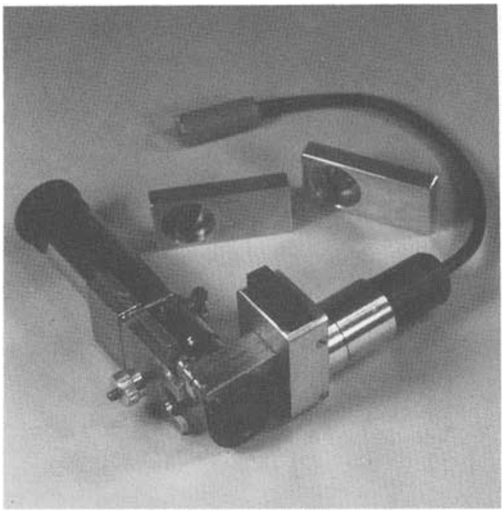

It can be used with a free-standing light source (M–19) or mounted on a light source and stand (M–1). Further details and applications are given in 'Colour Filters and Gemmological Colorimetry', J. Gemm., 1985, XIX, No. 7 (July), 597–624. Telephone or write for a descriptive gemstone instruments price list to:–

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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.

Twenty five copies of individual papers are provided on request free of charge; additional copies may be supplied, but they must be ordered at first proof stage or earlier.

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