Volume 21 No. 4.

October 1988

The Journal of Gemmology

GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

OFFICERS AND COUNCIL

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The Journal of Gemmology

VOLUME 21

NUMBER FOUR OCTOBER 1988

Cover Picture

The Airoldi Chalice; silver and gold plate, decorated with red coral carved as angel and cherub heads and leaf motifs. Sicilian workmanship, XVII century; height 230mm.
Photograph courtesy CISGEM, Milan

ISSN: 0022-1252

The Buckingham Award

Mr W.C. Buckingham, FGA, has very generously donated his fine collection of zircon rough to the Gemmological Association of Great Britain to mark his retiral after fifty years from the firm of George Lindley & Co. Ltd. He is also offering an award to newly-qualified Fellows of the Association who carry out research on samples from the collection.

The criteria for the research are:

1. The rough specimens originate from various localities, mostly Indo-China, and the research might be directed towards determining any variation in properties from the different localities. However, other research topics would be considered.
2. Having carried out the research programme, the Fellow must present the results in the form of a paper which would, in the opinion of the Editor, be worthy of publication in *The Journal of Gemmology.*
3. A Fellow whose research and paper satisfy these criteria will be awarded the sum of £100 or books and/or instruments to that value.
4. The Fellow must first apply in writing to the Secretary of the Association, setting out his proposed research and methodology and the instruments he proposes to use. The time to be taken must also be specified.

Research materials provided by the Association must be returned within the time stipulated.

The Association reserves the right to authorize or reject research projects at its sole discretion and will not enter into the reasons for any decision made.

Those interested in the Award are invited to write to the Secretary of the Gemmological Association, Saint Dunstan's House, Carey Lane, London EC2V 8AB, giving the information set out in item 4 above.

Imitation pearl coatings

S.J. Kennedy, J.G. Francis** and G.C. Jones***

*Gem Testing Laboratory of Great Britain, 27 Greville Street, London EC1N 8SU.
**Dept. of Mineralogy, British Museum (Natural History), London SW7 5BD.

Abstract

The coating on an imitation pearl was studied by a variety of techniques. The nacreous effect of the coating was found to be due to minute platy hexagonal crystals of basic lead carbonate suspended in a clear nitrocellulose lacquer. The form of the crystals was studied by scanning electron microscopy while their composition was revealed by infrared spectroscopy and electron microprobe analysis.

Introduction

A single-row, ungraduated bracelet of 24 'pearls' and 6 round, black beads with 3 colourless, stone-set metal spacers (Figure 1) was submitted to the Gem Testing Laboratory of Great Britain by a trading standards authority with the request to test both beads and 'pearls'.

Identification of the black beads as onyx was not difficult – the X-ray powder diffraction pattern obtained was that of quartz. A cursory examination of the pearls with a 10x loupe showed a form of the granular structure typical of imitation pearls. A radiograph of the necklace demonstrated clearly that these were not nacreous pearls. The radiograph (Figure 2) shows that the 'pearl' consists of a bead that is partly transparent to X-rays, surrounded by an X-ray opaque coating. This coating shows up as a lighter rim to the greyish disc of the bead.

This information would normally be sufficient, and a report would be issued to the effect that the beads were imitation pearls. However, in this case, because questionable claims had been made about the composition of the imitation pearls, it was necessary to identify the materials used in their manufacture. One 'pearl' was subjected to further examination.

Glass bead

The bead which formed the body of the 'pearl' was found to be glass by X-ray diffraction and electron microprobe techniques. The only point of interest here was that the glass was semi-transparent to X-rays, whereas coated imitation pearls have tended to be made of a glass that is opaque to X-rays. This difference can be

Fig. 1. Imitation pearl and onyx bead bracelet – the milky white bead next to an onyx bead (top right) is the glass bead from which the nacreous coating has been removed.

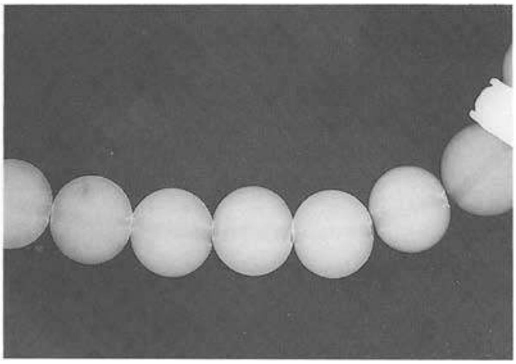

Fig. 2. Radiograph of imitation pearl from bracelet.

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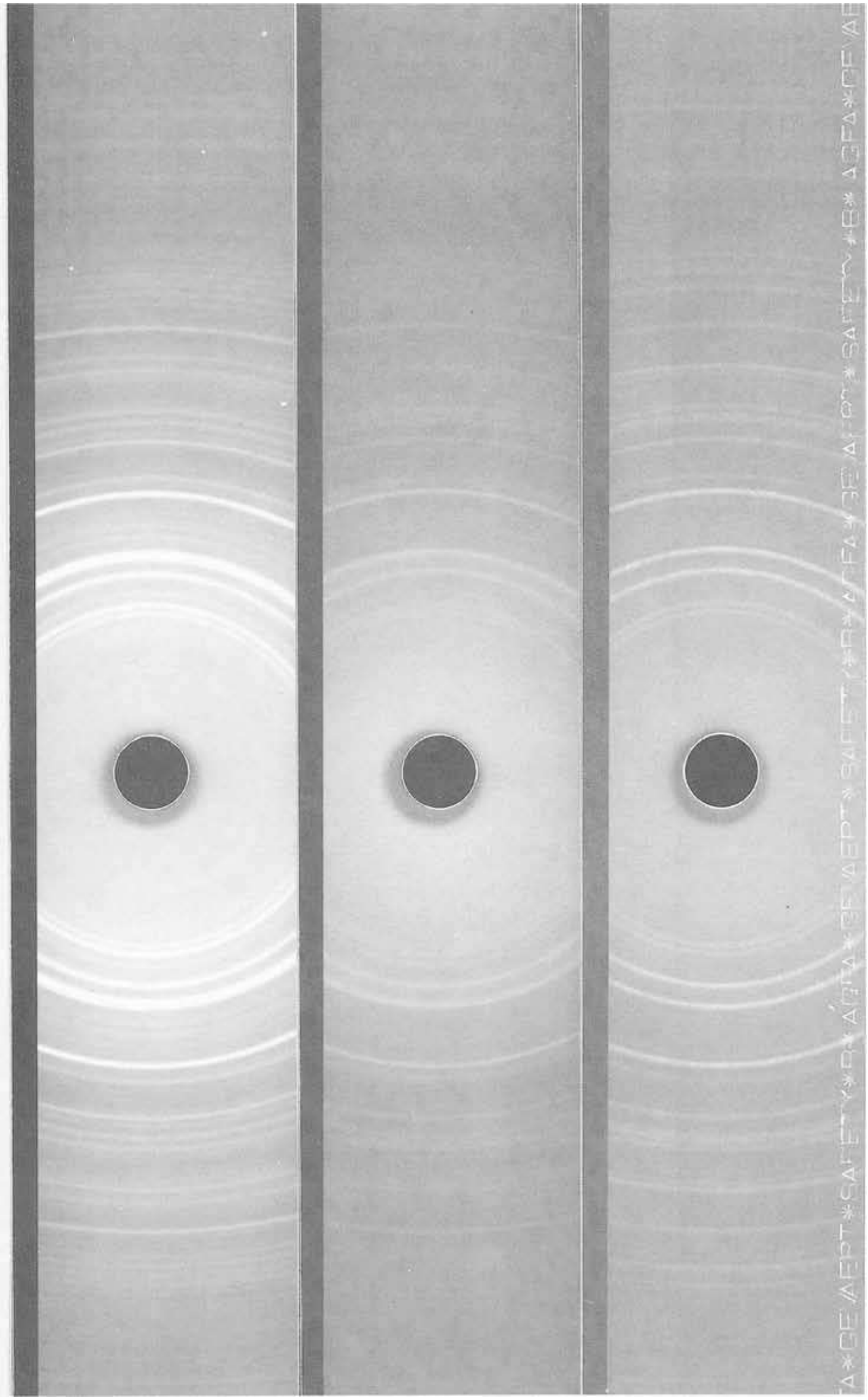

Fig. 3. X-ray powder diffraction patterns of: (top) material coating imitation pearl; (middle) commercial grade 'white lead'; (bottom) hydrocerussite; Ashover, Derbyshire, UK.

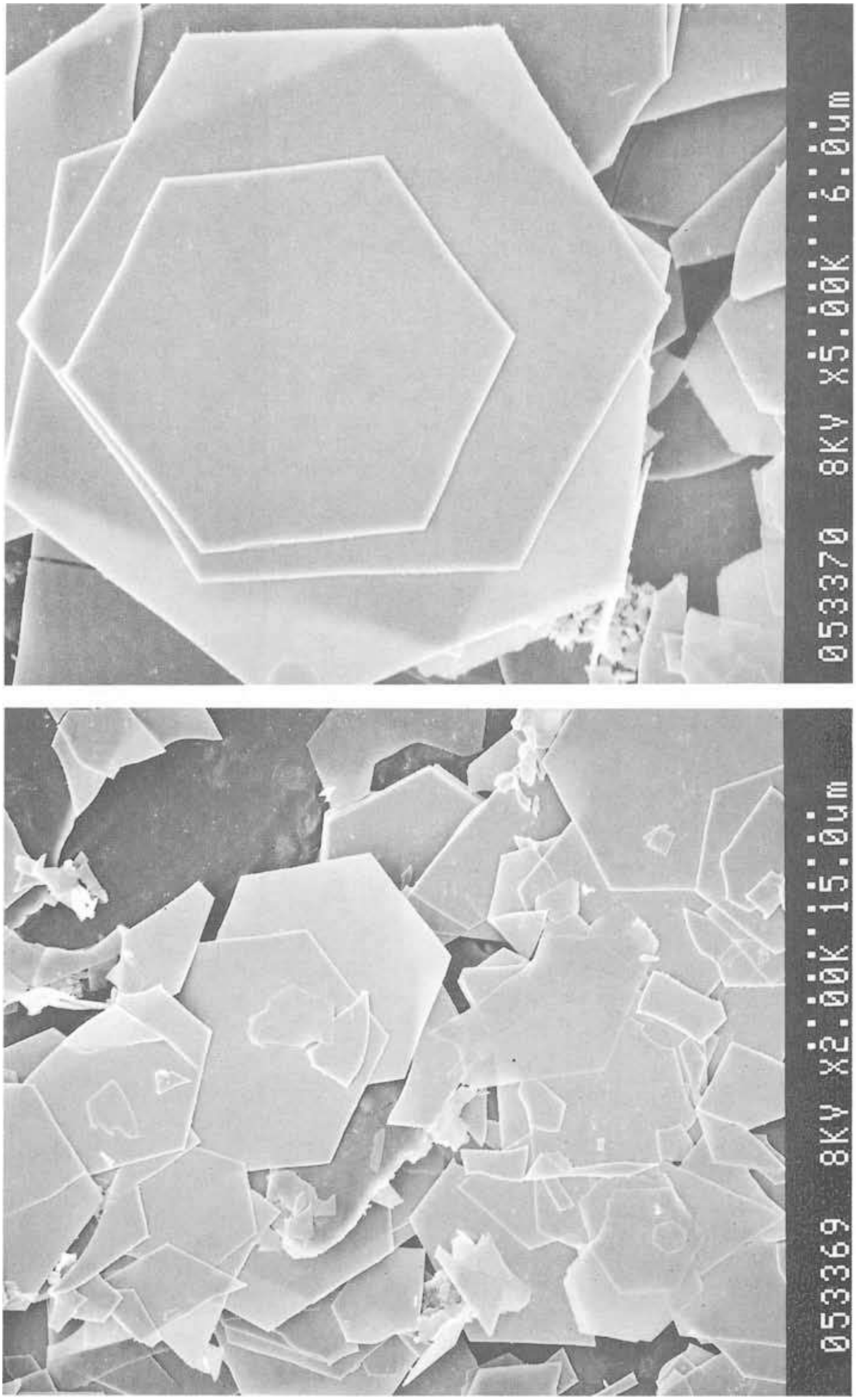

Fig. 4. Scanning electron microscope image of nacreous filler from imitation pearl coating (left) 2000x, (right) 5000x.

accounted for by the relatively low lead content (approx. 1% PbO) as found by electron microprobe analysis.

Coating

The X-ray powder diffraction pattern of the pearl coating obtained at the Gem Testing Laboratory (Figure 3a) was close to that of the mineral hydrocerussite (Figure 3c), but did not match it exactly. The use of hydrocerussite as an imitation pearl coating has been documented[1], but the anomaly in the diffraction photograph led us to pursue the matter further, using a variety of techniques available at the Department of Mineralogy, BM(NH).

An infrared spectrum of the coating material showed a mixture of nitrocellulose and another component. During an unsuccessful attempt to dissolve the coating in dichloroethane, it separated into two layers, i.e. a nitrocellulose 'sandwich' with nacreous inner surfaces. Acetone dissolved the nitrocellulose lacquer completely and allowed further infrared spectra to be run on the separated soluble and insoluble materials (approx. 56 wt% insol.). These spectra confirmed the identification of nitrocellulose and a hydrocerussite-like filler. Under the optical and scanning electron microscopes, the acetone-insoluble nacreous filler appeared as minute hexagonal plates of average size 15 × 0.25 micrometres (Figure 4). These plates were also examined in the electron microprobe, which revealed lead as the only detectable element (elements lighter than sodium are not detectable by this instrument).

Hydrocerussite or lead dihydroxydicarbonate has been produced synthetically by many different methods, some of which are quoted as giving rise to hexagonal nacreous plates[2].

The exact chemical composition of these synthetic products is in doubt, as is the composition of the pigment 'white lead' which is another form of hydrocerussite[3]. A specimen of white lead gave an X-ray diffraction pattern and an infrared spectrum both of which matched much more closely those of the pearl material than the mineral hydrocerussite (see X-ray patterns, Figures 3b & 3c).

Further background

After these investigations were completed, M. Jean Paul Poirot presented a paper at the International Gemmological Conference in Brazil in 1987 entitled 'Imitation pearls and their coatings'. He noted the following crystalline materials as being present in the nacreous coatings of imitation pearls and visible on microscopic examination of an acetone extract of the coating:

(1) rods of guanine approx. 5 × 30 micrometres – this is a component of the well-known 'essence of orient' extracted from fish scales and one of the longest-used pearl simulants; or
(2) square plates of bismoclite (bismuth oxychloride) approx. 10 micrometres across – this compound is also used in 'pearl' cosmetics such as nail varnish, etc.; or
(3) hexagonal plates of hydrocerussite approx. 15 micrometres across; or
(4) fragments of mica crystals, sometimes coated with titanium dioxide.

Conclusion

The imitation pearls in question are coated with a synthetic, basic lead carbonate in the form of minute hexagonal plates, suspended in and coated by clear nitrocellulose lacquer.

The anomalies in the X-ray powder diffraction patterns and infrared spectra are the result of the variable nature of the basic lead carbonate, the exact composition of which depends on its method of production.

References

1. Webster, R., 1983, *Gems, their sources, descriptions and identification*. Butterworths, London. 557 pp.
2. Mellor, J.W., 1930, *A comprehensive treatise on inorganic and theoretical chemistry*, VII, 836–9.
3. Ibid. 846–7.

[*Manuscript received 3 July 1988.*]

Alexandrite: natural or synthetic?

*H. Bank**, *E. Gübelin***, *U. Henn** *and J. Malley*†

*Idar-Oberstein, West Germany
**Meggen, Switzerland
†Mainz, West Germany

Since the appearance on the market of great quantities of rough and faceted alexandrites from Brazil (Bank *et al.*, 1987a; Bank *et al.*, 1987b; Gübelin and Schiffmann, 1988), the differentiation between these (to a great extent relatively inclusion-free) gemstones, and synthetic alexandrites, has naturally been pushed into the foreground of gemmological investigations. Recently a dark green-to-violet changing to red-violet stone of 1.34 ct (faceted, oval, 7.2 × 6.4 × 3.5 mm) arrived for investigation, which had been identified by a laboratory as a synthetic alexandrite. Yet the owner of the stone doubted this outcome, since he had purchased it personally in the rough at the mine in Brazil and had also cut it himself (which, however, does not prove that it is genuine).

The stone was doubly-refractive on the polariscope and biaxial on the conoscope. The standard gemmological values were as follows:
$n_x = 1.745$, $n_y = 1.748$, $n_z = 1.754$, $\triangle n = 0.009$, $D = 3.71$ g/cm^3.
These all indicate the mineral variety chrysoberyl ($BeAl_2O_4$), which crystallizes in the orthorhombic system. With the aid of spectroscopic analyses, the stone could be identified as an alexandrite through the presence of chromium lines. Yet the question of natural versus synthetic still remained unsolved.

Microscopically, step-like growth striations were observed – which are also no indication of natural origin – as well as 'fingerprint-feathers' of bizarre-shaped cavities (Figure 1). Some of the latter contained a solid substance which between crossed polars displayed interference colours, and was thus founded to be doubly-refractive. With overhead illumination, these inclusions reflect strongly (Figure 2) and are thus reminiscent of the flux residues in synthetic alexandrite (Gübelin and Koivula, 1986, Trossarelli, 1986, Henn, 1987).

Several inclusions were exposed to the surface of the faceted stone, allowing further investigations as to their identity with the help of more sophisticated methods. Qualitative energy-dispersive analyses with the aid of a scanning electron microscope (SEM), identified very diverse substances in the fissures surrounding the exposed inclusions. Figure 3 shows such an area of fissures; the white streak measures 50 μm. The white spherical grain could be identified as tin. Similar solid substances present in these fissures proved to be copper, nickel and lead. Lead-oxide was detected by means

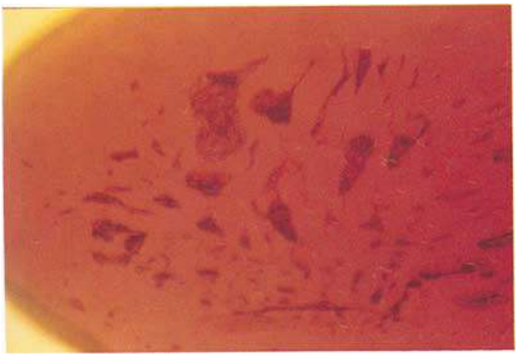

Fig. 1. Bizarre-shaped cavities, partly filled with solid substance. 15x.

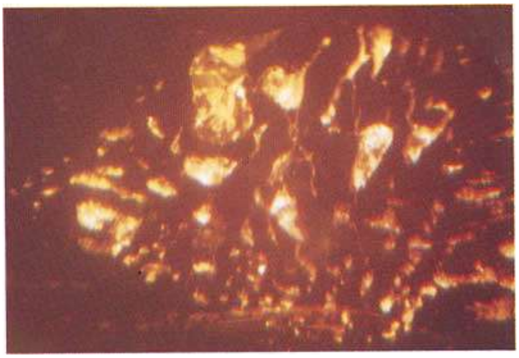

Fig. 2. Bizarre-shaped cavities, partly filled with solid substance. Reflected light. 20x.

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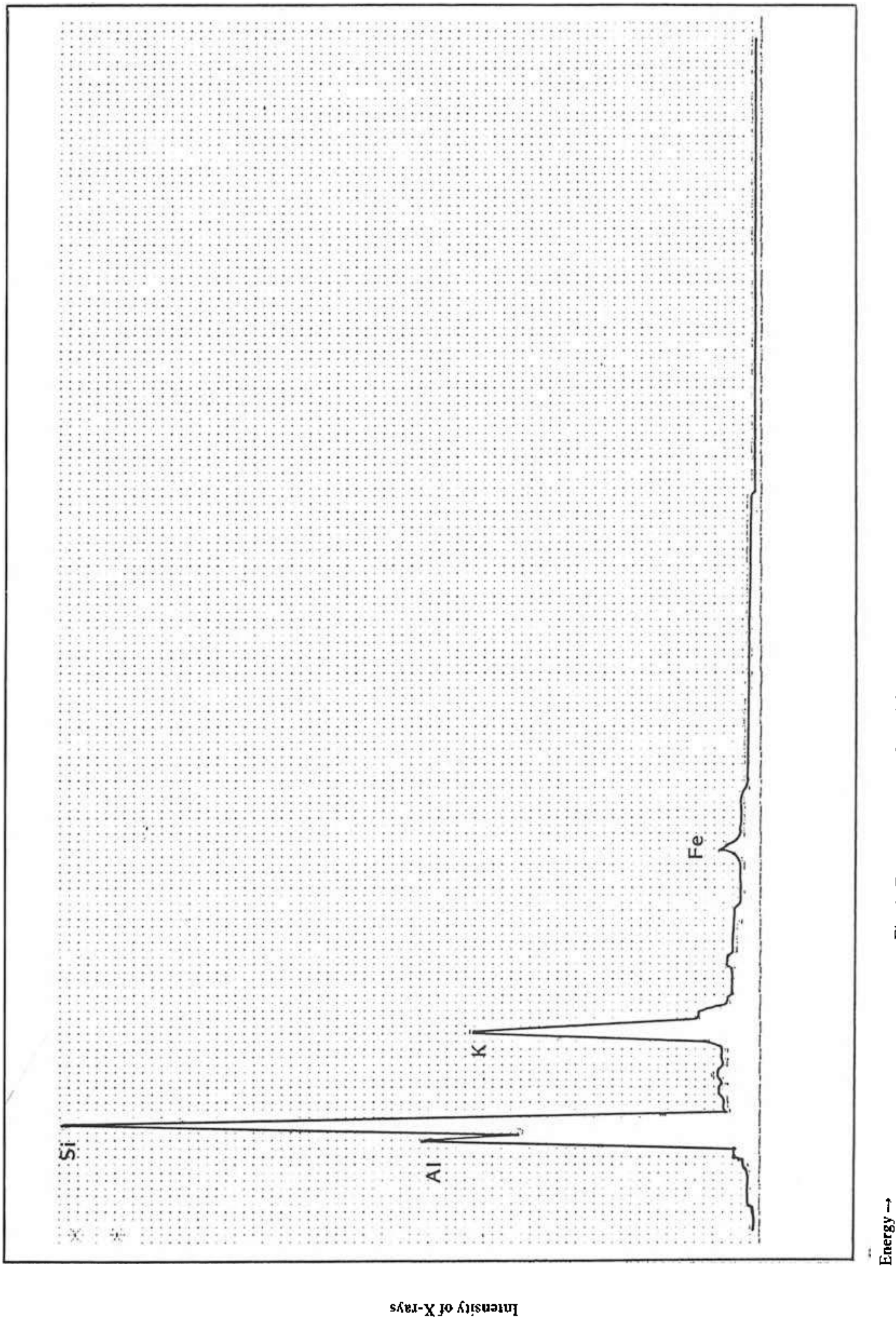

Fig. 4. Energy-spectrum of alkali-feldspar inclusion.

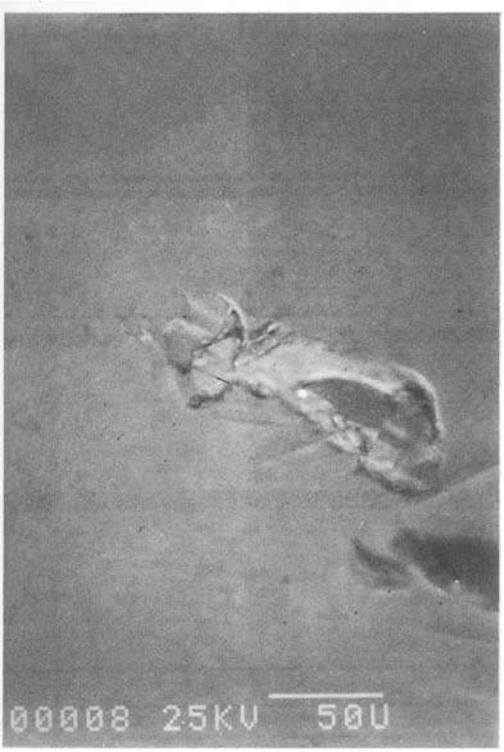

Fig. 3. SEM-photograph: fissure with solid substances.

of the Raman spectroscope. The latter was quoted as proof that the investigated stone was a synthetic alexandrite. These spherical metal grains, however, were not securely lodged in the fissures, and are probably remnants left by the cutting or polishing discs, which were forced into the fissures during these processes.

A more precise investigation of the solid fillings of these fissures revealed the presence of potassium-rich aluminium silicates – probably potassium feldspar (Figure 4). This definitely proves the natural origin of the stone.

Acknowledgements

Scanning electronic microscope analyses were carried out at the Max-Planck-Institut für Chemie, Abt. Kosmochemie, Mainz, West-Germany. Financial support was given by grants of the Wirtschaftsministerium des Landes Rheinland-Pfalz, FRG, within a project for applied research.

References

Bank, H., Henn, U. & Bank, F.H., 1987a. Ein neues Alexandritvorkommen in Brasilien. *Goldschmiede Zeitung*, Heft 9, 90–1.

Bank, F.H., Bank, H., Gübelin, E., Henn, U. 1987b. Alexandrite von einem neuen Vorkommen bei Hematita in Minas Gerais, Brasilien. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 36, 121-31.

Gübelin, E., Koivula, J.I., 1986. *Photoatlas of inclusions in gemstones*. ABC Edition, Zürich.

Gübelin, E., Schiffmann, C.A., 1988. Alexandrite from a Newly Discovered Occurrence in Brazil. *Schweizerische Uhrmacher und Goldschmiede Zeitung*, International issue, 2/1988.

Henn, U., 1987. Inclusions in yellow chrysoberyl, natural and synthetic alexandrite. *Australian Gemmologist*, **16**, 217–20.

Trossarelli, C. (1986): Synthetic alexandrite from USSR. *Gemmologia*, **11**, 6–22.

[*Manuscript received 3 May 1988.*]

A new type of twinning in natural sapphire

Dr Karl Schmetzer

Institute of Mineralogy and Petrography, University of Heidelberg, West Germany

Abstract

A new type of twin structure in natural sapphire from Sri Lanka is described. The samples reveal inserted irregularly shaped bodies of subordinate corundum individuals, which are confined to intercalated lamellae parallel to rhombohedral faces *r* (10$\bar{1}$1) and related to the dominant crystal by reflection across (10$\bar{1}$1).

In some cases, the recognition of certain types of twinning in ruby and sapphire is applicable to the distinction of natural and synthetic corundum. In general, a detailed knowledge about twin structures occurring in natural ruby and sapphire as well as in different types of synthetic corundum is necessary in order to avoid misinterpretations of structural properties during microscopic examination of samples of unknown origin. A general survey dealing with twin structures in natural rubies from different localities is given by Schmetzer (1987), and the results described in the paper cited are also valid for natural sapphires without any restriction. Twinning in flux-grown gem quality synthetic ruby and sapphire was described in detail by Schmetzer (1987) and Kiefert & Schmetzer (1988).

In natural corundum, three types of twinning are observable: contact twins on the basal plane *c* (0001) or on the positive rhombohedron *r* (10$\bar{1}$1) with two macroscopically developed individuals are rare. Repetitive twinning on *r* (10$\bar{1}$1), on the other hand, is common in natural ruby and sapphire but, in general, only thin lamellae of corundum in twin position are intercalated parallel to one, two or three rhombohedral faces of the dominant ruby or sapphire crystal. In some samples, intercalated lamellae were found to end irregularly within the dominant corundum individual. The new type of twin structure to be described in this paper is confined to intercalated lamellar twinning on *r* (10$\bar{1}$1). Up to now, twinning of this particular type was observable only in natural corundum, but never in synthetic rubies or sapphires of different producers.

The new type of twin structure was observed in the course of microscopical examination of some hundreds of light yellowish or bluish untreated (i.e. non-heat treated) natural sapphires from Sri Lanka. In about 50 of these cabochon cut samples, bodies of corundum crystals were found to occur in an orientation different from the dominant sapphire individual. Due to their different crystallographic orientation, these corundum crystals inserted into the dominant individual are clearly recognizable under crossed polarizers, but not in plane polarized light (Figures 1–6). Part of these inserted bodies reveal only irregular surfaces as boundaries between dominant and subordinate corundum individuals (Figures 1, 2). Both crystals differing in orientation, in general, are not related by reflection across the positive rhombohedron *r* (10$\bar{1}$1) and, at present, it is unknown to the author if both parts of the crystals are connected by an unknown twin law or not.

Samples of the second part of sapphire crystals with inserted bodies of corundum reveal at least one plane surface as boundary between dominant and subordinate individuals (Figure 3). A thorough microscopic examination indicates that, in all cases, these contact planes are parts of intercalated lamellae on *r* (10$\bar{1}$1) [Figures 4, 5, 6]. The remaining boundaries between main crystals and inserted irregular bodies, i.e. those boundaries which are not confined to an intercalated lamella on *r*, may consist of either irregular surfaces or of plane crystal faces (Figures 3–6).

In part of the crystals investigated, up to five inserted bodies of corundum were observed, which are confined to several intercalated lamellae parallel to one rhombohedral face *r* (10$\bar{1}$1). In two samples, inserted bodies of corundum in twin position were found which are confined to intercalated lamellae parallel to two rhombohedral faces *r* and *r'* {10$\bar{1}$1}.

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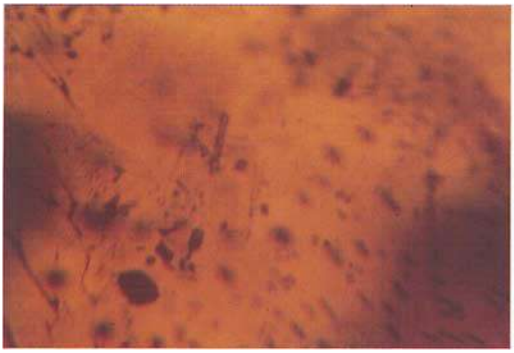

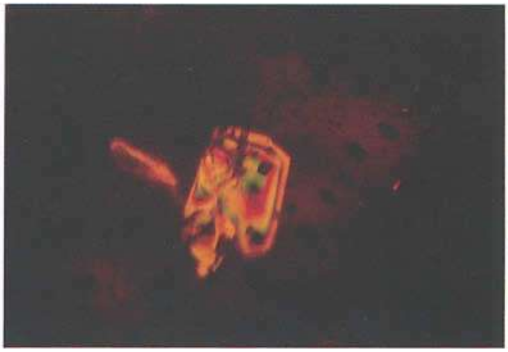

Figs. 1, 2. Natural sapphire from Sri Lanka; inserted bodies of corundum revealing irregular surfaces as boundaries between subordinate crystals and the dominant individual. Fig. 1, plane polarized light; Fig. 2 crossed polarizers. 100x.

Fig. 3. Natural sapphire from Sri Lanka; inserted bodies of corundum revealing plane boundaries between dominant and subordinate individuals. Crossed polarizers. 30x.

Fig. 4. Natural sapphire from Sri Lanka; inserted body of corundum [below] confined to an intercalated lamella on the positive rhombohedron r $(10\bar{1}1)$ [above] as boundary between dominant and subordinate individuals. View almost perpendicular to the intercalated lamella, crossed polarizers. 20x.

Fig. 5. Natural sapphire from Sri Lanka; inserted body of corundum confined to an intercalated lamella on the positive rhombohedron r $(10\bar{1}1)$ as boundary between dominant and subordinate individuals. View parallel to the intercalated lamella, crossed polarizers. 20x.

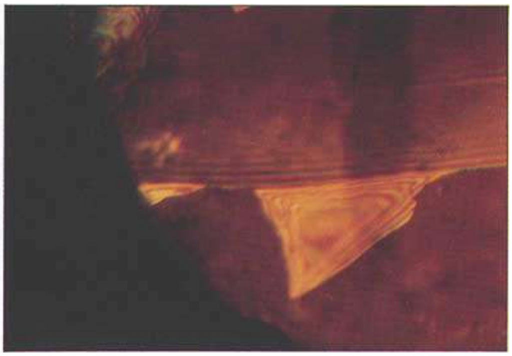

Fig. 6. Natural sapphire from Sri Lanka; inserted bodies of corundum confined to an intercalated lamella on the positive rhombohedron r $(10\bar{1}1)$ as boundary between dominant and subordinate individuals. View almost parallel to the intercalated lamella, crossed polarizers. 40x.

According to its properties, the new type of twin structure in corundum described combines both single types of rhombohedral twinning, i.e. contact twinning on r $(10\bar{1}1)$ [consisting of two macroscopically developed individuals] and lamellar twinning on r $(10\bar{1}1)$ [consisting of intercalated thin lamellae]. Consequently, this type of twinning is classified as combined rhombohedral twinning.

References

Kiefert, L., Schmetzer, K., 1988. Morphology and twinning in Chatham synthetic blue sapphire. *Journal of Gemmology*, 21, 16–22.

Schmetzer, K. 1987. On twinning in natural and synthetic flux-grown ruby. *Journal of Gemmology*, 20, 294–305.

[*Manuscript received 22 February 1988.*]

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An unusual ruby from Nepal[*]

H. Bank[1], E. Gübelin[2], R.R. Harding[3], U. Henn[1], K. Scarratt[4] and K. Schmetzer[5]

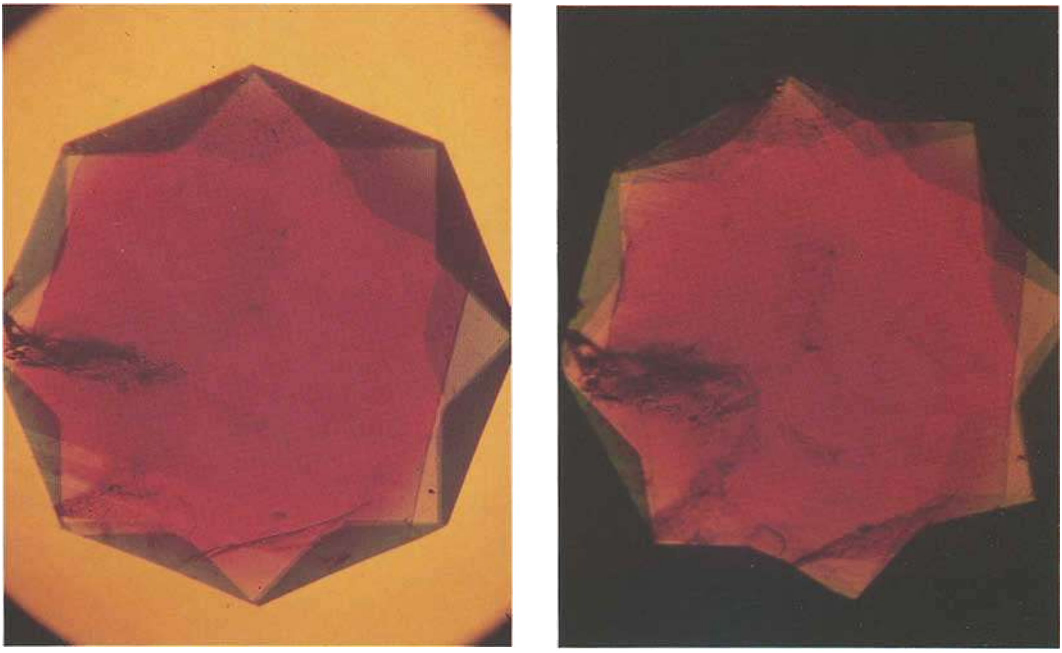
[1]Deutsche Stiftung Edelsteinforschung, Idar-Oberstein, West Germany
[2]Meggen, Switzerland
[3]British Museum (Natural History), London
[4]The Gem Testing Laboratory of Great Britain, London
[5]Institute of Mineralogy and Petrography, University of Heidelberg, West Germany

Abstract

A high quality ruby from Nepal is described. The stone, weighing 1.288ct, revealed extraordinary growth structures connected with colour zoning as well as mineral inclusions (phlogopite), feathers consisting of two- and most probably three-phase inclusions and ultra-fine fluid films, as diagnostic characteristics.

Introduction

A purely gemmological routine investigation can sometimes result in a false diagnosis, or at least create difficulties, especially when the problem concerns the differentiation between natural gems and synthetic stones. This is particularly so if the inclusions observed are not clearly indicative, but



Figs 1 and 2. Growth structures and colour zoning in a natural ruby from Nepal; view almost perpendicular to the *c*-axis; broad alternate colourless and red bands parallel to the basal pinacoid *c* (0001) forming the lower edge of the sample, colourless parts confined to growth structures parallel to the hexagonal prism *a* (11$\bar{2}$0) on the left side of the sample and parallel to the hexagonal dipyramid *ν* (44$\bar{8}$1) on the right of the sample, spindle-like growth structures in the dark red central part of the stone. Transmitted light using methylene iodide as immersion liquid. 22x. *(Photos by K. Schmetzer.)*

[*] The Editor received two papers on this subject on the same day. They have been combined to form this paper.

ISSN: 0022-1252

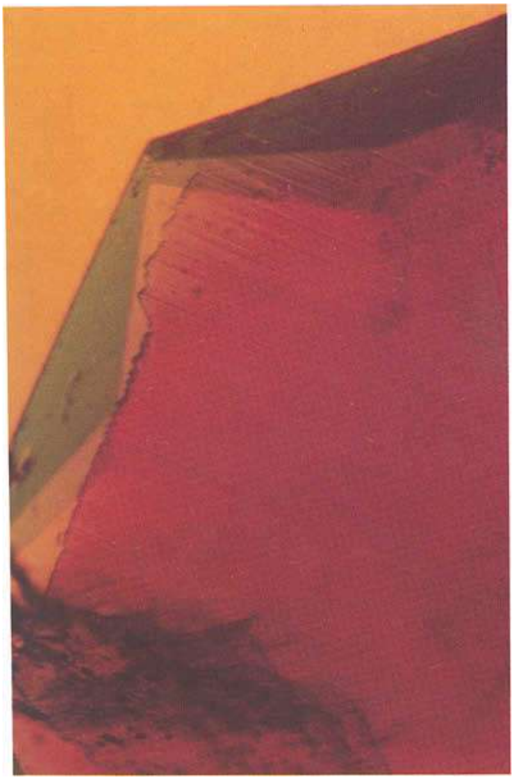


Fig. 3. Growth structures and colour zoning in a natural ruby from Nepal; view almost perpendicular to the *c*-axis; growth structure parallel to the hexagonal prism *a* $(11\bar{2}0)$ visible as boundary between colourless edge and dark red central part, spindle-like growth structures in the central part, parallel to the basal face *c* (0001). Transmitted light using methylene iodide as immersion liquid. 30x. *(Photo by K. Schmetzer.)*

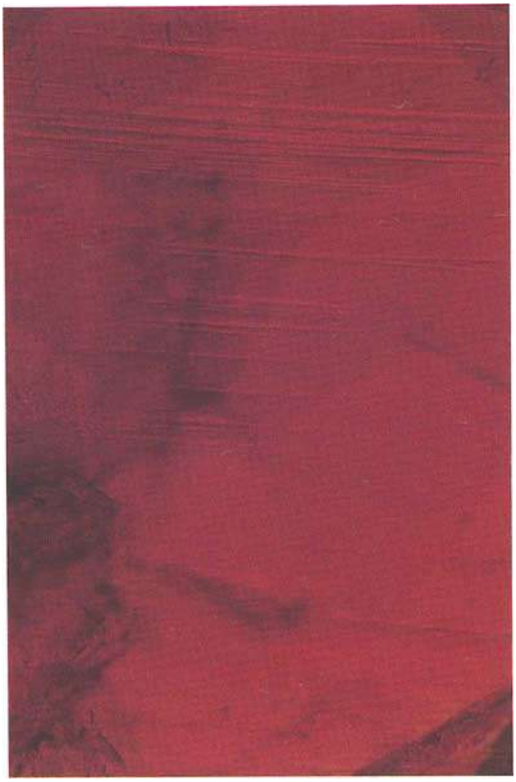


Fig. 4. Spindle-like growth structures in the dark red central part of a natural ruby from Nepal; view almost perpendicular to the *c*-axis. Transmitted light using methylene iodide as immersion liquid. 25x. *(Photo by K. Schmetzer.)*

ambiguous, i.e. if they could be found in both natural and synthetic stones and are not typical of either. This happened recently during the investigation of a faceted red stone, whereby the question was raised whether it was a natural or a synthetic stone, and whether it originated from the Kingdom of Nepal.

Ruby, as well as pink, violet and purplish sapphires, from Nepal were recently described by Harding and Scarratt (1986) and Kiefert and Schmetzer (1986, 1987). Most of the material available until now has been of cabochon quality and any faceted samples of notable transparency have been few. Thus, the authors were surprised to receive a faceted sample of more than one carat, with excellent purity, a good 'Burmese red' colour, and which was said to originate from Nepal. Under the microscope the ruby revealed characteristics which closely resembled some of the properties seen in Ramaura and Kashan synthetic rubies and which had not been observed previously in Nepalese rubies. So the stone was examined in detail using spectroscope, microprobe and further microscopic investigations.

Investigation

The faceted ruby weighs 1.288 ct and is cut as an almost equilateral octagon (6.00 × 6.00 × 4.15 mm). The physical properties of the sample are within the range known for both natural and synthetic ruby, i.e. $n_o = 1.770$, $n_e = 1.762$, $\Delta n = 0.008$, $D = 3.98\ g/cm^3$, and with the hand spectroscope the normal chromium spectrum of ruby was detected.

The absorption spectrum of the sample in the visible and ultraviolet regions, as examined with the aid of a UV/VIS spectrophotometer, is similar to the spectra already published for ruby and sapphire from Nepal by Harding and Scarratt (1986) and Kiefert and Schmetzer (1986, 1987), but does not contain a significant Fe^{2+}/Ti^{4+} charge transfer absorption in the red region of the visible spectrum. Due to the absence of iron and/or titanium in distinct amounts, the sample reveals a good ruby colour without any purplish hue, i.e. without an additional sapphire component.

Using methylene iodide as an immersion liquid, a microscopic examination of the ruby, in a direction normal to the table facet, revealed a dark red central area, two well-defined and near-colourless areas situated close to the girdle and on opposite sides and another area, also bounded at one edge by the girdle, in which there was strong colour zoning (Figures 1, 2 and 3). In the latter area the alternating broad colourless and red zones (Figures 1 and 2) are parallel to the basal pinacoid *c* (0001), and the two near-colourless areas form angles of 90° and 85° respectively, with the growth structures connected with this colour zoning. Consequently, these colour zones are confined to growth structures parallel to the hexagonal prism *a* $(11\bar{2}0)$ and parallel to the hexagonal dipyramid *v* $(44\bar{8}1)$. Similar almost rectangular growth structures connected with colour zoning have been observed previously by the authors in Ramaura synthetic rubies. However, in such stones the growth zones forming angles of 86° are made by two different rhombohedral faces *r* and *r*′ $(10\bar{1}1)$.

Many of the microscopic observations disclosed ambiguous features which could neither be attributed clearly to a natural nor a synthetic ruby. Amongst the most confusing characteristics of this 1.288 ct ruby are the spindle-like growth structures in the dark red central part of the stone. These are parallel to the basal pinacoid *c* (0001) (Figures 1 and 4), and are connected with the colour zoning. These structural characteristics resemble features often observed in synthetic flux-grown rubies.

Both at the girdle and near the culet of the stone several small, solid inclusions are exposed at the surface. Examination by electron microprobe both in London and Heidelberg indicated that these inclusions are phlogopite (Figure 5), a mica which has already been identified in the paragenesis of ruby and rose and violet sapphire from Nepal.

Further microscopic examination revealed the presence of dark 'feathers' consisting of small more

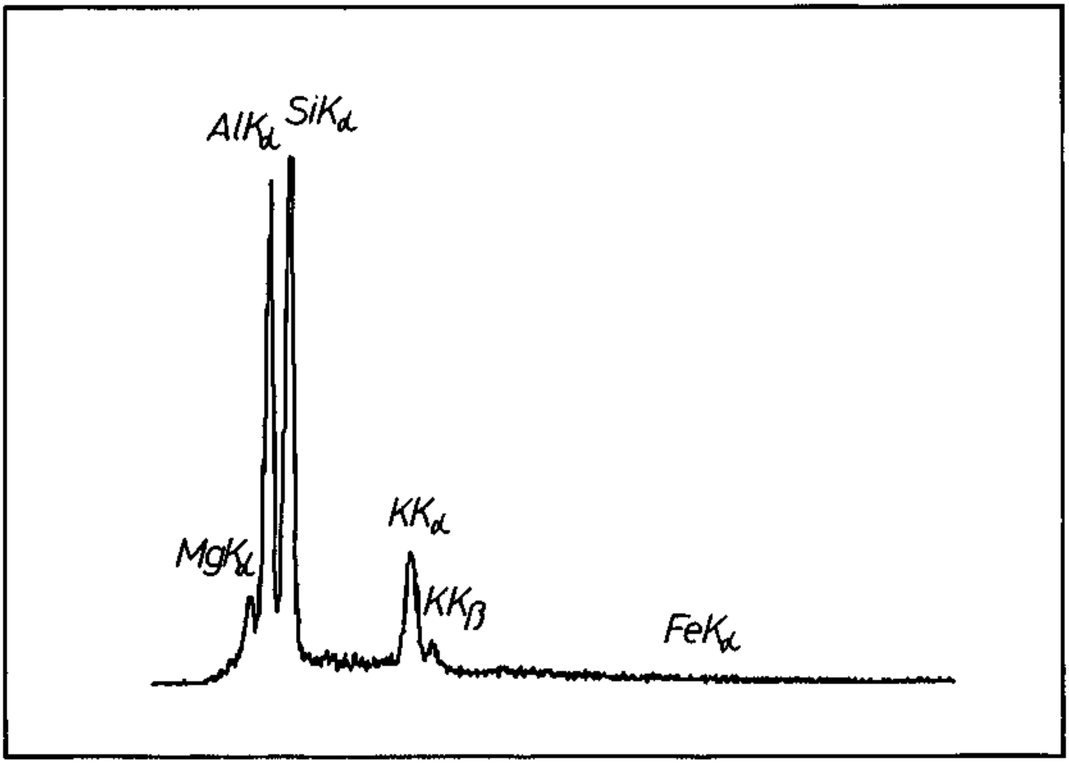


Fig. 5. Energy-dispersive X-ray spectrum of phlogopite in natural ruby from Nepal. This spectrum was performed by K. Schmetzer confirming results of R. R. Harding.

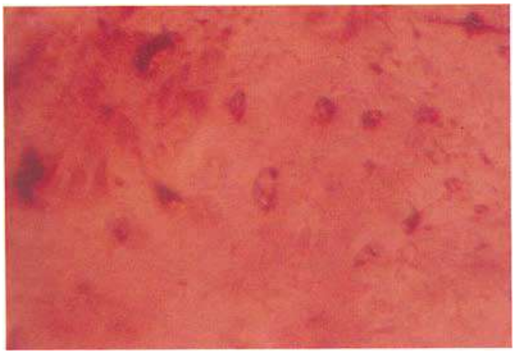


Fig. 6. 'Feather' consisting of irregular cavities and negative crystals with liquid and two-phase filling. Transmitted light using methylene iodide as immersion liquid. 75x. *(Photo by U. Henn.)*

Fig. 7. 'Feather' consisting of liquid, two- and most probably three-phase inclusions in natural ruby from Nepal. The solid components (probably margarite) show interference colours. Transmitted light using methylene iodide as immersion liquid, crossed polarizers. 80x. *(Photo by K. Schmetzer.)*

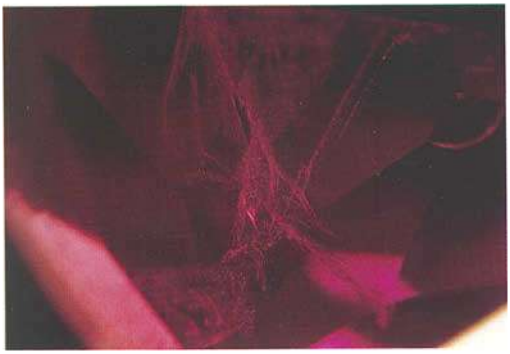


Fig. 8. 'Feather' consisting of small irregularly shaped cavities and negative crystals with multi-phase filling in natural ruby from Nepal. Darkfield illumination. 40x. *(Photo by K. Scarratt.)*

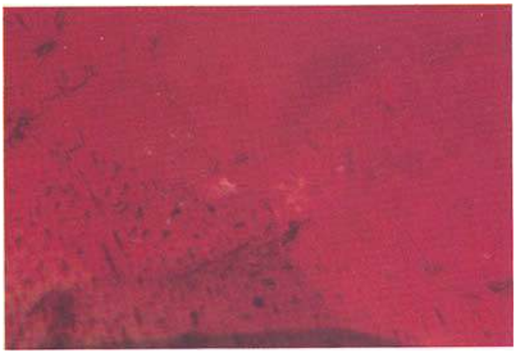


Fig. 9. 'Feather' consisting of small irregularly shaped cavities and negative crystals with multi-phase filling (lower left part) and ultra-thin liquid and two-phase inclusions showing interference colours under suitable illumination (central and upper right part). Transmitted light using methylene iodide as immersion liquid, crossed polarizers. 100x. *(Photo by K. Schmetzer.)*

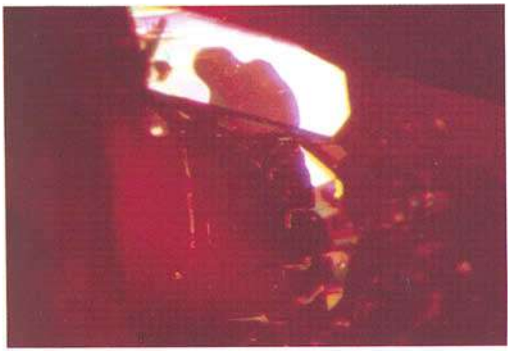


Fig. 10. Ultra-fine liquid films, partly also two-phase (liquid/gaseous) in natural ruby from Nepal; these fluid inclusions reveal interference colours under suitable illumination. Darkfield illumination. 50x. *(Photo by E. Gübelin.)*

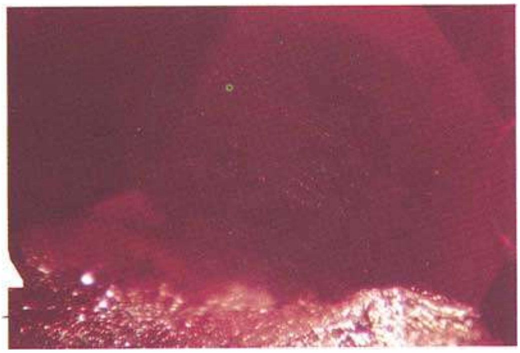


Fig. 11. Fine and bright dust-like 'fog' particles in natural ruby from Nepal. Reflected light. 60x. *(Photo by K. Scarratt.)*

or less irregularly shaped cavities as well as small crystals (Figures 6 to 9). The filling of the small cavities is liquid, two-phase (solid/liquid or liquid/gaseous) and, most probably, also three-phase (solid/liquid/gaseous). The solid parts of the inclusions displayed interference colours under crossed polarizers (Figure 4). Such feathers, which have been observed previously in Nepalese rubies of a much lower quality, closely resemble residual flux in flux-grown synthetic rubies. In addition, ultra-fine liquid films, sometimes also as two-phase inclusions (liquid/gaseous) were observed in the natural ruby from Nepal (Figures 9, 10). Under suitable illumination, these filmy inclusions glow with interference colours. The ultra-fine films testify – together with the phlogopite inclusions examined by electron microprobe – to the natural origin of the ruby. However, another type of inclusion was quite ambiguous at first sight; these are dust-like 'fog' striations (Figure 11), which are reminiscent of Kashan synthetic rubies.

Conclusion

In summary, the presence of phlogopite, two- and, most probably, three-phase inclusions, as well as ultra-fine fluid inclusions in this high quality, 1.288 ct ruby, on the one hand, proves the sample to be of natural origin, and, on the other, confirms its locality as Nepal. Until now the exceptional growth structures of this ruby had not been observed in natural rubies either from this or any other locality.

Acknowledgement

We would like to thank Ms F. Wall, Department of Mineralogy, BM(NH), for Microscan IX microprobe analyses of the ruby and its phlogopite inclusions.

References

Harding, R.R., Scarratt, K., 1986. A description of ruby from Nepal. *Journal of Gemmology*, 20, 3–10.

Kiefert, L., Schmetzer, K., 1986. Rosafarbene und violette Sapphire aus Nepal. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 35, 113–25.

Kiefert, L., Schmetzer, K., 1987. Pink and violet sapphires from Nepal. *Australian Gemmologist*, 16, 225–30.

[*Manuscript received 28 April, 1988.*]

ESR and optical spectra of Mn^{2+} sapphire

R. Liebach, Jill Dobbie, D.R. Hutton and G.J. Troup

Physics Department, Monash University, Clayton 3168, Victoria, Australia

Introduction

In our studies of the Electron Spin Resonance (ESR) spectra of natural sapphires (Troup and Hutton, 1983) we observed in many cases, a large number of small lines covering a large magnetic field range: an example is given in Figure 1. The hypotheses we put forward to explain these lines were: (a) that they could be due to pairs of Cr^{3+} or Fe^{3+} ions; (b) that they could be due to radiation damage; and (c) that they could be due to Mn^{2+}.

Although the Spin-Hamiltonian (ESR spectral parameters and behaviour) of Mn^{2+} in sapphire have been published previously (Low and Suss, 1960; Folen, 1962), no illustrations of spectra were given. It would have been possible to calculate the appearance of the spectra, but this involves assumptions about line-shapes. Accordingly, it was decided to synthesize some Mn^{2+} sapphire, in order to record the ESR spectra, and compare the appearance and line positions with the extended, small line spectra mentioned above.

Synthesis of Mn^{2+} sapphire

Crystals of Mn sapphire were grown in PbO–PbF_2 flux (Chase and Osmer, 1970). Analytical reagent grade chemical compounds were used, and the composition was: 17 mol % of Al_2O_3, 30 mol % of PbF_2, 53 mol % of PbO and 0.05 mol % of MnO_2. These amounts of the compounds were mechanically mixed in an alumina container by shaking with a mixing pulsator for two hours.

Subsequently the mixture was placed in a 60ml platinum crucible which was then closed with a platinum plug. The filled crucible was placed in a closed-end alumina tube and covered with alumina bubbles. A ceramic cap was used to close the open end of the tube. (Figure 2).

The alumina tube containing the Pt crucible was placed in the furnace and heated to 1270°C, held for 4 hours and cooled at 4°C/h to 900°C.

The crucible was then cooled with the furnace. The crystals which grew on the melt surface were removed from the solidified flux by leaching in hot

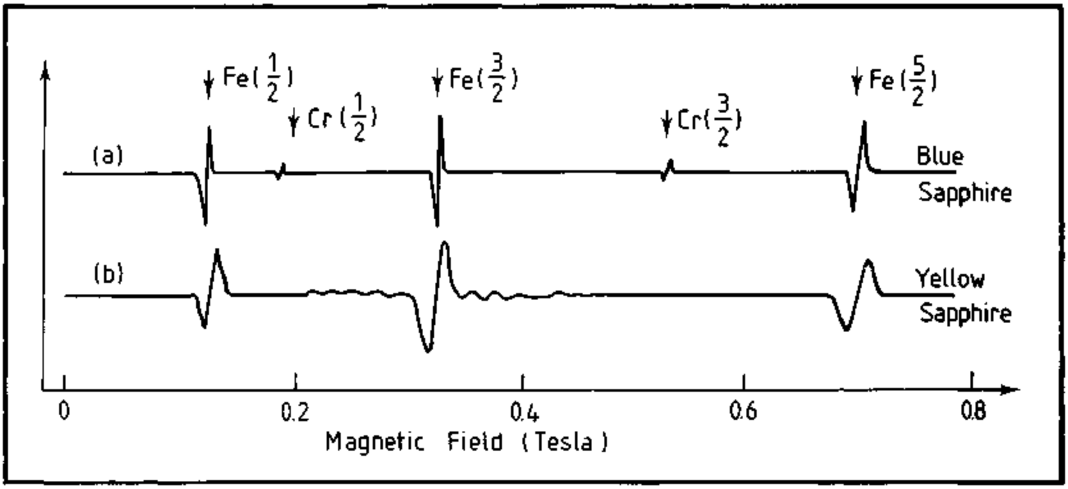


Fig. 1. ESR spectra of blue and yellow sapphire at ~ 3 cm wavelength with the steady magnetic field perpendicular to the trigonal axis.

ISSN: 0022-1252

25% HNO_3. They were in the form of pink pseudo-hexagonal or irregular platelets, which proved to have the large faces perpendicular to the c-axis. Most crystals had flux inclusions, and a somewhat irregular distribution of the pink coloration. Some of them are shown in Figure 3.

Optical spectrum

The optical (visible) spectra to be presented and discussed below were taken with a Varian DMS100 UV-Visible spectrophotometer. Because the Mn^{2+} sapphire crystals were thin basal pinacoids, only the ordinary ray spectrum, shown in Figure 4, could be obtained. A comparison spectrum of Cr^{3+} sapphire ('pink ruby') is shown in Figure 5. Because the spectrophotometer has an unpolarized light source, and because of the cut of the synthetic Cr^{3+} sapphire sample available to us, its spectrum is a 'mixture' of ordinary and extraordinary ray spectra.

However, the familiar absorption bands in the blue and green are clearly displayed, as is the ultraviolet absorption edge. The feature labelled 'D', in the red, results from the usually fluorescent 'ruby doublet'; in this case, because the dispersive element in the spectrophotometer comes immediately after the *source*, so that *monochrome* light falls on the sample, the lines are in absorption.

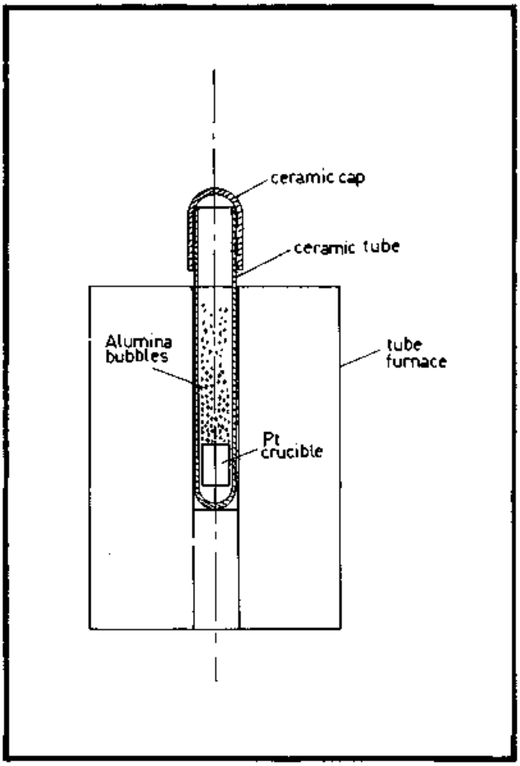


Fig. 2. Details of the arrangement used in the furnace in order to synthesize Mn^{2+} sapphire.

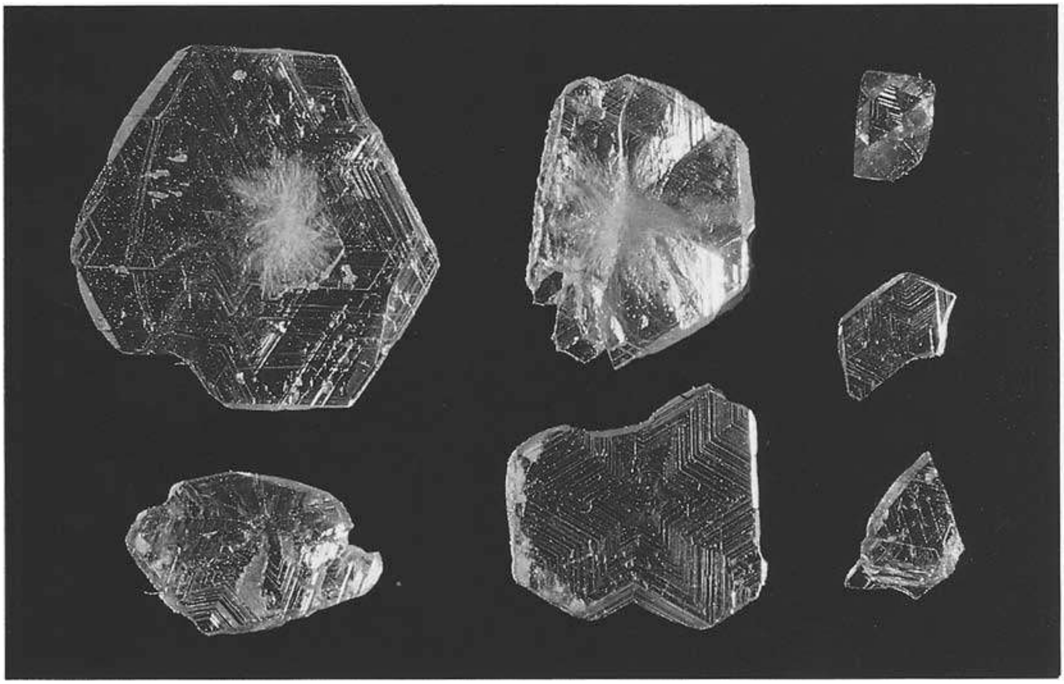


Fig. 3. Some crystals of Mn^{2+} sapphire. The largest crystal is ~ 1 cm across.

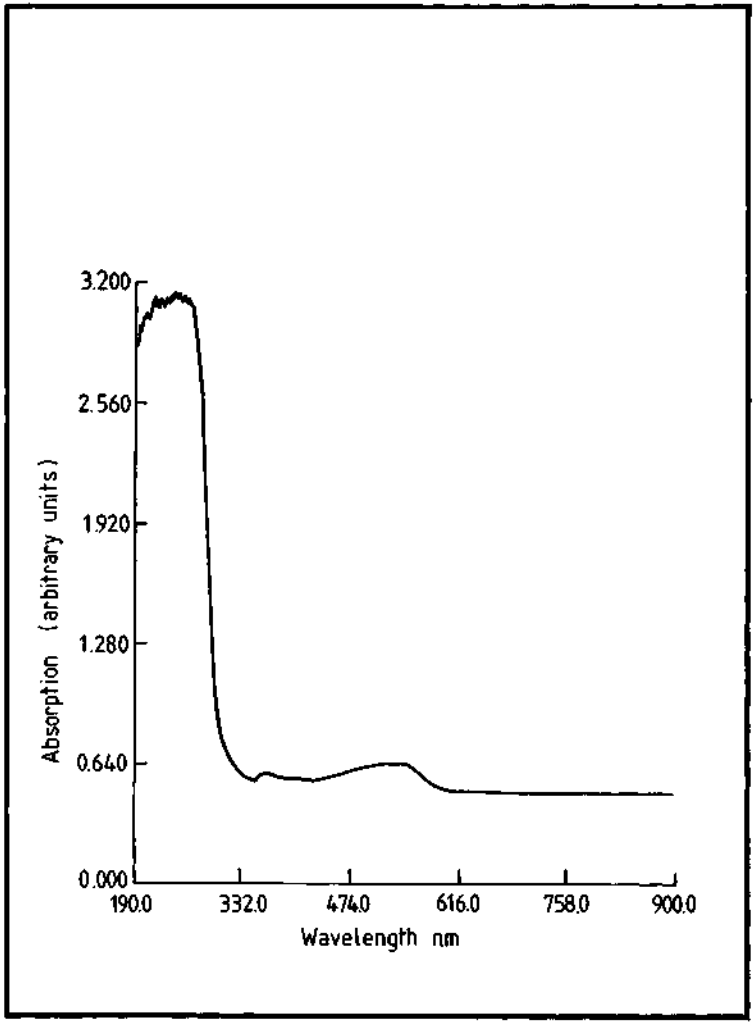


Fig. 4. Optical spectrum of Mn^{2+} sapphire: ordinary ray only.

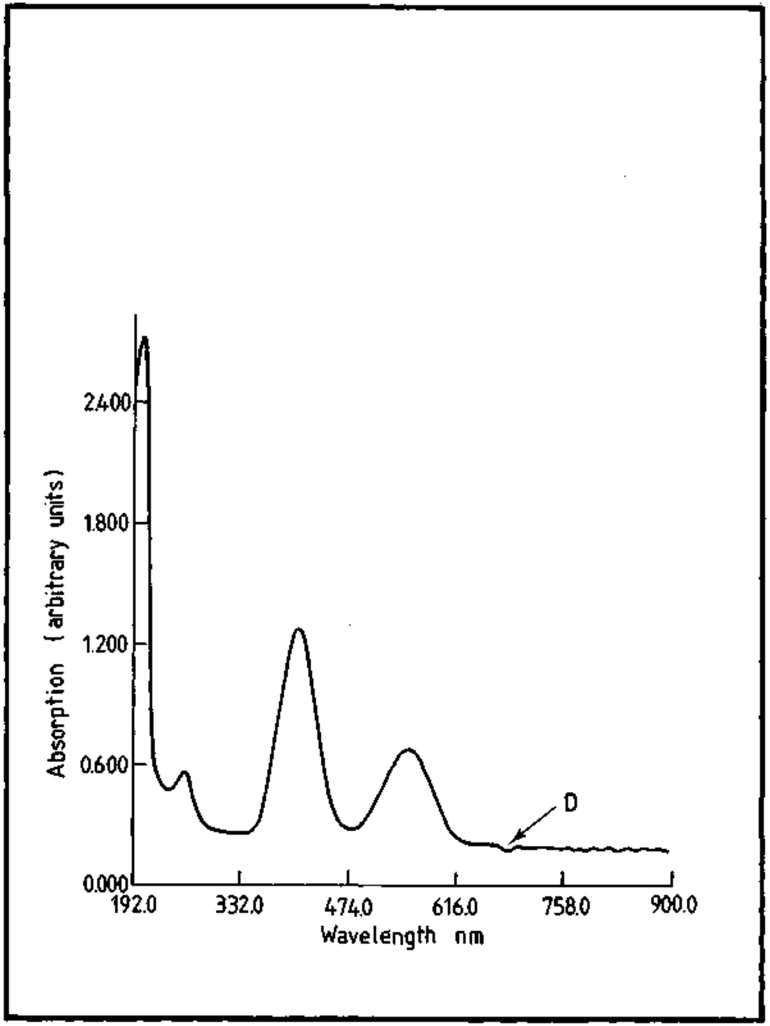


Fig. 5. Optical spectrum of synthetic ruby: 'mixture' of ordinary and extraordinary ray.

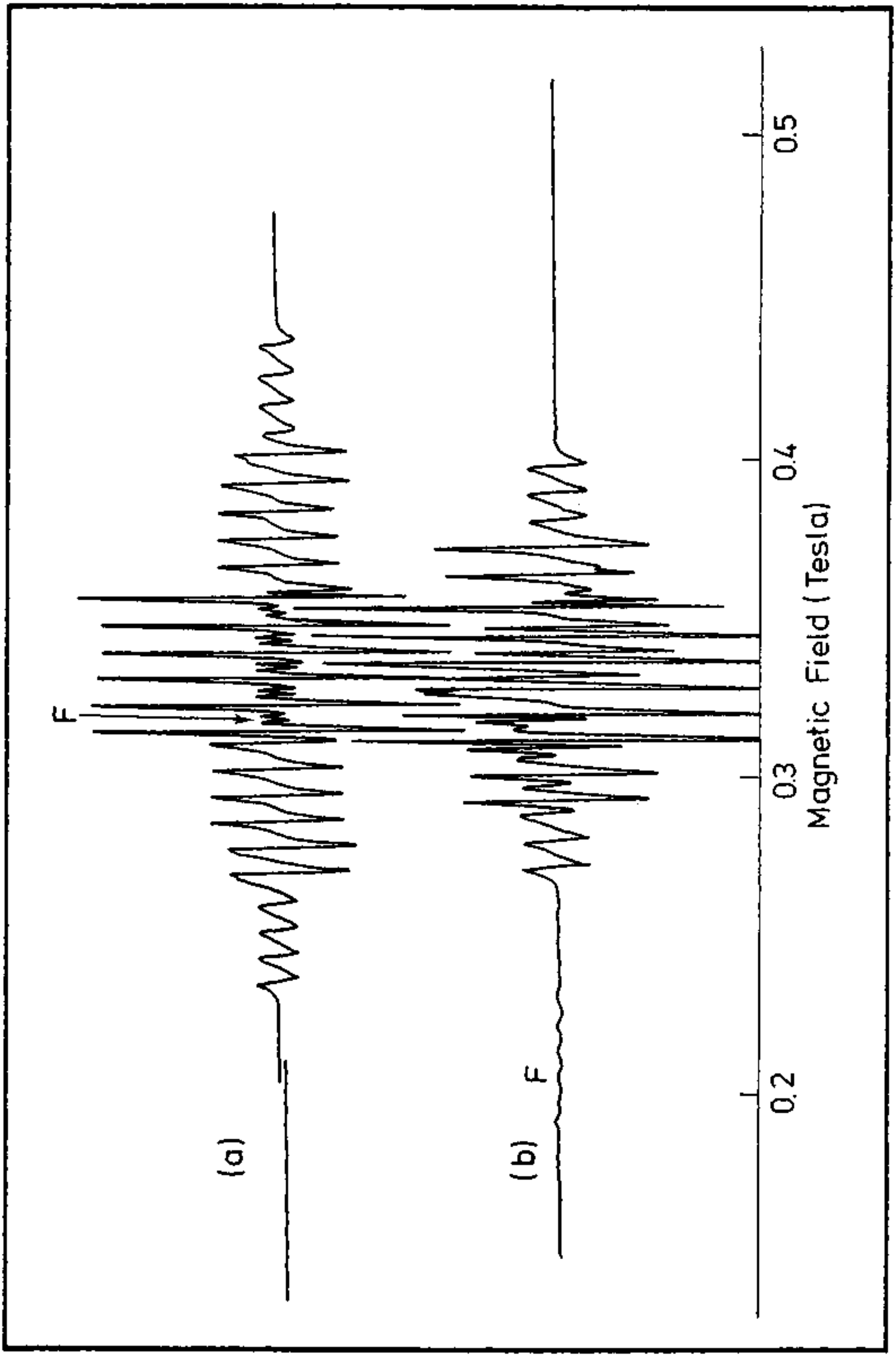


Fig. 6. ESR spectrum of Mn^{2+} sapphire at ~ 3 cm wavelength. Curve (a): static magnetic field parallel to the trigonal axis. Curve (b): static magnetic field perpendicular to trigonal axis.

The Mn^{2+} sapphire shows little absorption in the visible: what there is, occurs in a region not occupied by the ruby absorption bands. Further, the ultraviolet (UV) absorption edge is shifted, towards longer wavelengths, quite considerably. Because of the reduction process used to synthesize this material, it will contain not only Mn^{2+}, but charge compensation centres as well, and also some Mn^{3+}. Any or all of these may be the cause of the shift of the UV absorption edge.

The Mn sapphire fluoresces under UV light, appearing pink to the eye. A gemmological hand-held spectroscope showed a broad fluorescent line on the yellow-green edge of the spectrum.

ESR spectrum

The ESR spectrum of Mn^{2+} sapphire is shown in Figure 6: curve (a) for the static magnetic field parallel to the *c*-axis, curve (b) for the field perpendicular to the *c*-axis. The spectrum is complicated, and spread over quite a large region of magnetic field, in comparison to the Fe^{3+}-and CR^{3+}-sapphire spectra (static magnetic field perpendicular to the *c*-axis) shown in Figures 1(a) and (b). This spread comes about because the nucleus of Mn has a spin of 5/2, and this interacts with the total electron spin of 5/2. The phenomenon is known as 'hyperfine splitting'. The small lines in Figure 6, labelled F, in between the large lines, are due to 'forbidden transitions'. So is the group of lines, at comparatively low field, labelled 'L' in Figure 6(b).

Discussion

To our knowledge, pure Mn^{2+} sapphire does not occur naturally. Our hypothesis, that the ESR lines in the g = 2 region (near 0.3 Tesla) might be due to the presence of Mn^{2+} in natural sapphire is, for the most part, not supported, because the spread of the Mn^{2+} lines about this region is almost symmetrical. For reasons of space, we do not reproduce the spectra given in Troup and Hutton, 1983 here: these spectra, we believe, show that Mn^{2+} is *absent*. Thus the lines arising in many natural sapphires must be due to some other impurity ion, to radiation damage centres, to close pairs of Fe^{3+} ions, or a combination of these three.

However, there may be a good case for the natural yellow sapphire of Figure 1(a) containing Mn^{2+}, since the small lines appear approximately at equal strength on either side of the g = 2 Fe^{3+} line, for the appropriate field spread. The Fe^{3+} lines are very broad in this particular specimen, and magnetic interaction (known as 'anisotropic exchange interaction') is possible between the Fe^{3+} and Mn^{2+} ions. This would broaden the Mn^{2+} lines, thus including the small lines (labelled F in Figure 6) under the broadened large lines. The lower Mn^{2+} field lines of Figure 6(b) would simply be smeared out by this broadening, and thus would not be easily detected. However, the breadth of the Fe^{3+} lines could indicate a high Fe^{3+} concentration, in which case the small lines in the yellow sapphire could be due to close Fe^{3+} pairs. More work, including quantitative analysis, is necessary to resolve this question.

It is clear that either optical or ESR spectra will discriminate easily between (synthetic) Mn^{2+} and Fe^{3+} or Cr^{3+} sapphire. While Mn^{2+} sapphire is a pleasing pink colour, different from the colour of 'pink (Cr^{3+}) sapphire', it is unlikely to become a competitor on the synthetic sapphire market, because it is much more difficult to make.

References

Chase, A.B., Osmer, Judith A., 1970. Habit changes of sapphire grown from PbO–PbF$_2$ and MoO$_3$–PbF$_2$ fluxes. American Ceramic Society Journal, 53, 343–5.

Folen, V.J., 'Forbidden' transitions in the paramagnetic resonance of Mn^{2+} in Al$_2$O$_3$. Physical Review, 125, 1581–3.

Low, W., Suss, J.T., 1960. Paramagnetic Resonance Spectrum of Manganese in Corundum. Physical Review, 119, 132–3.

Troup, G.J., Hutton, D.R. 1983. The use of electron spin resonance spectroscopy to distinguish synthetic from natural sapphires. *Journal of Gemmology*, **XVIII**, 5, 421–31.

[*Manuscript received 23 December 1987.*]

The gemmological characteristics of Inamori synthetic cat's-eye alexandrite chrysoberyl

*John I. Koivula**, *Dr Emmanuel Fritsch** *and Chuck Fryer***

*Gemological Institute of America, Research Department, 1660 Stewart Street, Santa Monica, California 90404, USA
**GIA Gem Trade Laboratory Inc., Santa Monica, Los Angeles and New York

Abstract

Kyocera Corporation of Kyoto, Japan, has successfully synthesized, and is currently marketing, a chatoyant colour change material that gemmologically tests as cat's-eye alexandrite chrysoberyl. With the exception of microscopic characteristics, all the gemmological properties shown by this material are essentially the same as those encountered in natural alexandrite cat's-eyes. For those gemmologists without access to sophisticated testing equipment, the internal characteristics are the only universally available means of identifying this new synthetic product.

Fig. 1. The two largest synthetic Kyocera alexandrite chrysoberyl cat's-eyes described in this report. Incandescent fibre-optic illumination.

Introduction

Since late 1986 Kyocera America Corporation's 'Inamori' gemstone and jewellery division has been marketing, as 'Inamori', a new chatoyant colour change material that gemmologically tests as alexandrite cat's-eye chrysoberyl. This new synthetic is manufactured by their parent company, Kyocera Corporation, which has headquarters in Kyoto, Japan.

In an effort to provide the gemmological community with information on their new product, Kyocera recently loaned the Gemological Institute of America, in Santa Monica, California, some samples of these new colour change cat's-eyes for gemmological examination. The results of this detailed examination comprise the body of this report.

Description

The two largest stones supplied by Kyocera (Figure 1) were semi-transparent, well polished, oval double cabochons that weighed 3.27 and 3.31 carats respectively, with corresponding measurements of 9.00 × 7.01 × 5.55 mm and 8.92 × 7.11 × 5.61 mm. The remaining bulk of the test sample consisted of ten smaller uniform-cut 6 × 5 mm double cabochons with a total weight of 10.86 carats.

With the aid of a single overhead incandescent light source all the stones displayed a relatively sharp, moderately intense, bluish-white chatoyant band running across their length (Figure 1).

The stones showed a moderate change of colour that complemented their near transparency. The body-colour in incandescent light (Figure 1) was a vivid, slightly-dark, purplish-red. Under the sun, or in fluorescent light, the colour changed to a very

ISSN: 0022-1252

slightly brownish purple-green. In addition to the colour change, under all lighting conditions, the stones possessed a somewhat greyish milky overtone which is also shown in Figure 1.

In transmitted incandescent light these cat's-eyes showed a columnar cone of milky pink light (Figure 2). Its diameter was controlled by the size of the aperture placed between the light source and the stone.

Gemmological properties

The properties listed by Kyocera in the promotional brochure for their new 'Inamori Created' alexandrite cat's-eye are provided, for reasons of comparison, in the table below.

Classification	Chrysoberyl
Chemical composition	$BeAl_2O_4$
X-ray diffraction	Same as natural alexandrite cat's-eye
Spectograph	Same as natural alexandrite cat's-eye
Crystal system	Orthorhombic
Hardness (Mohs)	8½
Specific gravity	3.72
Melting point	1,870°C
Transparency	Transparent/semi transparent
Refractive index	1.743-1.752
Double refraction	0.008
Change of colour	Distinct
Average dispersion	0.015
Pleochroism	
Daylight	Strong green/yellowish green/dark red
Incandescent light	Reddish purple
Chelsea colour filter reaction	Red
Inclusion	Solidus

The results of the laboratory testing done by the authors on Inamori's alexandrite cat's-eyes are reported as follows:

Refractive index

Using the largest possible 'spot' contact area on the refractometer, and sodium light, the refractive index of these cat's-eyes was read as 1.747 to 1.753. Because the stones' surfaces were curved, more precise readings and accurate birefringence determination were not possible.

Pleochroism

Alexandrite chrysoberyls are trichroic and these stones were no exception. They showed brownish green, brownish yellow and slightly brownish red.

Reaction to ultra violet radiation

When exposed to long-wave ultraviolet radiation the cat's-eyes fluoresced a uniform dull, chalky red colour of moderate intensity. The short-wave reaction appeared to be a slightly stronger, very chalky, brownish-orange. Phosphorescence was not observed in any of the stones.

Specific gravity

Using the hydrostatic method the specific gravity of the two largest stones was determined. The average value for six tests was calculated as 3.74.

Colour filter reaction

As expected, the colour of these synthetic colour change cabochons appeared red when viewed through the Chelsea colour filter.

Spectroscopy

The visible light spectrum, obtained by transmitting white light through the domes of the cabochons, was typical of those recorded previously for alexandrite (Liddicoat, 1981). The observed lines were located at 680, 650, 625, 616 and 471 nanometres. In addition there was a smudged band between 590 and 535 nanometres, and a cut-off in the blue at 445 nanometres. It was also noticed that the largest of the stones showed a weak cat's-eye in transmitted light.

Microscopy

When microscopically examining these synthetic cat's-eyes the first thing noticed is the transmitted light appearance of a multitude of apparently parallel colour zones (Figure 3) that run perpendicular to the chatoyant band (Figure 1). At first these zones appear to be perfectly straight, but close scrutiny, in combination with shadowing, shows that they are very slightly undulating. This suggests that these cat's-eyes are crystallized from a high temperature melt rather than grown as euhedral crystals by a flux or hydrothermal process.

When incident illumination is used, numerous thin, purplish blue-white, milky zoned bands appear where the colour zones are (Figure 4). The precise directional relationship between these milky bands and the colour zones is revealed when the stones are examined, directly through the cabochon's dome, using both fibre optic and shadowed transmitted light in combination (Figure 5).

These zoned bands are composed of tiny white particles which are far too small to be individually resolved microscopically. They are the cause of the chatoyancy, and their appearance suggests that they may be the result of a controlled annealing and exsolution process: much the same as the chemical precipitation mechanism that was used by Union Carbide's Linde division in making its synthetic star corundums.

Another feature worth mentioning is the limited visibility of these zones. When looking straight down on the edges of the colour zones or milky bands they are easily seen (Figures 3, 4 and 5). But even a very slight change in the viewing angle and these important diagnostic features will no longer be clearly visible. So, in addition to the proper illumination technique, viewing direction is equally important.

The microscope reveals significant features that are contrary to what one expects from nature's environment. In general, the internal motif observed in Kyocera's product in no way resembles the suite of characteristic inclusions recognized so far in natural chrysoberyls (Gübelin and Koivula, 1986).

Spectrophotometry

Using a Pye Unicam PU8800 spectrophotometer, the ultraviolet-visible absorption spectrum of one of these synthetic cat's-eye alexandrites was taken in a direction normal to the cabochon girdle. The result is shown in Figure 6 (top). The very strong absorption background towards the UV is in fact due to the diffusion of light by the inclusions that cause the chatoyancy. The sharp 'chromium lines' situated around 680 nanometres, are also detectable with the hand-held spectroscope.

Two broad absorption bands, with maxima around 440 and 560 nanometres, separate two transmission windows, one in the blue-green, the other in the red. Such a spectrum is responsible for the colour change effect.

The emission spectrum of sunlight has a maximum in the green, so in daylight there is more light transmitted through the window in the blue-green, and the crystal appears bluish green. Longer wavelengths predominate in incandescent illumination and the red body colour results from more light transmitting through the window in the red.

Comparing the spectrum of this synthetic cat's-eye (Figure 6 top) with the spectrum of a natural alexandrite from Tanzania, also shown in Figure 6 (bottom), one notices the absence of the 375 nanometres absorption in the synthetic. This band in the natural stone is due to the presence of Fe^{3+} ions (Farrell and Newnham, 1965) and is present in all optical directions. Iron is a common impurity in natural alexandrite but it is absent from the synthetic cat's-eyes tested so far. Therefore, if a gemmologist has access to a UV-visible spectrophotometer, then this Fe^{3+} related absorption band can be used as an additional means of separating natural from synthetic cat's-eye alexandrite.

One of the synthetic cabochons was also run on the GIA's Nicolet 60SX Fourier Transform Infrared Spectrometer to check for the possible presence of water within the structure. No water was found.

This total lack of water adds support to the premise that Kyocera's alexandrite cat's-eyes are crystallized from a high temperature melt.

X-ray diffraction

All the standard gemmological tests pointed to the conclusion that this synthetic material was chrysoberyl. And in Kyocera's promotional brochure they list chrysoberyl as the result of their X-ray diffraction testing.

However, since this is a new form of synthetic, it was decided to confirm the chrysoberyl identification by means of our own X-ray powder diffraction test.

A glass fibre spindle was prepared and mounted in a Debye-Scherrer powder camera. Then the sample was exposed for 9 hours to X-rays generated from a copper target tube by a voltage of 46 kilovolts and a current of 26 milliamperes.

The exposed X-ray film was developed and allowed to air-dry. The resulting pattern was compared to our standard pattern for chrysoberyl and the two X-ray films matched.

Conclusion

This study of the new Inamori synthetic alexandrite chrysoberyl cat's-eye was based on the examination of only twelve stones.

Although very close, the important gemmological properties, as listed by Kyocera, are not an exact match with those obtained by the authors during testing, and probably reflect average values for a great number of stones. The gemmological properties may vary slightly in a larger test sample and might possibly more closely reflect those reported by Kyocera.

With the exception of microscopy, all the other gemmological properties shown by these Inamori cat's-eyes, such as ultraviolet fluorescence and specific gravity, overlap with those shown by natural alexandrite chrysoberyls. Therefore, unless one has access to a UV-visible spectrophotometer, the microscope is the only means available to the gemmologist for the positive identification of Kyocera's newest synthetic.

How much of this synthetic cat's-eye alexandrite will enter the gem market is open to speculation.

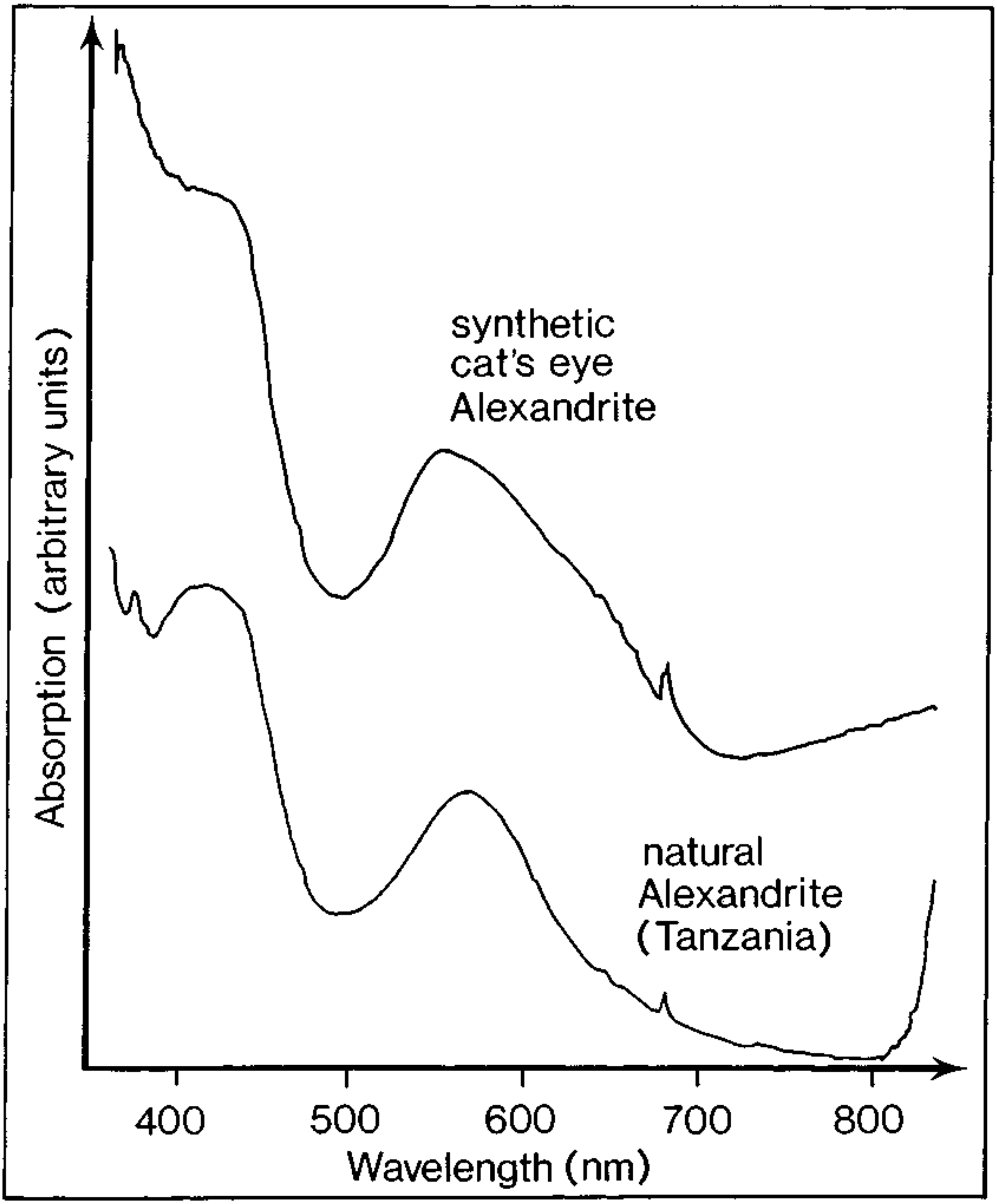


Fig. 6. Top: Ultraviolet-visible absorption characteristics of a synthetic alexandrite cat's-eye, run perpendicular to the girdle plane of the stone. Bottom: Ultraviolet-visible absorption characteristics of a natural alexandrite from Tanzania, run in a random direction. Drawing by Peter Johnston.

Fig. 2. The typical conical-shaped milky light transmission effect shown by the Inamori alexandrite cat's-eyes.

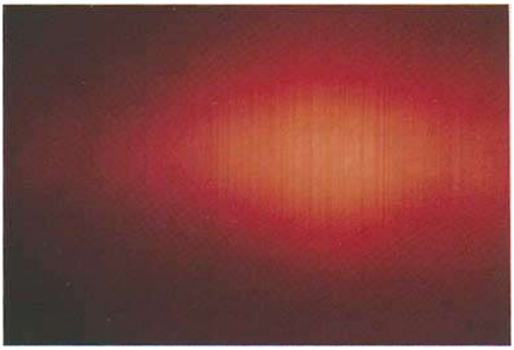


Fig. 3. The very slightly undulating growth-colour zones,. shown here in shadowed transmitted light, are the single most important diagnostic feature of Kyocera's new product 30x.

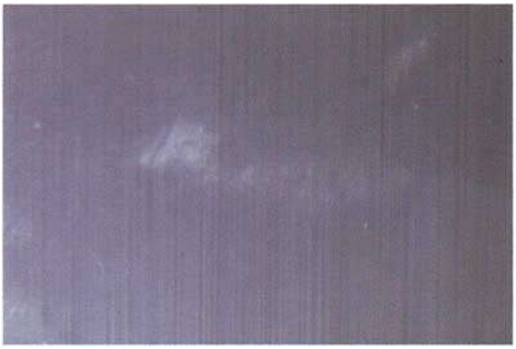


Fig. 4. In oblique incident light these characteristic growth features show up as a series of fine laminated milky layers. 30x.

Fig. 5. The directional relationship between the milky bands and the colour zones is shown in this photomicrograph. Oblique incident and shadowed transmitted light. 30x.

But, according to their brochure, Kyocera is currently selling their rough, and two grades of the cut material as 'Gemstones for the 21st Century – Created by Science and Technology' under the trade name Inamori.

Acknowledgements

The authors are grateful to Mr Ken Takada, director of the jewellery division of Kyocera America, Inc., for supplying the 'Inamori' cat's-eye alexandrites examined in this report. Thanks are also extended to Mr Dino DeGhionno, supervisor of the Gemological Institute of America's resident coloured stones programme, for his assistance in obtaining the stones.

References

Kyocera Corporation's promotional brochure,*'Inamori Stones' Scientific Gemstones – The Jewelry New Age.*

Liddicoat, Richard T., Jr., 1981, *Handbook of Gem Identification*, 11th edition, Gemological Institute of America, Santa Monica, California.

Gübelin, E.J., Koivula, J. I., 1986, *Photoatlas of Inclusions in Gemstones*, ABC Edition, Zurich, Switzerland.

Farrell, E.F., Newnham, R.E., 1965. Crystal-field spectra of chrysoberyl, alexandrite, peridot and sinhalite, *American Mineralogist*, **50**, 11/12, 1972–81.

[Manuscript received 30 September, 1987.]

Violet emeralds?

Dr Hans-Werner Schrader, Dip.Min., FGA

Institut für Edelsteinforschung, University of Mainz, West Germany

Abstract

Colour changes induced by ionizing radiation on synthetic emeralds from green to smoky or to violet are attributed to colour centres and are similar to those of irradiated quartz. These kinds of colour centres may also be present in natural emeralds. Electron microprobe analyses (EMPA) presented in cations per formula unit show the replacement of Si-cations by Al and other elements.

Introduction

In order to distinguish between natural and synthetic gemstones such as emeralds, extensive chemical analyses at a high technical level may be required. In analytical methods, such as X-ray fluorescence analyses (XFA) or neutron activation analyses (NAA) used for the detection of trace elements, samples are exposed to ionizing radiation which may cause changes in colour.

During investigation by NAA synthetic emeralds were found to change from green to smoky or to violet and these colours were found to be of variable stability. Corresponding colour changes in synthetic emeralds have been reported by Bank (1982) and Lind *et al.* (1986). A similar colour change was also observed in a natural emerald during X-ray fluorescence analyses, so these colour changes do not seem to be restricted to synthetic emeralds.

As heat treatment at different temperatures and for different durations may cause the total restoration of the colour, colour centres are probably involved in the transformations.

Ionizing radiation causes the following colour changes:

– from green to smoky colours in hydrothermal synthetic emeralds (Figure 1), and even – from green to violet colours in flux-grown synthetic emeralds (Figures 2 and 3),

both being demonstrated by polarized UV-visible spectra. These transmission spectra still show the typical absorption of emeralds, for instance the chromium bands, on which are superimposed additional, stronger absorptions caused by the neutron radiation. Exposing these violet samples to normal daylight for five months bleaches them but still leaves them with smoky colours.

Colour centres by the replacement of Si

These colour changes suggest an analogy with radiation-induced colour changes of colourless quartz to smoky quartz or amethyst involving one of the following mechanisms:

- the irradiation of quartz showing a coupled replacement of Si by Al together with a corresponding charge compensation in the lattice forms activated $[AlO_4]^{4-}$ centres by the loss of an electron (Nassau and Prescott, 1977). These colour centres cause the well known smoky colour;
- the irradiation of quartz showing a corresponding replacement of Si by Fe^{2+} forms activated $[FeO_4]^{5-}$ centres with citrine colours (Nassau, 1984);
- the continuing irradiation of these citrine centres or those with a replacement of Si by Fe^{3+} activates $(FeO_4]^{4-}$ amethyst colour centres (Nassau, 1984).

  The stability of such amethyst centres is correlated to the absence of water as shown in natural amethrines (amethyst/citrines) by Aines and Rossman (1986).

Considering that the Si_6O_{18} rings of the beryl structure present quartz-like surroundings, corresponding radiation effects on emeralds might be caused by corresponding mechanisms:

- water containing, i.e. hydrothermal, synthetic emeralds on radiation only develop smoky colours. Possible citrine colour centres are not perceptible visually;
- among the water free, i.e. flux-grown, synthetic emeralds violet amethyst colour centres may be developed;
- the wavelengths of these additional absorptions resemble those of irradiated quartzes. An insignificant shift to shorter wavelengths corresponds to shorter metal-oxygen bonds of beryl com-

ISSN: 0022-1252

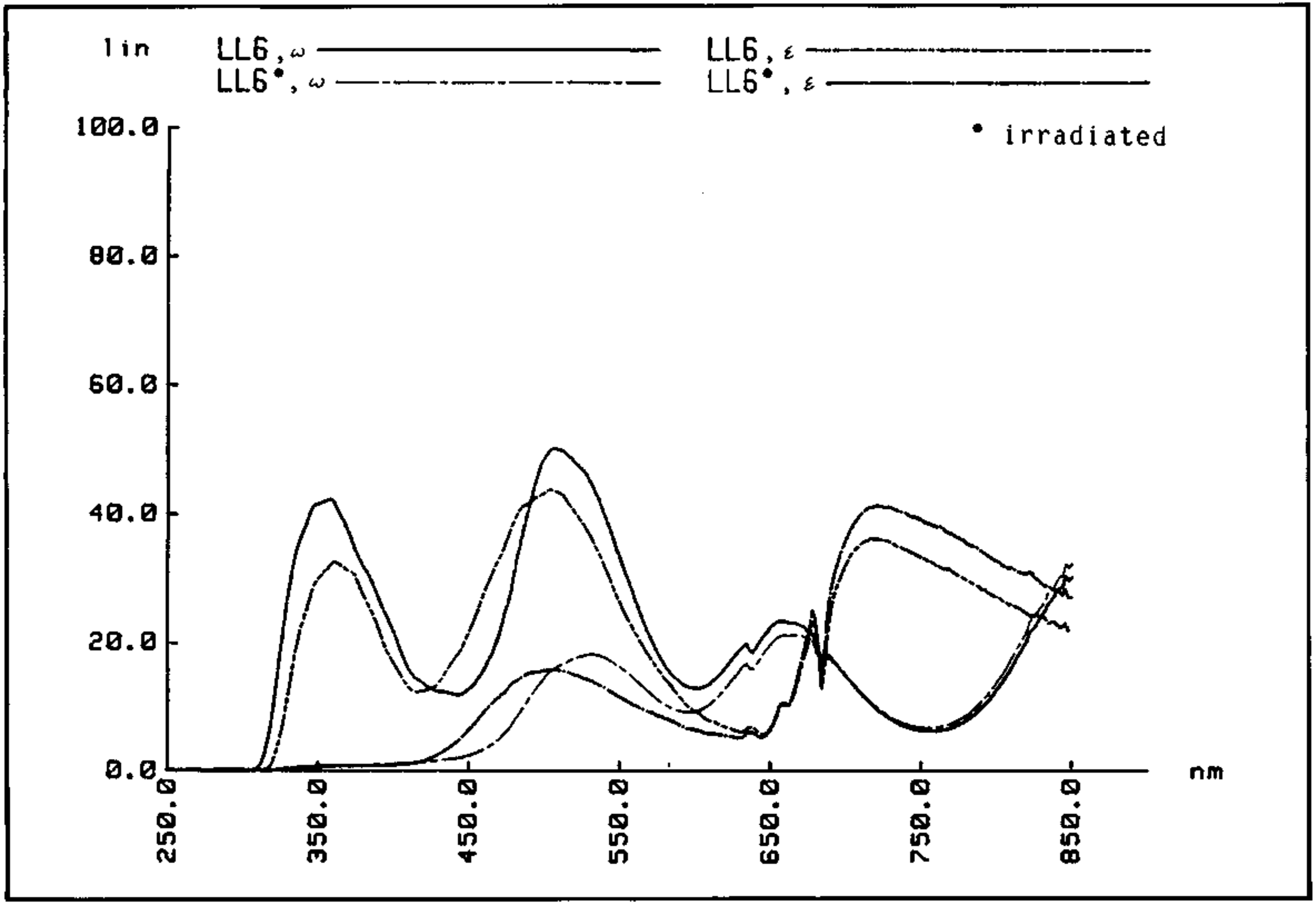


Fig. 1. Transmission spectrum of a *Lechleitner* synthetic hydrothermal emerald (LL 6) before (ε — -- — ---, ω ——) and after (ε —·—·—, ω —— · —— · —— ·) irradiation.

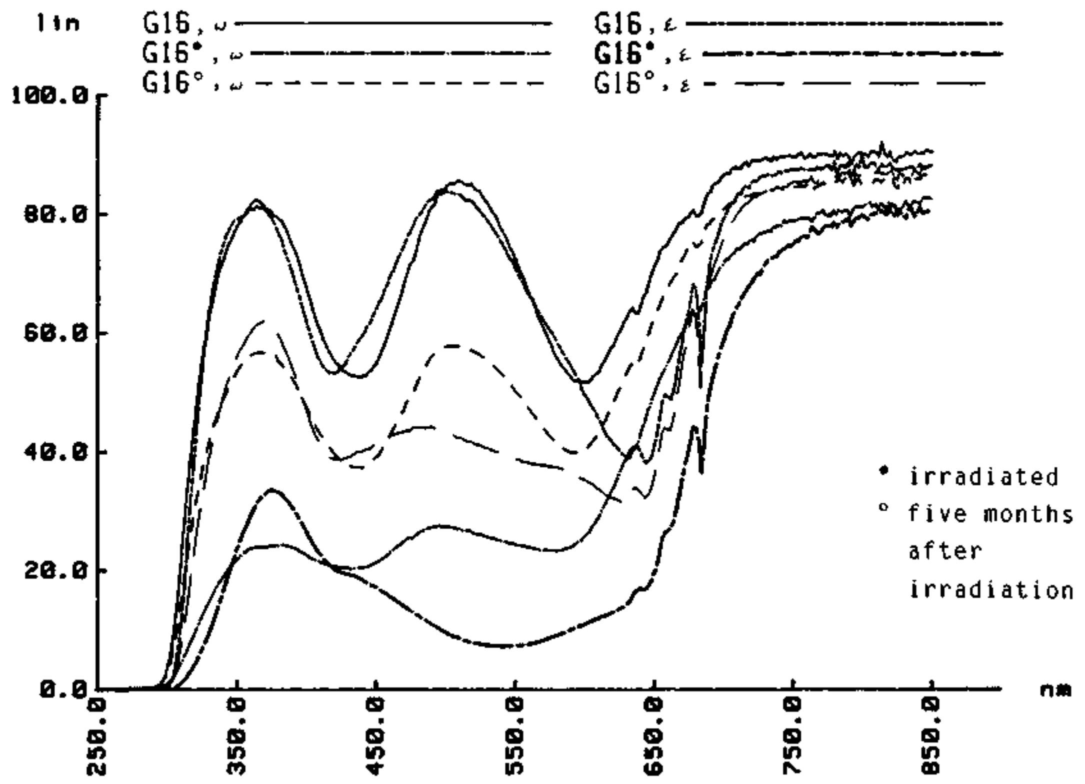


Fig. 2. Transmission spectra of a *Gilson* synthetic flux-grown emerald (G 16) before (ε — ·· —·· —, ω ——), after ε — · — · —, ω —·—·—) irradiation, and after five months after irradiation (ε ———, ω — — — — — —).

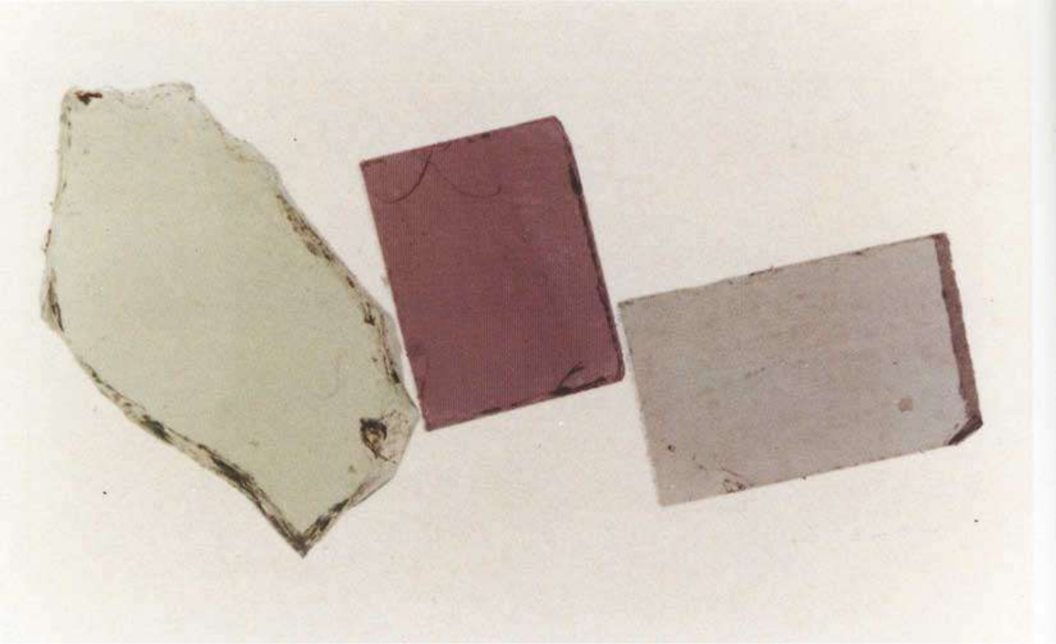


Fig. 3. Slices of a *Gilson* flux-grown synthetic emerald (G 16), thickness ~ 1.1 mm, green (left, irregular shaped) before – violet (middle, rectangular shaped, 2.6 × 3.5 mm) after irradiation and smoky (right, rectangular shaped, 2.6 × 4.2 mm) five months after irradiation.

pared to quartz according to the crystal field theory.

The possibility of the replacement of Si in the beryl structure by Al ($Si^{4+} \rightarrow Al^{3+} + R^{+}$) has been already demonstrated by Shatskiy, *et al.* (1981) and by Nassau and Nassau (1980) only as an example for the incorporation of alkalies ($Si^{4+} \rightarrow Al^{3+} + Na^{+}$). But the consequences of irradiating centres associated with these replacements have not been recognized up till now.

Chemical analyses

The presence of the replacement of Si by Al and Fe in emeralds is demonstrated by electron microprobe analyses (EMPA) of:

- 16 natural emeralds of different origin;
- 8 different flux-grown; and
- 6 different hydrothermal synthetic emeralds (Table 1).

From these three groups a representative example of each is represented by its chemical analyses

Table 1. Origin and label of samples of natural and synthetic emeralds analysed by EMPA.

Origin	Label	Flux-grown synthetic emeralds:	
Natural emeralds:		Gilson	G 16
Colombia, Chivor	C 69	Gilson	GMT
Colombia, Chivor	C 75	Gilson	GDT
Colombia, Chivor	C 85	Lennix	Lens
Colombia	SMG C	Inamori	IJ 1
Brazil, Sta. Maria de Itabira	SMI 2	Lechleitner	LL 10
Brazil, Carnaiba	BC 9	Lechleitner	LL 11
Brazil, Socotó	SOC 41	Lechleitner	LL 12
Brazil, Saliniha	BS 2		
Brazil	B 24		
Brazil	BX	Hydrothermal synthetic emeralds:	
Nigeria	N 4b	Linde	L1
South Africa, Cobra-Mine	A 39	Lechleitner	LL 14
Mozambique, Morrua	M 3	Lechleitner	LL 16
Zambia	S 47	Lechleitner	LL 67
USSR, Urals	R 8	USSR	SSR
Afghanistan, Pandjir-Valley	HAB	Biron	BIR 2

Table 2. Chemistry of a Colombian emerald (C 85), 40 points analysed by a line-scan EMPA, distance 2μm.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
SiO_2	64,842	64,536	64,369	63,926	64,268	63,826	64,345	64,136	64,134	64,200	64,433	64,117	64,179	64,467	64,179	64,153	64,189	64,125	64,076	64,048
Al_2O_3	17,670	17,693	17,649	17,407	17,498	17,513	17,558	17,449	17,498	17,523	17,596	17,500	17,432	17,649	17,258	17,337	17,574	17,536	17,487	17,583
Cr_2O_3	,172	,193	,243	,219	,191	,244	,172	,229	,210	,213	,232	,250	,209	,193	,174	,246	,215	,196	,208	,221
V_2O_3	,062	,034	,046	,057	,088	,057	,046	,077	,085	,115	,072	,056	,021	,069	,072	,021	,038	,062	,088	,043
FeO	,010	,021	,090	0	,050	,040	,021	,085	,021	,071	,030	0	,066	,005	,060	,085	0	,024	,040	,010
ZnO	0	0	,045	0	,045	0	,037	,075	0	0	,103	,015	,030	,097	0	,111	0	,103	0	0
MgO	,156	,161	,177	,126	,158	,207	,186	,176	,177	,184	,162	,172	,189	,182	,187	,172	,184	,196	,158	,164
Na_2O	,168	,174	,159	,159	,173	,208	,166	,162	,194	,170	,156	,177	,204	,129	,190	,170	,155	,190	,205	,159
CaO	0	,020	,003	,027	0	0	0	,018	0	,010	0	0	0	0	,003	,007	,011	0	0	0
Σ	83,081	82,830	82,780	81,922	82,471	82,095	82,531	82,406	82,320	82,485	82,786	82,286	82,328	82,793	82,123	82,301	82,366	82,432	82,261	82,228
Si	6,013	6,004	5,997	6,013	6,008	5,993	6,008	6,004	6,004	6,001	6,003	6,005	6,009	6,003	6,023	6,013	6,005	5,998	6,004	6,002
Al	1,931	1,940	1,938	1,930	1,928	1,939	1,932	1,925	1,931	1,930	1,932	1,932	1,924	1,937	1,909	1,915	1,937	1,933	1,931	1,942
Cr	,013	,014	,018	,016	,014	,018	,013	,017	,016	,016	,017	,018	,015	,014	,014	,018	,016	,015	,015	,016
V	,005	,003	,003	,004	,007	,004	,003	,006	,006	,009	,005	,004	,002	,005	,006	,002	,003	,005	,007	,003
Fe	,001	,002	,007	0	,004	,003	,002	,007	,002	,006	,002	0	,005	,001	,005	,007	0	,002	,003	,001
Zn	0	0	,003	0	,003	0	,003	,005	0	0	,007	,001	,002	,007	0	,008	0	,007	0	0
Mg	,021	,022	,025	,018	,022	,029	,026	,025	,025	,026	,023	,024	,026	,025	,026	,024	,026	,027	,022	,023
Na	,030	,032	,029	,029	,031	,038	,030	,029	,035	,031	,028	,032	,037	,023	,035	,031	,028	,035	,037	,029
Ca	0	,002	0	,003	0	0	0	,002	0	,001	0	0	0	0	0	,001	,001	0	0	0

	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.
SiO_2	64,318	64,395	64,634	64,373	64,872	64,621	64,277	64,504	65,143	64,555	64,709	64,275	64,551	64,333	64,585	64,673	64,324	64,442	64,628	64,718
Al_2O_3	17,583	17,483	17,275	17,541	17,587	17,651	17,715	17,598	17,317	17,405	17,504	17,388	17,630	17,670	17,823	17,553	17,409	17,679	17,711	17,919
Cr_2O_3	,205	,183	,203	,228	,273	,200	,235	,256	,229	,292	,189	,279	,263	,222	,238	,199	,194	,203	,151	,186
V_2O_3	,028	,022	,062	,062	,063	,085	,106	,046	,069	,106	,049	,057	,063	,075	,065	,075	,063	,040	,034	,026
FeO	,015	0	,040	,045	,015	,140	,030	0	,100	,055	0	,050	,040	,060	0	,035	,060	0	,066	,015
ZnO	,030	0	0	,156	,015	0	,007	0	0	0	,037	,045	0	,037	,022	0	,067	0	0	,037
MgO	,191	,159	,179	,167	,169	,141	,171	,189	,192	,204	,194	,154	,158	,166	,158	,164	,164	,148	,181	,194
Na_2O	,183	,173	,177	,178	,173	,152	,181	,220	,205	,174	,209	,174	,174	,179	,171	,174	,167	,177	,189	,182
CaO	,001	,007	0	,006	0	,010	0	,008	0	0	,004	0	,008	,001	,017	,021	,011	,014	,013	0
Σ	82,554	82,421	82,570	82,756	83,167	83,001	82,722	82,820	83,256	82,792	82,894	82,423	82,887	82,753	83,079	82,893	82,461	82,702	82,971	83,278
Si	6,004	6,018	6,032	6,001	6,013	6,004	5,990	6,002	6,032	6,013	6,015	6,013	6,004	5,994	5,992	6,013	6,015	6,004	6,002	5,989
Al	1,934	1,926	1,900	1,927	1,921	1,933	1,946	1,930	1,890	1,911	1,918	1,918	1,917	1,941	1,949	1,923	1,918	1,941	1,939	1,954
Cr	,015	,014	,015	,017	,020	,015	,017	,019	,017	,022	,014	,021	,019	,016	,018	,015	,014	,015	,011	,014
V	,002	,002	,005	,005	,005	,006	,008	,003	,005	,008	,004	,004	,005	,006	,005	,006	,005	,003	,003	,002
Fe	,001	0	,003	,003	,001	,011	,002	0	,008	,004	0	,004	,003	,005	0	,003	,005	0	,005	,001
Zn	,002	0	0	,010	,001	0	,001	0	0	0	,003	,003	0	,003	,002	0	,005	0	0	,003
Mg	,027	,022	,025	,023	,023	,020	,024	,026	,026	,028	,027	,022	,022	,023	,022	,023	,023	,021	,025	,027
Na	,033	,031	,032	,032	,031	,027	,032	,040	,037	,031	,038	,032	,031	,032	,031	,032	,030	,032	,034	,033
Ca	0	,001	0	,001	0	,001	0	,001	0	0	,001	0	,001	0	,002	,002	,001	,001	,001	0

Table 3. Chemistry of a *Gilson* flux-grown synthetic emerald (G 16), 40 points analysed by a line-scan EMPA, distance 2μm.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
SiO_2	65,103	64,855	65,139	65,265	64,861	65,246	64,891	65,103	64,889	65,066	65,047	65,084	65,049	64,974	65,133	64,910	64,395	64,970	65,486	65,094
Al_2O_3	19,095	19,183	18,707	18,781	19,021	19,079	19,032	18,953	18,862	19,008	18,974	18,741	19,051	18,783	18,726	18,758	18,811	18,745	19,015	18,985
Cr_2O_3	,284	,326	,346	,295	,380	,256	,336	,341	,294	,289	,358	,326	,304	,402	,390	,364	,269	,399	,339	,224
V_2O_3	,021	,009	,026	,018	,026	,026	,015	0	0	,046	0	,003	0	0	0	0	,003	0	0	0
FeO	,005	,040	,055	,040	0	,045	,114	,075	,021	,060	,060	,035	,075	,010	,024	,030	,021	0	0	0
ZnO	0	,215	0	0	0	,060	,060	,052	0	,096	,045	0	0	,037	0	0	,052	,075	,045	0
MgO	0	,010	,003	0	,007	,010	,008	,003	,002	,005	0	,012	,027	0	0	,015	0	,003	0	0
Na_2O	,077	,109	,078	,074	,074	,084	,116	,071	,062	,082	,080	,116	,067	,098	,081	,094	,074	,074	,059	,086
CaO	0	0	,027	,008	,008	,024	,003	,007	,004	,001	,013	0	,011	,024	0	,020	,004	0	0	,007
Σ	84,583	84,747	84,383	84,482	84,378	84,830	84,575	84,605	84,133	84,654	84,576	84,316	84,584	84,329	84,354	84,191	83,629	84,266	84,944	84,396
Si	5,932	5,908	5,953	5,955	5,927	5,932	5,920	5,936	5,945	5,930	5,933	5,951	5,930	5,943	5,954	5,945	5,937	5,947	5,944	5,943
Al	2,051	2,060	2,015	2,020	2,049	2,044	2,047	2,036	2,037	2,042	2,040	2,019	2,047	2,025	2,017	2,025	2,044	2,022	2,034	2,043
Cr	,021	,024	,025	,021	,027	,018	,024	,025	,021	,021	,026	,024	,022	,029	,028	,026	,020	,029	,024	,016
V	,002	,001	,002	,001	,002	,002	,001	0	0	,003	0	0	0	0	0	0	0	0	0	0
Fe	,001	,003	,004	,003	0	,003	,009	,006	,002	,005	,005	,003	,006	,001	,002	,002	,002	0	0	0
Zn	0	,015	0	0	0	,004	,004	,003	0	,006	,003	0	0	,003	0	0	,003	,005	,003	0
Mg	0	,001	,001	0	,001	,001	,001	,001	0	,001	0	,002	,004	0	0	,002	0	,001	0	0
Na	,013	,019	,013	,013	,013	,014	,020	,012	,011	,014	,014	,020	,011	,017	,014	,016	,013	,013	,010	,015
Ca	0	0	,002	,001	,001	,002	0	,001	0	0	,001	0	,001	,002	0	,001	0	0	0	,001

	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.
SiO_2	65,126	65,017	65,757	65,041	64,908	65,214	65,368	65,135	64,673	65,154	65,638	65,002	65,263	64,910	65,000	65,280	65,197	65,469	65,261	65,188
Al_2O_3	18,917	19,138	18,756	19,146	19,015	19,055	19,021	19,208	19,144	19,219	18,722	18,892	19,117	19,098	19,062	19,263	19,374	19,138	18,870	19,155
Cr_2O_3	,303	,278	,425	,301	,313	,351	,272	,284	,285	,282	,362	,365	,311	,310	,292	,278	,330	,355	,384	,412
V_2O_3	,022	,016	0	0	0	0	0	,026	,003	0	,013	,012	0	0	0	0	0	,024	0	0
FeO	,045	,015	,060	,030	0	,035	,105	,005	0	,066	,045	,010	0	,075	,045	,060	0	,090	,030	,066
ZnO	,060	0	,082	,022	0	0	0	0	,052	0	0	0	,022	0	,045	,030	,082	0	,045	0
MgO	0	,015	0	,005	0	,010	0	,017	0	0	0	0	,010	,013	0	0	,003	0	0	0
Na_2O	,092	,046	,040	,066	,104	,066	,073	,063	,062	,050	,055	,063	,085	,063	,061	,070	,054	,063	,055	,062
CaO	,004	,001	,004	,027	,010	0	,011	,017	0	,028	,011	0	,007	,010	,011	,008	0	,010	,028	,034
Σ	84,568	84,527	85,126	84,637	84,350	84,730	84,850	84,755	84,219	84,799	84,847	84,345	84,816	84,479	84,517	84,990	85,041	85,148	84,673	84,917
Si	5,940	5,929	5,961	5,925	5,932	5,934	5,940	5,924	5,920	5,924	5,965	5,942	5,932	5,925	5,930	5,923	5,913	5,931	5,945	5,922
Al	2,033	2,057	2,004	2,056	2,048	2,044	2,037	2,059	2,065	2,059	2,005	2,035	2,048	2,054	2,050	2,060	2,071	2,043	2,026	2,051
Cr	,022	,020	,030	,022	,023	,025	,020	,021	,021	,020	,026	,026	,022	,022	,021	,020	,024	,025	,028	,030
V	,002	,001	0	0	0	0	0	,002	0	0	,001	,001	0	0	0	0	0	,002	0	0
Fe	,003	,001	,005	,002	0	,003	,008	,001	0	,005	,003	,001	0	,006	,003	,005	0	,007	,002	,005
Zn	,004	0	,006	,002	0	0	0	0	,003	0	0	0	,001	0	,003	,002	,006	0	,003	0
Mg	0	,002	0	,001	0	,001	0	,002	0	0	0	0	,001	,002	0	0	,001	0	0	0
Na	,016	,008	,007	,011	,018	,011	,012	,011	,011	,008	,009	,011	,014	,001	,010	,012	,009	,011	,009	,011
Ca	,001	0	,001	,002	,001	0	,001	,001	0	,002	,001	0	,001	,001	,001	,001	0	,001	,002	,003

Table 4. Chemistry of a *Linde* hydrothermal synthetic emerald (L 1), 40 points analysed by a line-scan EMPA, distance 2μm.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
SiO_2	67,463	67,692	66,907	67,586	67,820	67,696	67,636	67,572	67,815	68,181	67,477	67,910	66,675	67,580	66,286	67,899	67,905	67,657	67,738	67,728
Al_2O_3	18,583	18,577	18,677	18,745	18,987	18,771	18,762	18,441	18,335	18,516	18,412	18,573	18,295	18,445	17,851	18,148	18,333	18,462	18,520	18,641
Cr_2O_3	,152	,158	,193	,345	,297	,254	,284	,248	,215	,172	,235	,232	,275	,275	,345	,411	,263	,229	,238	,248
V_2O_3	0	,060	0	0	,043	,024	0	,021	,021	0	,032	,046	,006	,018	,018	0	,035	,054	0	0
FeO	,011	,060	,027	0	,050	,022	,044	0	,012	0	,022	,072	,094	,012	0	,005	,033	0	,005	0
ZnO	,170	,014	,156	0	0	0	0	0	0	,044	0	0	,044	,029	,129	0	,015	0	,057	0
MgO	0	0	,028	0	,012	,007	,010	0	,020	,013	0	0	,010	0	,012	,002	0	,008	0	,007
Na_2O	,019	,041	,076	,030	,024	,032	,047	,024	,059	,044	,009	,009	,042	,044	,019	,031	,016	,015	0	,011
CaO	0	0	0	0	,022	,004	0	,004	0	0	,018	,007	0	0	,006	,018	0	0	,015	0
I	86,397	86,602	86,064	86,706	87,254	86,810	86,782	86,310	86,477	86,971	86,207	86,849	85,440	86,402	84,665	86,513	86,601	86,426	86,575	86,635
Si	6,019	6,023	5,997	6,008	5,994	6,010	6,008	6,030	6,040	6,037	6,029	6,025	6,018	6,027	6,037	6,047	6,040	6,030	6,028	6,021
Al	1,955	1,948	1,972	1,964	1,978	1,964	1,964	1,939	1,925	1,932	1,939	1,942	1,946	1,939	1,916	1,905	1,922	1,939	1,942	1,953
Cr	,011	,011	,014	,024	,021	,018	,020	,017	,015	,012	,017	,016	,020	,019	,025	,029	,018	,016	,017	,017
V	0	,005	0	0	,003	,002	0	,001	,001	0	,002	,003	,001	,001	,001	0	,003	,004	0	0
Fe	0	,005	,002	0	,004	,002	,003	0	,001	0	,002	,005	,007	,001	0	,001	,003	0	,001	0
Zn	,011	0	,009	0	0	0	0	0	0	,003	0	0	,003	,002	,009	0	,001	0	,004	0
Mg	0	0	,005	0	,001	,001	,001	0	,003	,002	0	0	,001	0	,002	0	0	,001	0	,001
Na	,002	,007	,014	,005	,004	,006	,008	,004	,010	,008	,002	,002	,007	,008	,003	,005	,003	,003	0	,002
Ca	0	0	0	0	,002	,001	0	,001	0	0	,002	,001	0	0	,001	,002	0	0	,002	0

	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.
SiO_2	68,168	67,942	67,441	67,651	67,728	67,240	67,758	63,627	62,681	63,188	67,807	67,610	66,724	67,090	67,247	67,161	67,428	67,356	67,189	66,977
Al_2O_3	18,628	18,641	18,951	18,688	18,598	18,904	18,397	18,575	18,418	18,630	18,639	18,877	19,062	18,758	18,328	18,476	18,291	18,552	18,421	18,419
Cr_2O_3	,172	,175	,266	,402	,320	,314	,269	,232	,266	,235	,161	,158	,142	,368	,238	,196	,157	,220	,181	,205
V_2O_3	0	0	0	0	0	0	,024	0	0	,043	0	,018	,024	,044	0	0	,017	,006	0	0
FeO	0	0	,022	0	0	0	0	0	,028	,012	0	,044	,044	0	0	,027	0	,027	0	,038
ZnO	,086	0	,015	0	,144	,187	,115	0	0	0	0	0	0	,086	0	,113	,297	,057	,113	0
MgO	,025	0	,018	0	,015	,013	,002	0	,002	,008	0	0	,022	0	,012	0	0	,006	,001	,001
Na_2O	,046	,042	,085	,027	,061	,050	,039	,047	,040	,023	,011	,069	,001	,050	,012	,078	,044	,035	,039	,064
CaO	,004	,006	,003	0	,018	,004	0	0	0	0	0	,001	,011	0	,020	,010	,002	,001	,006	,005
I	87,129	86,805	86,801	86,768	86,884	86,716	86,603	82,481	81,436	82,139	86,618	86,777	86,030	86,397	85,857	86,060	86,236	86,260	85,950	85,709
Si	6,028	6,027	5,992	6,010	6,014	5,986	6,031	5,950	5,939	5,935	6,027	6,004	5,978	5,992	6,031	6,018	6,033	6,019	6,023	6,022
Al	1,941	1,949	1,984	1,957	1,946	1,983	1,930	2,047	2,057	2,063	1,953	1,976	2,013	1,975	1,938	1,951	1,927	1,953	1,946	1,951
Cr	,012	,012	,019	,028	,023	,022	,019	,017	,020	,017	,011	,011	,010	,026	,016	,014	,011	,016	,014	,014
V	0	0	0	0	0	0	,002	0	0	,003	0	,001	,002	,003	0	0	,002	0	0	0
Fe	0	0	,002	0	0	0	0	0	,002	,001	0	,003	,003	0	0	,002	0	,002	0	,002
Zn	,006	0	,001	0	,009	,012	,008	0	0	0	0	0	0	,006	0	,007	,021	,005	,007	0
Mg	,003	0	,002	0	,002	,002	0	0	0	,001	0	0	,003	0	,002	0	0	0	0	0
Na	,008	,007	,014	,005	,011	,009	,007	,009	,007	,004	,002	,012	0	,009	,002	,014	,007	,007	,007	,012
Ca	,001	,001	0	0	,002	,001	0	0	0	0	0	0	,001	0	,002	0	0	0	0	0

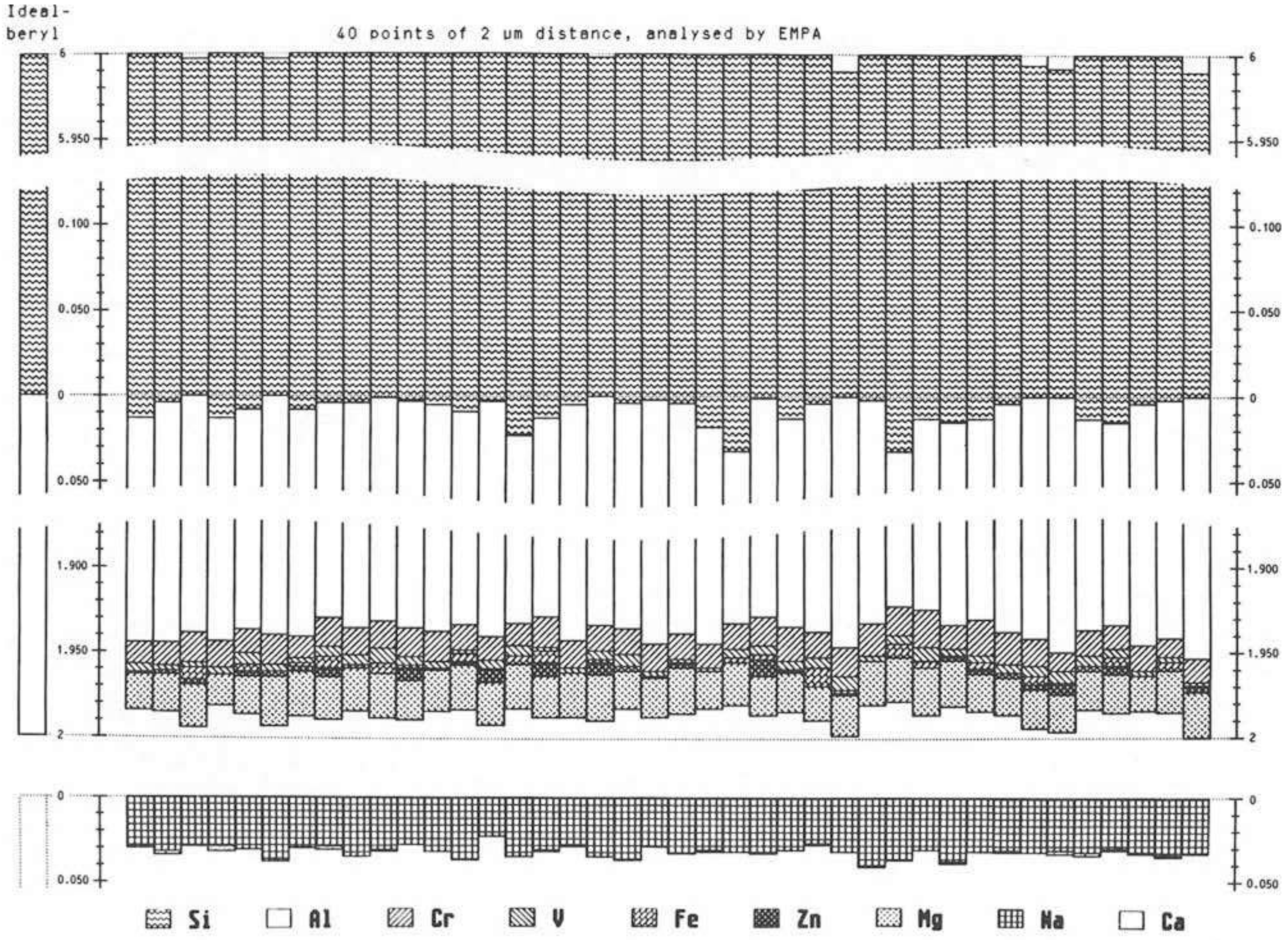


Fig. 4. Elements occupying the Si-, the Al-, and the interstitial structural channel positions of a Colombian emerald (C 85) presented in cations per formula unit. The distance from point to point is 2μm.

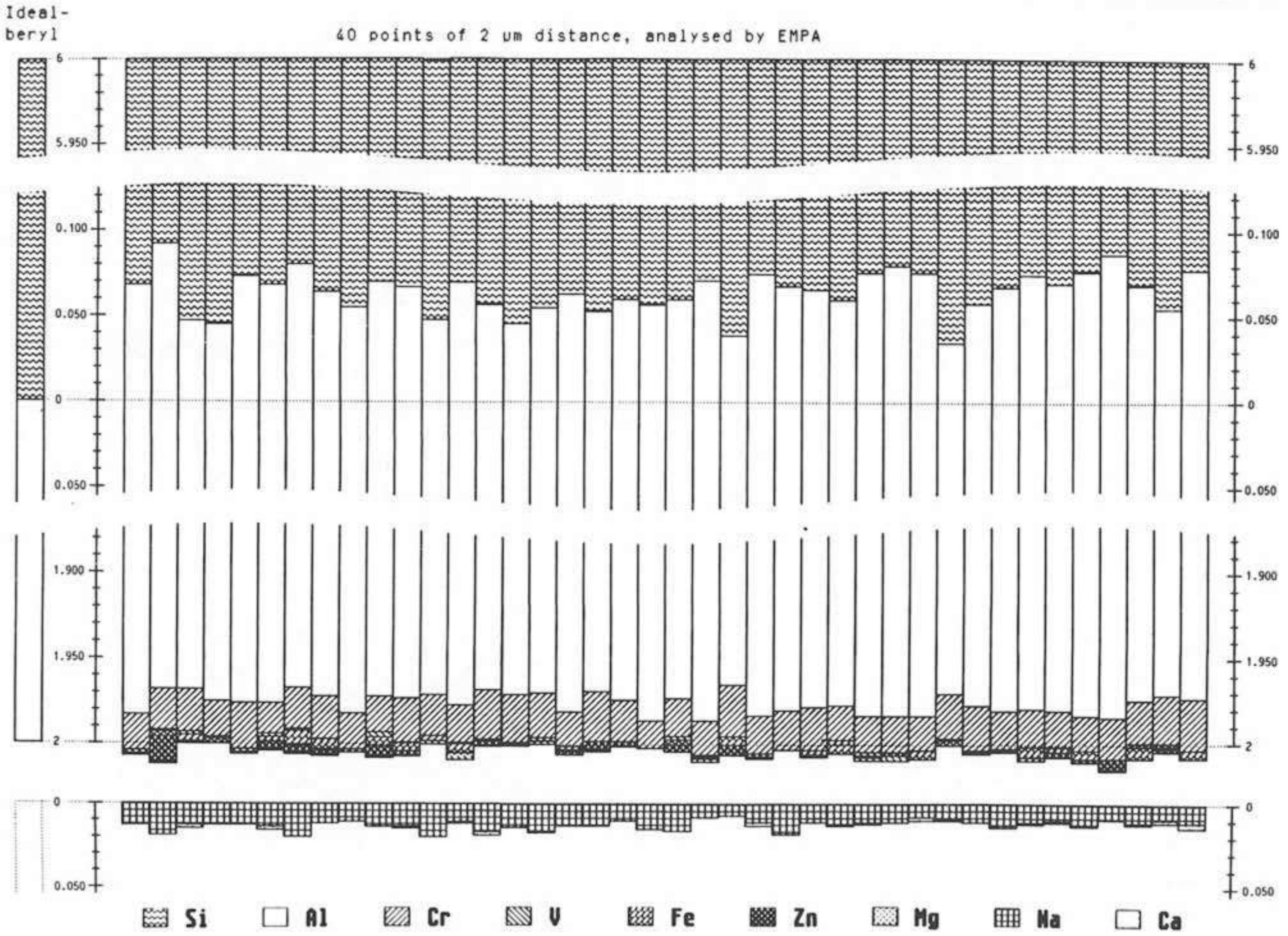


Fig. 5. Elements occupying the Si-, the Al-, and the interstitial structural channel positions of a *Gilson* flux-grown synthetic emerald (G 16) presented in cations per formula unit. The distance from point to point is 2μm.

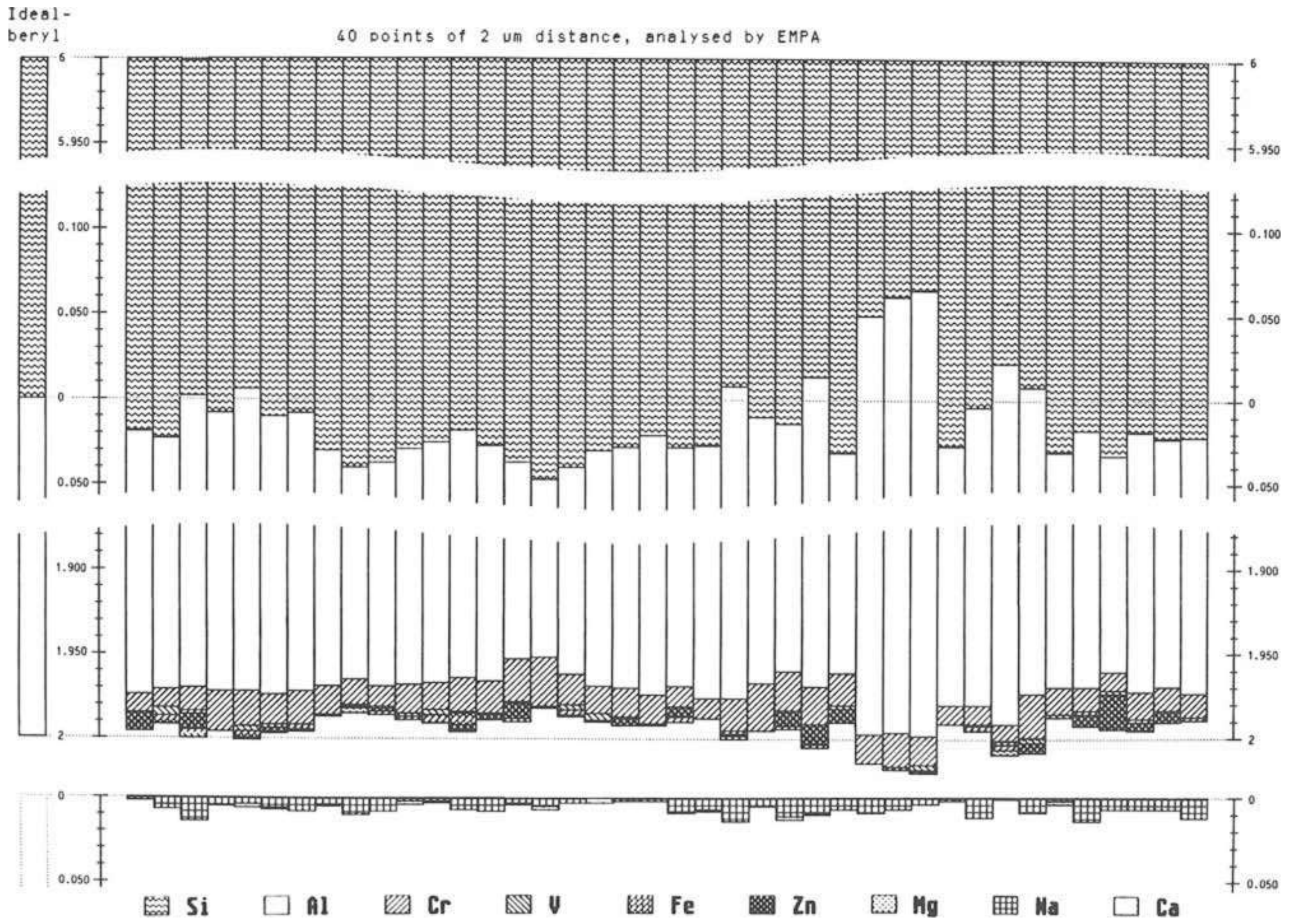


Fig. 6. Elements occupying the Si-, the Al-, and the interstitial structural channel positions of a *Linde* hydrothermal synthetic emerald (L 1) presented in cations per formula unit. The distance from point to point is 2μm.

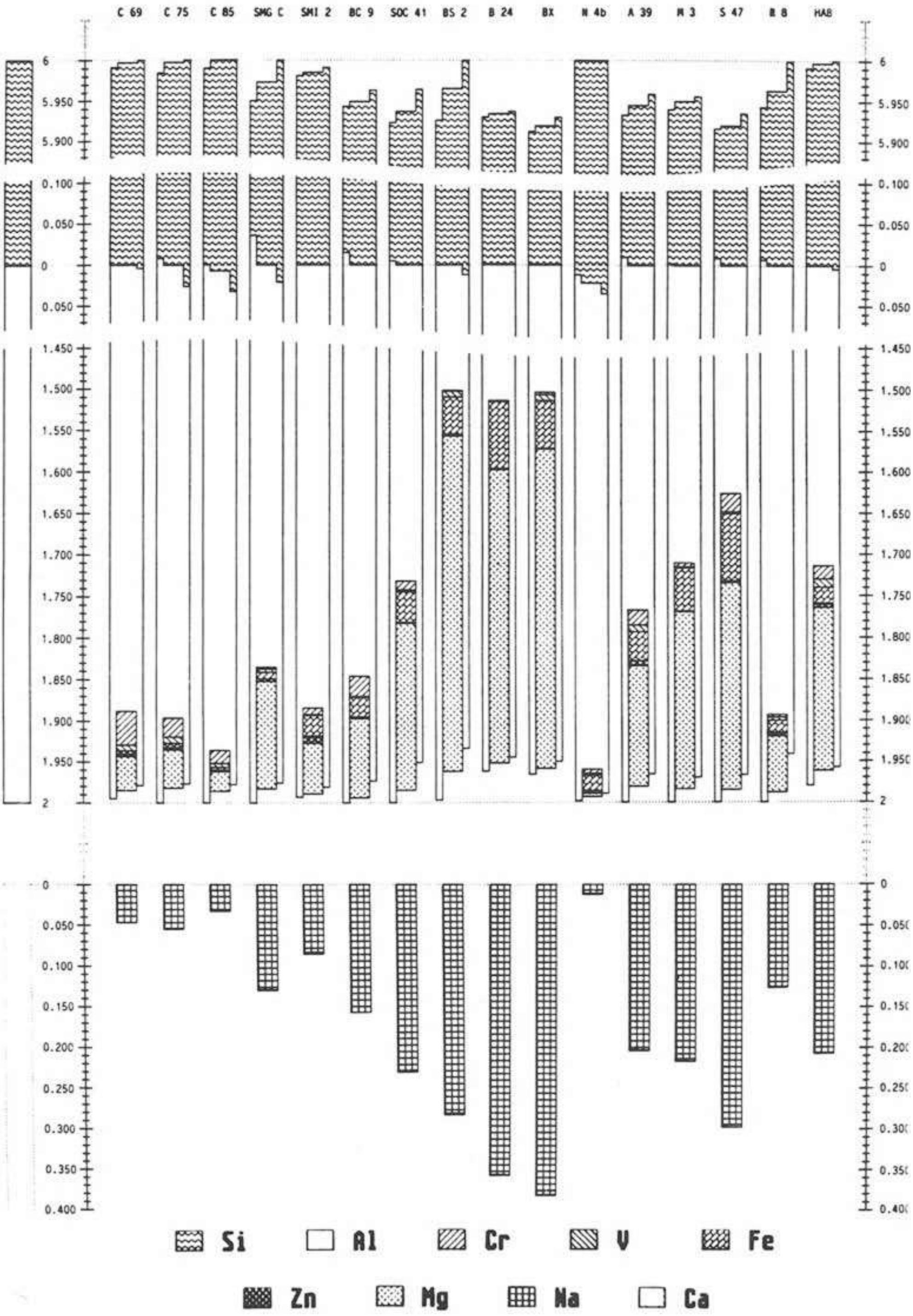


Fig. 7. Average chemistry of 16 natural emeralds presented in cations per formula unit attached to their lattice position (including their maximum deviation).

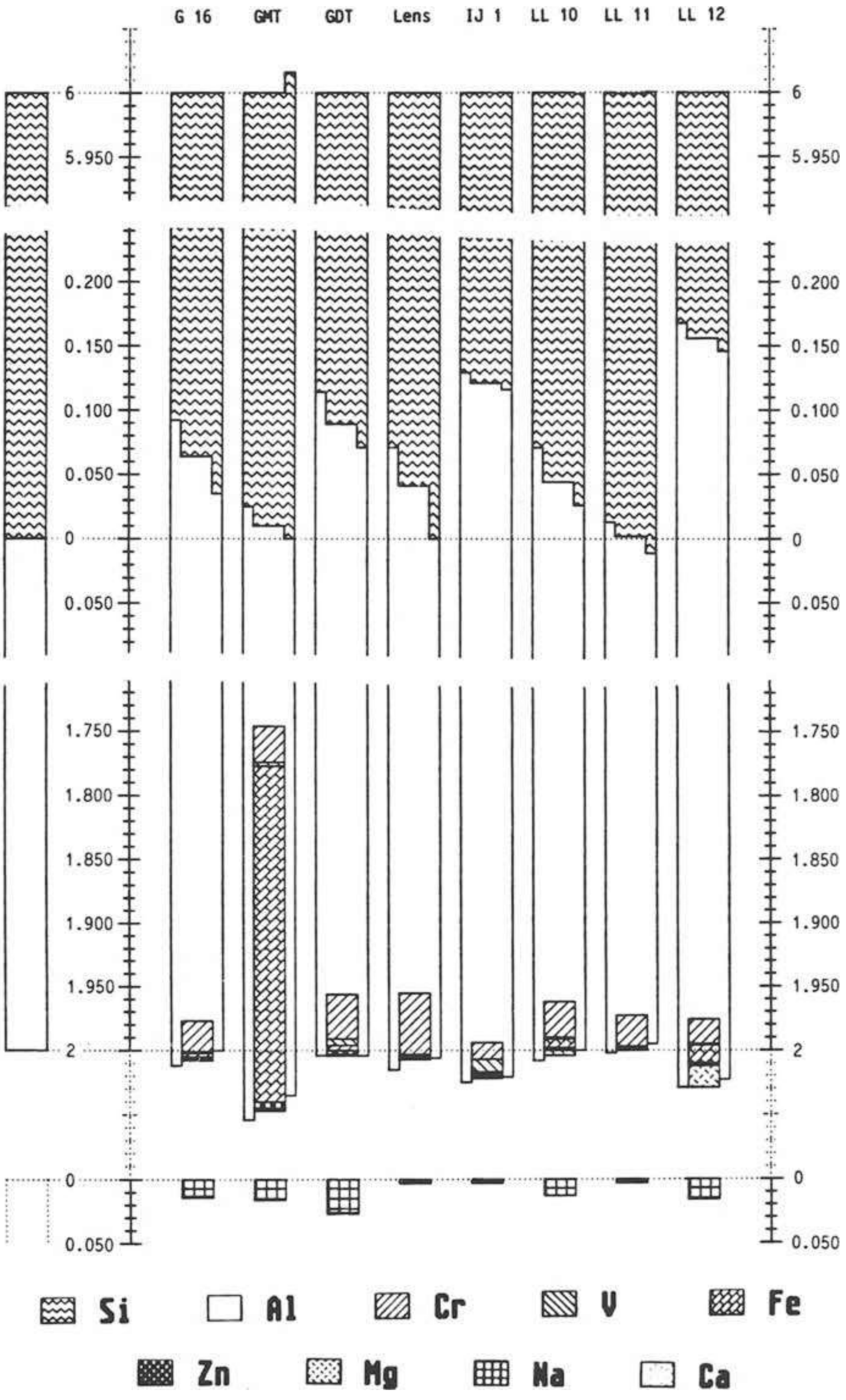


Fig. 8. Average chemistry of 8 flux-grown synthetic emeralds presented in cations per formula unit attached to their lattice position (including their maximum deviation).

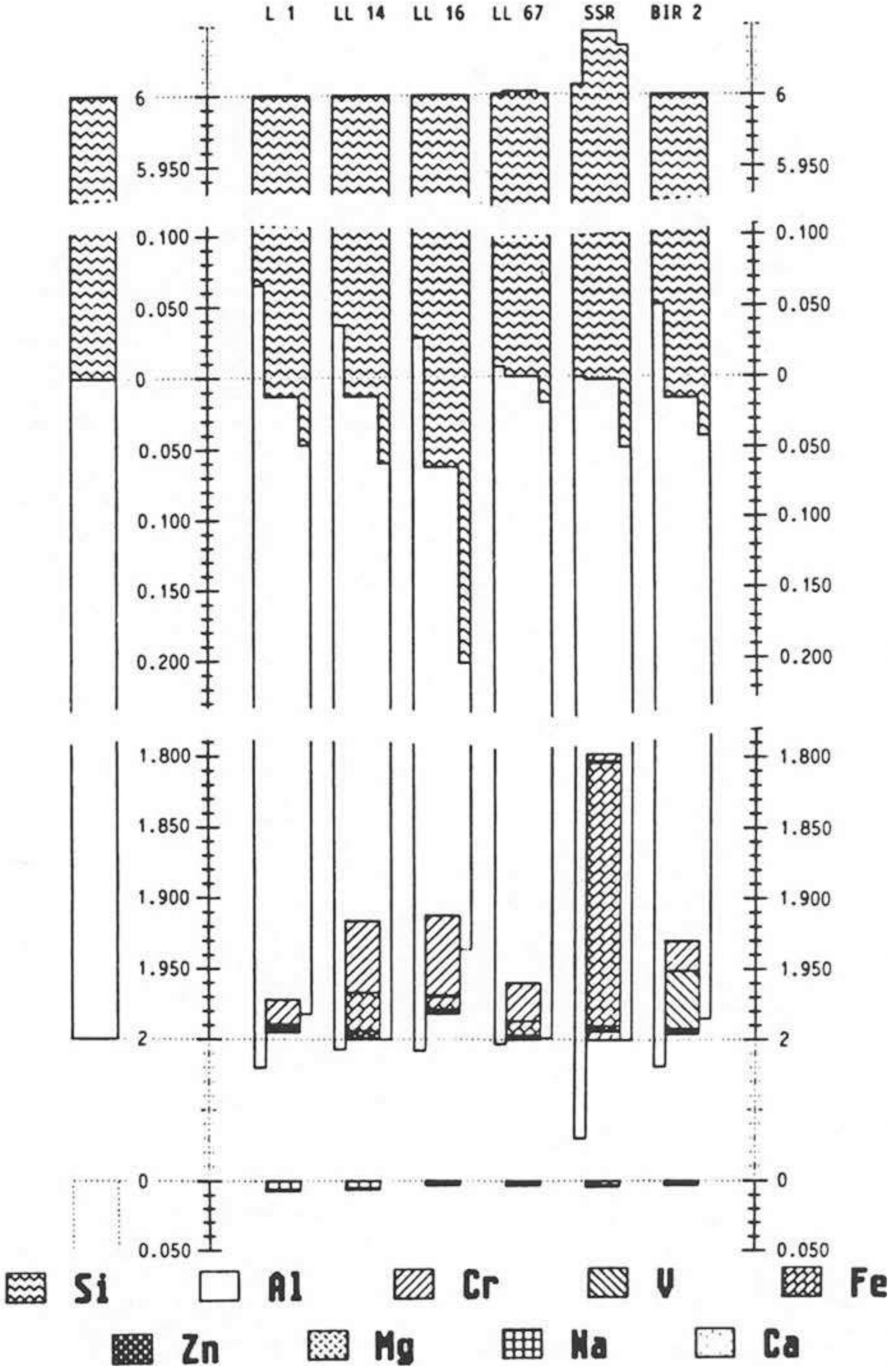


Fig. 9. Average chemistry of 6 hydrothermal synthetic emeralds presented in cations per formula unit attached to their lattice position (including their maximum deviation).

using a line scan EMPA of 40 points 2μm apart perpendicular to the zoning. The analysed values have been converted to cations per formula unit (Tables 2 to 4) so that variation can be considered on an atomic basis.

The converted Si-cations were allocated to the Si-positions of the lattice and the converted Al-, Cr-, Fe-, Zn-, and Mg- cations to the Al-positions. In Figures 4 to 6 the Si-cations are shown with Al- and replacement cations. Excess cations in one position were used to compensate deficiencies in the other; remaining excess values are shown in the diagrams. The amounts of alkali- and alkali earth-cations located in the structural channels are also presented.

All measurements by EMPA yielded totals between 82 and 86 wt% which is within the stochiometric range of beryl, assuming that Be, Li and water not detectable by EMPA make up the remainder.

Natural emeralds:

All natural emeralds (Figures 4 and 7) show Al-deficiencies. In some emeralds from deposits in Brazil and Africa these deficiencies are accompanied by Si-deficiencies. The Al-deficiencies are partly compensated by contents of Cr, V, Fe, Zn, and Mg and even Si. The number of alkali cations corresponds very closely with the number of divalent cations and this is consistent with coupled replacement.

Flux-grown synthetic emeralds:

These synthetic emeralds show a general deficiency in Si (Figures 5 and 8). The deficiencies may be partly compensated by Al-cations and the minor quantities of Cr, V, Fe, Zn, and Mg, for their number distinctly exceeds the number of Al-positions in the beryl structure (=2). The necessary charge compensation is provided by the alkalies in excess of those assigned to the divalent cations in the coupled replacement.

Hydrothermal synthetic emeralds:

These synthetic emeralds reveal regions with Al-deficiencies next to regions with Si-deficiencies (Figures 6 and 9). The content of alkalies is not sufficient to satisfy charge compensation requirement and show likely that H-cations are incorporated. Located in the structural channels they have been confirmed by infra-red spectroscopy (Schrader, in prep.).

These investigations indicate the replacement of Si by Al and other cations in synthetic emeralds which form colour centres when subjected to intense radiation. The direct proof will probably come from electron paramagnetic resonance (EPR) investigations later on.

Colour centres in natural beryls

Fe-cations replacing Si in natural beryls have already been proven as:

- Fe^{3+} in Si-positions (Wood and Nassau, 1968);
- Fe^{3+} in the tetrahedral lattice position (= Si) by EPR (Samoilovich *et al.*, 1971);
- Fe^{2+} in the tetrahedral lattice position (= Si) by Mössbauer-spectroscopy (Price, *et al.*, 1976).

Therefore the possibility of the activation of corresponding colour centres in natural beryls should not be excluded. For instance the Colombian emerald (Figure 4) reveals some regions with Si-deficiencies. But in these cases the Al-deficiencies are hindering the replacement of Si by Al. Further the observation of X-ray luminescence from natural beryls by Kuznetsov, *et al.* (1979), caused by the replacement of Si, may also indicate the existence of colour centres.

However, activated centres will be destroyed immediately by atomic hydrogen because of its high reactivity. The H_2O-contents of natural beryls are sufficient to enable development of atomic hydrogen on ionizing radiation as proven by EPR by Koryagin and Grechusnikov (1966), Bershov (1970), and Anderson (1974).

Acknowledgements

For providing facilities for the NAA thanks are due to the Max-Planck-Institute, Mainz, Dept. of Cosmochemistry, and for the microscopic spectral measurements the German Bundeskriminalamt (Federal Criminal Police Office), Wiesbaden, Dept. of Criminal technology is thanked.

References

Aines, R.D., Rossman, G.R., 1986. Relationship between radiation damage and trace water in zircon, quartz and topaz. *American Mineralogist*, **71**, 1186–93.

Andersson, L.O., 1974. EPR of hydrogen atoms in beryl crystals. *Proc. 18th. Congress Ampere*, **18**, 129–30.

Bank, H., 1982. Aus der Untersuchungspraxis. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **31**, 1/2, 97–9.

Bershov, L.V., 1970. Methane and atomic hydrogen in some natural minerals. *Geochemistry International*, **7**, 853–6.

Koryagin, V.F., Grechushnikov, B.N., 1966. Electron paramagnetic resonance of atomic hydrogen in beryl. *Soviet Physics – Solid State*, **7**, 8, 2010–12.

Kusnetsov, G.V., Platanov, A.N., Tarashchan, A.N., Voloshin, A.V., 1979. A study of the development of luminescence centres in beryls from rare-metal pegmatites in the north-western part of the USSR. *Mineralogicheski Zhurnal*, **1**, 2, 60–7.

Lind, T., Henn, U., Bank, H., 1986. Synthetische Smaragde nach dem Hydrothermalverfahren aus der UdSSR. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **35**, 3/4, 189.

Nassau, K., 1984. *Gemstone enhancement*. Butterworths, London.

Nassau, K., Nassau, J., 1980. The growth of synthetic and imitation gems. In: *Crystals – growth, properties and applications*, **2**, 1–50, Springer Verlag.

Nassau, K., Prescott, B.E., 1977. Smoky, blue, greenish yellow, and other irradiated-related colours in quartz. *Mineralogical Magazine*, **41**, 319, 301–31.

Price, D.C., Vance, E.R., Smith, G., Edgar, A., Dickson, B.L., 1976. Mössbauer effect studies of beryl. *Journal de Physique Colloque*, C6, Supple. 12, 37, 811–17.

Samoilovich, M.I., Tsinober, L.I. Dunin-Barkovskii, R.L., 1971. Nature of coloring in iron-containing beryl. *Soviet Physics – Crystallography*, **16**, 1, 147–50.

Shatskiy, V.S., Lebedev, A.S., Pavlyuchenko, V.S., Kovaleva, L.T., Koz'menko, O.A., Yudin, A.N., Belov, N.V., 1981. Conditions for the entry of alkali cations into beryl. *Geochemistry International*, **18**, 2, 7–17.

Wood, D.L., Nassau, K., 1980. The characterisation of beryl and emerald by visible and infrared absorption spectroscopy. *American Mineralogist*, 53, 777–800.

[*Manuscript received 5 May 1987, revised 13 January 1988.*]

The Presidium 'Duotester' – a test report

Peter Read, C. Eng., FGA, Dia.Dip.

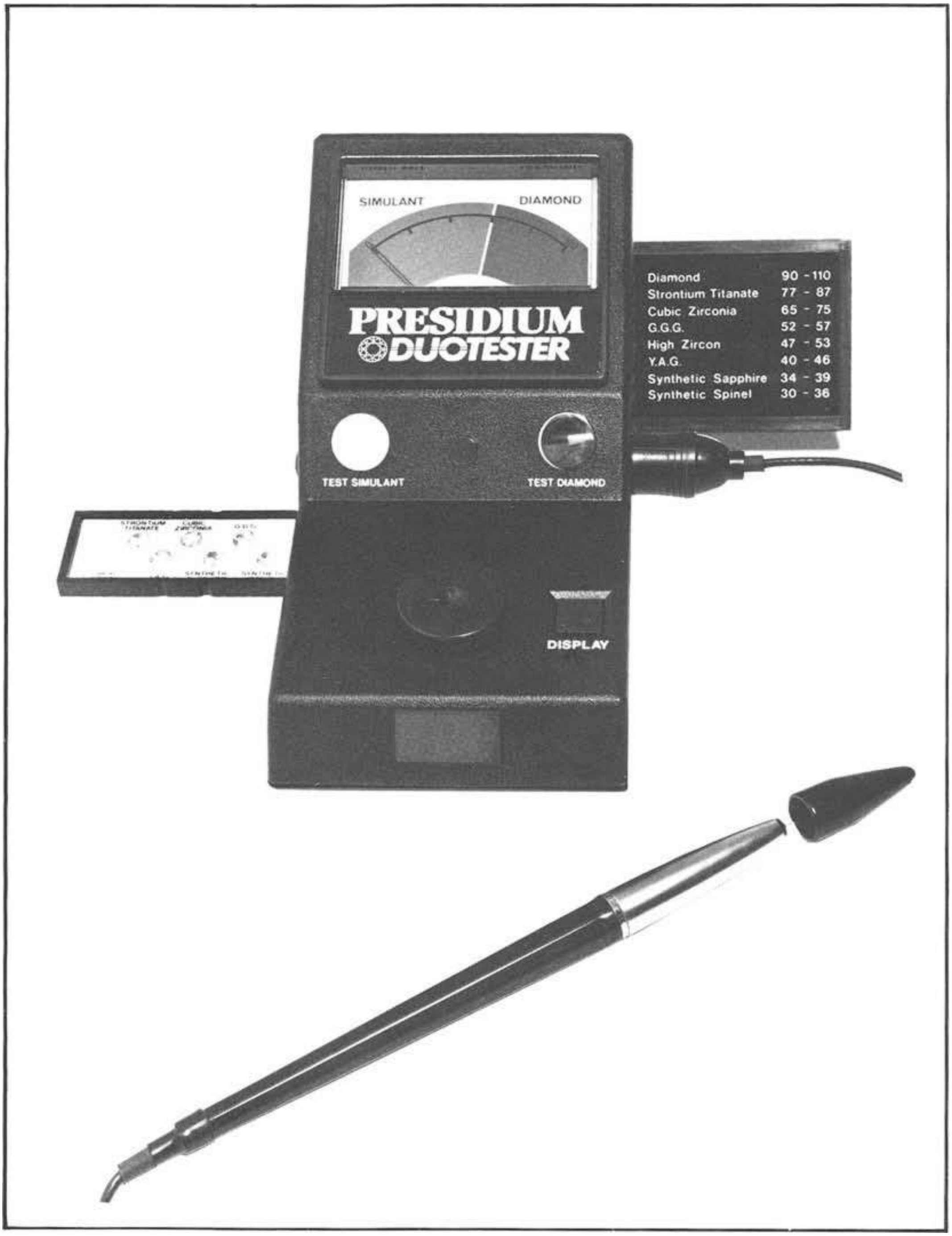
In the first issue of the 'Gem Instrument Digest'[1] I made the following observations on the use of reflectivity and thermal methods for the identification of gemstones:-

'Apart from differences in measuring technology between reflectivity and thermal instruments, there is also the difference in test *information*. With the reflectivity meter it is possible to identify the nature of the stone even if it is not a diamond. The thermal conductivity tester, however, with one interesting exception . . ., only proves that the stone is, or is not, a diamond.

'What is perhaps more important is the fact that the advantages and disadvantages of each type of instrument conveniently *complement* each other. For example, the reflectivity of strontium titanate is uncomfortably close to that of diamond, and with a small error in instrument calibration could result in a wrong identification. The thermal conductivity of strontium titanate, however, is so much smaller than that of diamond that no error of identification could occur even with the simplest type of thermal conductivity meter. Similarly, corundum's thermal conductivity is closer to diamond's than any other simulant, with the result that a large cold sapphire may produce a diamond indication on some of the simpler thermal conductivity testers. Fortunately, however, it is not possible (even with a reasonable degree of mis-calibration) to confuse sapphire with diamond on a reflectivity meter as their relative lustres are conspicuously different. It is sound gemmological practice to base an identification on the results of more than just one type of test. For this reason it makes good sense to exploit the complementary features of these two types of instrument and check a suspect diamond with both reflectivity and thermal conductivity tests. Whatever instrument is used, it is equally important that its calibration is checked both before and during use by reference to known comparison stones.'

Perhaps these observations did not go unnoticed, as some time later the Presidium company of Singapore introduced their Duotester instrument which not only combined a reflectivity meter in the same case as their original 'Gem Tester' instrument (this was one of the earlier thermal testers) but also provided a set of diamond simulants for calibration checking.

In this new combined instrument, the probe of the thermal tester section has been redesigned and has a metallized barrel which is used to activate a



The Presidium Duotester is a combined thermal and reflectivity meter. Seven diamond simulants are provided in a tray which extends from the left side of the unit's case. The typical reflectivity ranges for diamond and the seven simulants are displayed on a panel which slots into the right-hand side of the instrument.

warning buzzer if the probe tip comes into contact with the gemstone mount (gold, silver and platinum give a response similar to diamond). This 'metal alert' buzzer is operated by means of a small voltage which is connected between the probe's test tip and its metallized end section. Provided that the user is holding the gem mount in one hand, and the metallized section of the probe in the other hand (and does not have dry skin!) a very small current will pass through the user when the tip comes into contact with the mount, and this is used to trigger the buzzer circuit.

The reflectivity meter section of the Duotester has its test platform mounted in the horizontal section of the case, and its 3-digit display is located in the front edge of the unit. Both reflectivity and thermal tests can be compared with, and instrument calibration checks made against readings obtained on a set of seven diamond simulants which are supplied with the instrument. These stones are held in a tray which slides neatly away into the control box for transit purposes. An aperture in the opposite end of this tray forms a convenient holder for the probe. A pull-out panel is also provided on the control box, and when extended reveals a list which gives the range of reflectivity readings to be expected for diamond and the seven simulants provided.

As with the original Presidium 'Gem Tester', the thermal probe can be unplugged for transit and replacement purposes. The two built-in thermal test surfaces for checking simulant/diamond calibration are also retained in the new model. The 'Gem Tester' was unique in being the only commercial diamond tester to use a resistor-heated thermocouple as the transducer in its test probe, and this technique is repeated in the Duotester. As before, the thermocouple uses a copper-constantan combination, one end of the copper section being extended to form the spring-loaded test tip of the probe. The meter reading on the original thermal tester used to reach a maximum as heat was conducted away from its probe tip; after a few seconds, the reading then began to fall back as heat was also conducted away from the reference section of the thermocouple. During tests on the new version, this minor defect appeared to be far less noticeable. When used in its thermal mode, the Presidium Duotester is sensitive enough to distinguish a diamond from a simulant down to 0.02 carat in size. As is normal with reflectivity meters, the minimum size of stone that can be tested is limited by the diameter of the test aperture. In the Duotester, the minimum size is around 0.05 carat.

As the Duotester is designed for operation from an internal battery as well as from a mains supply, a warning indication is provided by two dots which are displayed between the digits on the reflectivity display panel when the battery needs replacing. A plug-in unit is supplied with the instrument for mains operation

To sum up, the Presidium Duotester has cleverly exploited the complementary characteristics of the reflectivity and thermal tester in one instrument, and has also made full provision for calibration checks on both ranges.

Reference

1. Read, P.G. 1983. Comment – Reflectivity versus Thermal Conductivity, *Gem Instrument Digest*, 1, (1), 2–3.

[*Manuscript received 17 March 1988.*]

Gemmological Abstracts

Balfour, I., 1988. Famous diamonds of the world. XXXIII. The Tiffany. *Indiaqua*, **49**, 1988/1, 119-22.

The bulk of this section of Balfour's series is concerned with the financial struggle to amalgamate the many separate mining companies in Kimberley into De Beers Consolidated Mines Ltd. The stone that was to become the Tiffany diamond was found in one of the Kimberley mines in 1877 or 1878. The 287.42ct canary-yellow octahedron was cut in Paris in 1878 into a cushion-cut brilliant of 128.51ct. In 1879 the gem was purchased by Tiffanys for $18,000 and is still owned by the store.

P.G.R.

Balfour, I., 1988. Famous diamonds of the world. XXXIV. The De Beers diamond. *Indiaqua*, **49**, 1988/1, 123.

In 1888, a 439.86ct light yellow octahedron was found in the De Beers mine, not long after the incorporation of De Beers Consolidated Mines Ltd. It was cut, probably in Amsterdam, into a 234.50ct cushion-cut stone and was exhibited at the Paris exhibition of 1889. At a Sotheby's auction in Geneva in 1982 it failed to achieve its reserve price. More recently it has been acquired by a private buyer.

P.G.R.

Balfour, I., 1988. Famous diamond of the world. XXXV. Cleveland. *Indiaqua*, **50**, 1988/2, 139-40.

The rough stone, which was found in one of the Kimberley mines, weighed over 100 old carats. It was cushion-cut into a gem of 50ct and eventually named after Grover Cleveland who had just been elected the twenty-second President of the United States. Its present whereabouts are unknown.

P.G.R.

Balfour, I., 1988. Famous diamonds of the world. XXXVI. The 'Punch' Jones diamond. *Indiaqua*, **50**, 1988/2, 140-1.

This greenish-grey 34.46ct octahedron stone is the largest alluvial diamond to have been found in the United States. Discovered in the Appalachians in 1928 by William 'Punch' Jones, it was kept by him as a curio because he was not sure it was a diamond. In 1943 it was identified as a diamond by Professor Holden. The stone was never polished, and for a period was loaned to the Smithsonian Institution. It was auctioned by Sotheby's in 1984 for £67,500.

P.G.R.

Banerjee, A., 1988. Gilson-Opale der neuen Generation. (New generation Gilson opals.) *Kurzmitteilungen aus dem Institut für Edelsteinforschung*, **4**, 2, 12, 2 figs.

Opal imitations created by Gilson are described. Instead of silica gel, zirconium dioxide is used as a matrix. In cases where it is difficult to identify the Gilson opal by optical means, IR-spectroscopy can be applied successfully, according to characteristic Si-O vibration in the region around 1250 cm^{-1}.

(Author's abstract) A.B.

Bank, F.H., Bank, H., Gübelin, E., Henn, U., 1988. Alexandrite von einem neuen Vorkommen bei Hematita in Minas Gerais, Brasilien. (Alexandrites from a new occurrence near Hematita in Minas Gerais, Brazil.) *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **36**, 3/4, 122-31, 15 figs, 1 table, bibl.

Alexandrites from the newly discovered alluvial occurrence near Hematita are discussed. Some of the stones show very good colour change and are remarkably clean. Some stones have a colour change plus chatoyancy, i.e., there are some alexandrite cat's-eyes. Physical data are within range of known natural and synthetic alexandrites. Microscopic feathers of liquid and two-phase inclusions or cavities filled with apatite, fluorite and cacite are visible. Stones show distinct growth structures. Typical alexandrite spectrum, red fluorescence.

E.S.

Bergman, S.C., Dunn, D.P., Krol, L.G., 1988. Rock and mineral chemistry of the Linhaisai

Minette, Central Kalimantan Province, Indonesia, and the origin of Borneo diamonds. *Canadian Mineralogist*, **26**, 23-43, 9 figs.

The alluvial diamonds found in central Kalimantan, Indonesia, may owe their origin to an unidentified lamproite or kimberlite in Borneo or adjacent south-east Asia. M.O'D.

Bracewell, H., 1988. The Argyle diamond mine. *Wahroongai News*, **22**, 4, 31-2.

A short account of today's largest diamond mine. A remote difficult region of north Western Australia has been opened up and Argyle Village built to accommodate 700 plus workers in virtual self-sufficiency. Some staff commute daily by air from Kunanurra, 220km away. Mine is open-cast, worked by modern earth-moving techniques. Treatment of spoil by crushing, scrubbing, screening and gravity separation, precedes diamond recovery by X-ray fluorescence. Product is 45% gem (5% of which are fine) and 55% industrial. R.K.M.

Brown, G., 1988. Danburite. *Wahroongai News*, **22**, 4, 23-5, 3 figs.

A brief account of this calcium boro-silicate, which can be confused with topaz, particularly in its crystal form. R.K.M.

Brown, G., 1988. Trapiche emeralds. *Wahroongai News*, **22**, 5, 20-2, 3 figs.

An interesting account of this strange crystallographic anomaly compiled from authoritative sources. The larger or better crystals are segmented to extract the emerald areas for faceting. The 'spokes' are better quality than the core. R.K.M.

Brown, G., 1988. Chrysoberyl. *Wahroongai News*, **22**, 6, 21-5, 4 figs.

An exhaustive compilation of facts culled from half a dozen authoritative sources. Includes details of several known synthetic alexandrite products. R.K.M.

Butini, E., 1987. Impiego della 'Xeroradiografia' nell'indagine gemmologica qualitativa delle perle. (The use of 'xeroradiography' in the qualitative gemmological study of pearls. *La Gemmologia*, **12**,, 1/4, 6-22, 35 figs (31 in colour).

Xeroradiography is based on the interaction of X-rays with the atomic structure of some photoconductive substances such as selenium. A standard X-ray generator is used with a plate having an aluminium base with a thin deposited selenium layer on it. Selenium is capable of conducting electricity on exposure to X-rays and other radiations. This apparatus is capable of recording the structures of various types of pearl and examples are given with illustrations. When the photograph is taken the result is then recorded on special plastic paper which then provides a coloured image. M.O'D.

Cassedanne, J., 1988. L'Améthyste au Brésil (2). (Brazilian amethyst.) *Revue de Gemmologie*, 95, 3-9, 18 figs (3 in colour).

Second and final part of a paper on amethyst deposits of Brazil which are listed and geologically described. A bibliography is appended. M.O'D.

Caveney, R.J., 1987. De Beers Research Report No. 25. *Indiaqua*, **48**, 1987/3, 119-21.

The report deals with the surface properties of diamond and explains why diamond, normally hydrophobic (non-wettable) sometimes becomes hydrophilic (wettable) when its surface is contaminated. More rarely, some 'clean' diamonds refuse to adhere to the grease on diamond-recovery grease tables and belts. The mechanism here is still a mystery, but research is continuing into the surface chemistry of diamond, and this is becoming particularly relevant to the bonding of diamond particles to the surface of cutting and grinding tools. P.G.R.

Caveney, R.J., 1988. Comments upon De Beers large synthetic diamonds. *Indiaqua*, **50**, 125-8, 15 figs (14 in colour).

A single crystal synthetic diamond weighing 11.14ct has been grown by De Beers Diamond Research Laboratory. A selection of smaller crystals were sent to the GIA and reported on in the Winter 1987 issue of *Gems and Gemology*. M.O'D.

Currie, S.J.A., 1988. Some aspects of the heat treatment of ruby. *Wahroongai News*, **22**, 6, 2-3.

A 'guest editorial' describing a method seen in Thailand in 1987 in which ruby crystals were sealed in a clay crucible with an acidic solution, probably dilute nitric acid and salt, and baked in a charcoal kiln. Some speculation is made on the possible reaction, but the writer did not see the treated stones to assess the result. R.K.M.

de Bruyn, Wim, 1987. World diamond record. *Industrial Diamond Review*, 6/87. 271, 1 fig.

The Amsterdam diamond dealers, D. Drukker & Zn NV, have succeeded in fashioning the world's smallest brilliant-cut diamond. It is 0.22mm in diameter, and weighs 0.0001022 ct. It has been accepted by the *Guinness Book of Records* as a new world record, easily beating the last holder of this title (a diamond 0.53mm in diameter). P.G.R.

Delbasteh-Miandoab, R., 1988. Spodumene afghanischer und brasilianischer Herkunft. (Spodumene from Afghanistan and Brazil.) *Kurzmitteilungen aus dem Institut für Edelsteinforschung*, **4**, 2,9-10, 2 figs.

Spodumene crystals of different colours (pink, green and colourless) from Afghanistan and Brazil have been investigated by means of X-ray diffraction technique, optical microscopy, SEM, NAA, OES, UV-VIS and IR-spectralphotometry. The following inclusions have been identified: idiomorphic beryl, quartz, Ca-amphiboles and Ca-pyroxenes, micas (muscovite and lepidolite), and zircon; two-and three-phase inclusions, negative crystals and some opaque ore minerals were also observed. Moreover, bent fissures and unusually shaped 'etched tubuli' were found. The Mn-contents of the pink kunzites were found to be approximately proportionate to the intensity of their colours. In hiddenites, the results of the chemical analyses indicate that only Fe, and not Cr, must be responsible for the green colour.
(Author's abstract) R.D-M.

FRITSCH, E., ROSSMAN, G.R., 1988. An update on color in gems. Part 3: Colors caused by band gaps and physical phenomena. *Gems & Gemology*, **24**, 2, 81-102, 16 figs in colour. 4 tables.

Concludes this important and informative series which now covers colour due to coarser physical features in gem minerals. Authors include an exhaustive table of gems, colours and causes, and three pages of references. Series as a whole is valuable. R.K.M.

FRYER, C.W. (ED.), CROWNINGSHIELD, R., HURWIT, K.N., KANE, R.E., 1988. Gem Trade Lab notes. *Gems & Gemology*, **24**, 2, 112-18, 18 figs in colour.

Almandite garnet star which is almost a cat's-eye; greyish-purple diamond; heart-shaped inclusion in diamond; pink diamonds offered as natural, showed zoning in yellow and pink, proved by absorption lines to be treated. All described and illustrated.

Biron synthetic emerald had high RI (1.570-1.578) and birefringence (0.008), otherwise similar to others seen. Unusual black opaque glass with red/green 'blink' is mentioned but neither the term nor its cause are explained. Variegated jadeite, fine green flecked with white, mounted in close-backed yellow setting described and illustrated. White jadeite teapot of exceptional translucency is described. Glass bead imitation pearls described as Edwardian are attributed to late 1800s or early 1900s. A cultured pearl in a necklace was found to have a wax bead centre. Plastic earring said to contain diamond, was shown to have none. A black pyrope with ilmenite inclusions was confirmed. A synthetic yellow sapphire showed Plato line effect without magnification. A blue synthetic sapphire had intersecting curved colour banding. Two specimens of brecciated tiger's-eye quartz are illustrated.
R.K.M.

GERRYTS, E., 1988. Memories of Mwadui in the 1950s. *Indiaqua*, **49**, 21-31, 16 figs (7 in colour).

The former chief diamond geologist at the Mwadui mine in Tanzania gives recollections of the mine and of Dr John T. Williamson. M.O'D.

GONZALEZ-CARRENO, T., FERNANDEZ, M., SANZ, J., 1988. Infrared and electron microprobe analysis of tourmalines. *Physics and Chemistry of Minerals*, **15**, 452-60, 6 figs.

Tourmalines from the dravite-schorl and elbaite-schorl series were examined with infra-red and electron microprobe equipment. The infra-red study differentiates between OH groups located at the centre of hexagonal rings and those which are placed between hexagonal pillars and which are coordinated to two Al ions. Electron microprobe tests on zoned coloured samples has shown that the Mn and Fe distribution is partially ordered in some samples of the elbaite-schorl series. M.O'D.

GÜBELIN, E.J., 1988. Feldspars as host and guest minerals. *Indian Gemmmologist*, **1**, 4, 5-11, 18 figs (16 in colour).

The feldspar minerals are reviewed in their roles as host and inclusion. A series of microphotographs illustrate various types of feldspar inclusion in a variety of gemstones. M.O'D.

HÄNNI, H.A., 1987. Corindoni trattati con microotturazioni in vetro. (Corundum treated with microscopic glass infillings.) *La Gemmologia*, **12**, 1/4, 30-8, 10 figs (5 in colour).

Examples of glass infillings in corundum are discussed and illustrated. M.O'D.

HARRIS, J.W., 1987. Recent physical, chemical and isotopic research of diamond. *Mantle Xenoliths*, 477-500.

Recent advances in the following fields of diamond research are reviewed: morphology, growth history, characterization and classification, surface features, substitutional and non-substitutional molecular impurities, colour, age and genesis. Diamond characteristics from southern Africa, Western Australia and North America are compared in detail; > 40 pristine surface features are recognized on common diamond morphologies and distinctions are made between diamonds from different kimberlite and alluvial sources, particularly in southern Africa. Only impurities of atomic size are considered. The substitutional impurities boron and nitrogen are important because of their influence on colour and diamond type. $\delta^{13}C$ variations range between $+5.0$ and -34.4°/oo and the results discussed in terms of paragenetic associations and some preliminary nitrogen isotope studies; 55 non-substitutional impurities are known, but emphasis is placed on noble gas and alkali elements because of their potentially important role in determining the age of diamond. Radiogenic impurities from within diamond currently give ambiguous diamond ages. A new age-dating method, using the impurity of nitrogen, may help resolve some of these problems. J.M.H.

Heflik, W., Natkanieo-Nowak, L., Sobczak, N., Sobczak, T., 1988. Nephrit aus Niederschlesien. (Nephrite from Lower Silesia.) *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **36**, 3/4, 153-60, 1 graph, 1 table, bibl.

Finds of nephrite in Lower Silesia were already mentioned in 1775 by the Swedish scientist Linne, but only recently workings were started. The occurrence is north-west of Jordanow and found together with serpentinite. Gabbro is found in the vicinity. The nephrite contains zoisite and diopside giving it a pink and white coloration. The white colour is also caused by veins of tremolite which are very poor in FeO. Blocks measuring 2.5m and up to 0.4m thickness have been found, but these sizes are unusual. Application is mainly the jewellery industry and to some extent it is used for production of mortars. E.S.

Hrabanek, J., Malley, J., 1988. Moldavite aus Süd-Böhmen und Süd-Mähren. (Moldavite from south Bohemia and south Moravia. *Kurzmitteilungen aus dem Institut für Edelsteinforschung*, **4**, 2, 10-11, 1 fig.

Moldavites are one of the most famous occurrences of glass in nature; they are found in southern Czechoslovakia, and have been used as tools and gemstones since prehistoric times. Archeologists date specimens from cultural layers in sites in Austria and Czechoslovakia back to 30000 BC. The bulk chemistry of more than 30 recent findings are analysed and proved to be within the usual range. Typical inclusions such as lechatelierite 'Schlieren' help to distinguish moldavites from artificial glasses, as well as distinctive Al/Na_2O+K_2O ratios. Moldavites are assumed to be derived from the Nordlinger Ries meteoritic impact, south-west Germany. The impact of a meteorite of approx. 600m in diameter subjected the surrounding rocks to shock-wave metamorphism of more than 1000 kbar and 5000°C, causing a crater of 25km in diameter. Molten material burst out of the crater, and smaller particles (so-called tektites) were thus enabled to pass a distance of several hundred kilometers; after rapid cooling during their flight they were then deposited as glass pebbles with particular surface structures. (Author's abstract) J.H.

Hughes, R.W., 1988. Brilliance, windows and extinction in gemstones. *Gemmological Digest*, **2**, 1/2, 10-15, 5 figs.

Brilliance, windows and extinction are discussed with reference to the grading of coloured gemstones. Diagrams illustrate the three concepts. M.O'D.

Kessler, P.F., 1988. Black slag, moon rock or natural glass? *Gemmological Digest*, **2**, 1/2, 15-19.

The author gives a brief survey of tektites with references to the literature. M.O'D.

Koivula, J.I., Kammerling, R.C., 1988. Gem news. *Gems and Gemology*, **24**, 2, 120-3, 8 figs in colour.

Very large floating diamond/gold dredge at Tejucana, Minas Gerais, is described and illustrated. Very efficient, but scars the land badly. A 52.59 ct emerald-cut diamond at Christie's, New York, has achieved a price of $7.48 million, $142,232 per carat, the highest so far!

Iridescent andradites are again reported from Sonora, Mexico. A 2.53 ct ruby crystal was found in North Carolina. Reports from Sri Lanka include considerable finds of ekanite [hope they are keeping this well screened]. Uranite, another radio-active mineral, also found. Orange sapphire and orange scapolite reported. Plastic imitations of malachite and lapis lazuli have been seen. Blister packs for synthetics, rather like pills, have reached the States. R.K.M.

Koivula, J.I., 1988. Remarkable dissolution in diamond. Deutschen Gemmologischen Gesellschaft, **36**, 3/4, 149-52, 2 photographs, 1 photomicrograph, line drawings.

A natural diamond crystal section containing a negative crystal cavity open to the surface was studied. A small loose diamond crystal was found trapped within the cavity; both this crystal and the inner walls of the cavity were covered with brownish-green radiation stains. No such stains were observed on surface of the host diamond. Some theories as to how this could have happened are produced. E.S.

Kozlowski, A., Metz, P., Jaramillo, H.A.E., 1988. Emeralds from Somondoco, Colombia; chemical composition, fluid inclusions and origin. *Neuves Jahrbuch für Mineralogie, Abhandlungen*, **159**, 1, 23-49, 1 map.

Emeralds from the Somondoco district have been analysed by electron microprobe colorimetry, emission spectrography, TGA and IR absorption. On the basis of 18 O, they typically show atomic substitutions: 0.13≃0.21 Al in the SiO_4 tetrahedra, 0.14≃0.40 for $\Sigma(Cr+V+Fe+Mg)$ in the AlO_6 octahedra and 0.02≃0.06 Li +0.00≃0.17 □ in the BeO_4 tetrahedra; the 'channel' alkalis, mostly Na, total 0.13≃0.29. Fluid inclusions contain liquid H_2O and CO_2, together with daughter crystals of halite and calcite(?), and liquid and gaseous hydrocarbons; homogenization T are ⩾470°C, but a rough P correction (⩽1 kbar) would add ~100°C to these values. The microprobe analyses for seven emeralds show Cr_2O_3 0.01≃0.34, V_2O_3 0.01≃0.12%. The ratio emerald : ore in the Chivor mines is 1 : 165 million, i.e. one tenth of the abundance of diamond in South African kimberlites. R.A.H.

Landmesser, M., 1988. Über den sogenannten 'Streifenchalcedon'. *Kurzmitteilungen aus dem Institut für Edelsteinforschung*, **4**, 2, 5-8, 7 figs (1 in colour).

Banded, bluish quartz aggregates have been studied by polarizing microscopy. There are distinct differences between these gemstones and agates: length-fast chalcedony is rare in these aggregates; they mainly consist of length-slow chalcedony and bigger quartz crystals. Their banding is different from the ordinary banding and Uruguay banding in agates. Some aspects of the genesis of these banded aggregates are discussed, and problems of their nomenclature are described.

(Author's abstract) M.L.

Landmesser, M., 1988. Transport und Akkumulationsmechanismen des SiO_2 in petrologischen Systemen: Achate. (Mechanisms of transport and accumulation of SiO_2 in petrological systems: agates.) *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **36**, 3/4, 101-19, 4 photographs, 3 tables, 5 graphs, bibl.

The problem of silica transport and accumulation during agate formation is discussed. A newly discovered mechanism by diffusion at low temperature is described. This is not confined to agate formation, but can be applied to other rock-forming processes such as silification of wood, formation of chert and flint and opaline materials. The conditions necessary for this process are outlined. E.S.

Lindberg, J.D., 1988. Rabb Canyon sanidine. *Lapidary Journal*, **42**, 1, 39-44, 1 fig. in colour.

Gem quality sanidine is reported from Rabb Canyon, New Mexico, USA. The location is in the Black Range in the western part of the state.

M.O'D.

Livstrand, U., 1988. Australisk Labradorit (Australit). (Australian labradorite (Australite). *Gem Bulletinen*, 1, 6-7.

Describes an Australian location for labradorite which has been undesirably named 'Australite'.

M.O'D.

McGee, E.S., 1988. Potential for diamond in kimberlites from Michigan and Montana as indicated by garnet xenocryst compositions. *Economic Geology*, **83**, 428-32, 2 figs.

Mg-and Cr-rich garnet is used in the location of kimberlites as an indicator mineral. A subset of pyrope-type composition from garnet peridotites may indicate the presence of diamond. Most peridotitic garnets are Mg-rich while those associated with diamond have sub-calcic Cr-rich compositions. In the study crystals of garnet with purple coloration were used to increase the chance of identifying subcalcic Cr-rich compositions.

M.O'D.

Mannucci, G., Gambini, E., 1987. Note sui caratteri cristallochimici di alcune imitazioni del diamante. (An investigation of some zirconia and hafnia imitations of diamond.) *La Gemmologia*, **12**, 1/4, 23-9.

Two varieties of cubic zirconia and one of cubic hafnia are identified on the grounds of their chemical composition and unit cell parameters. Hafnia constants are given as RI 2.23 and SG 9.07. M.O'D.

Meyer, H.O.A., 1987. Inclusions in diamond. *Mantle Xenoliths*, Wiley-Interscience, 501-22.

A large number of minerals occur as inclusions in diamonds, notably olivine, garnet, pyroxene, spinel and sulphides. They may be subdivided into two, major groups on the basis of chemical composition, i.e. an ultramafic suite and an eclogitic suite, and possibly a new minor calc-silicate suite. These suites reflect differences in the geochemical environment in which the host diamonds formed. The physical nature of the environment is uncertain since evidence can be cited in favour of crystallization from a partial melt (igneous) or from a solid state transformation (metamorphic). Data from various isotopic studies are at present insufficient to provide an answer to this problem, although recent isotopic investigation of inclusions has suggested that these, and by inference the host diamonds, are

Archaean in age, in spite of the kimberlite from which they were obtained being Mesozoic. The relationship of diamond to kimberlite, and probably lamproite, is one of passenger to transporting medium. In the absence of evidence to the contrary it is possible that some diamonds are the result of subduction whereas others represent primitive mantle carbon. J.M.H.

Möller, R., 1987. Establecer, dentro de lo posible, las relaciones historico-linguisticas de las denominaciones 'verde' y 'esmeralda'. (To establish as far as possible the historical-linguistic relationship between the terms 'green' and 'emerald'.) *Gemologia*, **26/27**, 73/76, 5-40, 23 figs.

The author attempts to list and discuss the terms for green and emerald in a number of major languages including Russian and Chinese. Useful lists of terms are given. M.O'D.

Möller, R., 1987. La gemologia en los sellos. (Gemmology in stamps.) *Gemologia*, **26/27**, 73/76, 41-5, 11 figs.

A brief review of gemstones appearing on stamps. M.O'D.

Möller, R., 1987. Gemoterapia. (Gem therapy.) *Gemologia*, **26/27**, 73/76, 46-58.

A review of the curative powers attributed at various times to gemstones. M.O'D.

Nassau, K., 1988. Mount Saint Helen's ashes. *Lapidary Journal*, **42**, 4, 41-2, 2 figs in colour.

Mount Saint Helen's ash from the eruption of 1980 has been found to consist of partly glassy and partly crystalline material. Particles range from over 1mm to less than 1 micrometre in size. A green glass purporting to consist of this ash and having an RI of 1.508 has been on sale in the United States; glassy material made from known specimens of the ash are black and have an RI ranging from 1.500-1.526. The green sample had an SG of 2.448 and the black 2.485. A flow test showed conclusively that the green glass could not have been made from the same material as the black glass. The green glass contained, it is thought, only 5-10% of the ash, if any. M.O'D.

Pearson, D.G., 1988. Graphitized diamonds from North Morocco? *Indiaqua*, **50**, 35-9, 21 figs (20 in colour).

During the collision of Africa with Europe a portion of the mantle was tectonically emplaced into the crust. From investigations of the Beni Bousera peridotite in northern Morocco it appears that this portion of mantle was once very rich in diamond concentration. The diamonds were altered to graphite while being transported up from the mantle and can now be found as octahedral graphite aggregates. This is a new non- volcanic type of diamond occurrence. M.O'D.

Pough, F.H., 1988. Beryl sources. *Lapidary Journal*, **41**, 10, 20-6, 4 figs in colour.

Review of the gem beryl minerals with emphasis on their mode of occurrence. M.O'D.

Pough, F.H., 1988. Allanite. *Lapidary Journal*, **42**, 1, 16-18.

Allanite is a member of the epidote group of minerals and is usually black with brownish-greenish, greyish or yellow overtones. M.O'D.

Pough, F.H., 1988. Augelite. *Lapidary Journal*, **42**, 4, 14-16.

A brief description of the aluminium phosphate augelite, which is very rarely cut as a gemstone. Details of its occurrence and formation are given. M.O'D.

Pough, F.H., 1988. An introduction to mineralogy. *Lapidary Journal*, **42**, 4, 21-34, 7 figs (1 in colour).

The introduction attempts to cover basic mineralogy for the student of gemmology. M.O'D.

Read, P., 1987. Procesos de obtención de la esmeralda sintética Lennix, de Leonard Lens. (The testing of the Lennix synthetic emerald made by Leonard Lens.) *Gemologia*, **26/27**, 73/76, 59-62.

Spanish version of an article first published in the *Gem Instrument Digest*. M.O'D.

Read, P.G., 1987. Ultra-violet spectroscopy. *Canadian Jeweller*, August 1987, 28.

Includes a description of the Krüss second-generation UV spectroscope (the UVS-2000), in which the imaged spectra are stronger and sharper as a result of more intense illumination and improved optics. Dispersion has also been increased to give an effective scale length of 50mm. (Author's abstract) P.G.R.

Read, P.G., 1987. Synthetic gem-quality diamonds. *Canadian Jeweller*, September 1987, 14.

A review of the identification techniques so far available for the detection of gem-quality synthetic diamonds (GE and Sumitomo). Techniques covered are spectral, magnetic, fluorescent, and the absence of crystalline defects revealed by high-contrast surface inspection. (Author's abstract) P.G.R.

Read, P.G., 1987. An affordable sodium light source and microscope. *Canadian Jeweller*, October 1987, 14.

Describes the new Rayner sodium lamp unit which employs a low-cost GEC lamp having an operating life in excess of 6,000 hours (compared with 200 hours for the smaller Philips lamp used in the original Rayner unit). Also described is the Hodgkinson/Morgan Zenith immersion microscope. (Author's abstract) P.G.R.

Read, P.G., 1987. Measuring refractive index. *Canadian Jeweller,* November 1987, 27.

A review of the development of the critical angle refractometer. The article also describes other methods of determining a gem's refractive index including the 'direct' method, immersion in liquids of known RI and the use of the Brewster-angle of polarization. (Author's abstract) P.G.R.

Read, P.G., 1988. Gemstone optics. *Canadian Jeweller,* February, 1988, 14.

Describes the evolution of the modern 'ideal' cut for diamond, the 'Radiant' cut improvement on the emerald-cut for diamond and the optics of the preferred cuts for coloured stones.

(Author's abstract) P.G.R.

Read, P.G., 1988. Outback sapphire and opal. *British Jeweller,* April 1988, 40-1.

Describes lesser known sapphire and opal fields in New South Wales and Queensland respectively.

(Author's abstract) P.G.R.

Read, P.G., 1988. De Beers bring out the big gems. *British Jeweller,* July 1988, 11.

Covers the announcement of the De Beers Centenary diamond and a mention of the recovery of other large diamonds from the Premier mine. Also included are details of the large Sumitomo and De Beers gem-quality synthetic diamonds.

(Author's abstract) P.G.R.

Ringsrud, R., 1988. Muzo emerald. *Lapidary Journal,* **41,** 10, 27-34, 7 figs (6 in colour).

A useful and topical account of present-day emerald mining at Muzo, Colombia. A map of the area is included. M.O'D.

Robert, D., 1988. Qu'est-ce que l'émeraldonite? (What is emeraldonite?) *Revue de Gemmologie,* 95, 19-20, 5 figs (1 in colour).

Emeraldonite is an undesirable name which has been given to a material consisting of an emerald deposit on a colourless natural beryl. A chemical analysis is given. M.O'D.

Schmetzer, K., 1987. Lamellare Einschaltungen von Diaspor in Korund. *Aufschluss,* **38,** 335-7, 3 figs.

Natural corundums usually show conchoidal fracture without natural cleavage, but can sometimes be split parallel to the positive rhombohedron $r(10\bar{1}1)$, or even parallel to the base $c(0001)$. What is much rarer and seldom mentioned in text books, is the splitting along slightly curved, not crystallographically orientated faces when only slight mechanical pressure is applied. The blue-grey corundum crystals examined come from an occurrence in Mato Grosso, Brazil; they are barrel-shaped crystals of up to 5cm long. When slight mechanical pressure is applied these macroscopically well developed crystals split easily along slightly curved faces. Along these broken faces a thin lamellar mineral with a lower RI than corundum could be observed. This was found to be diaspore. The splitting is therefore assumed to be due to lamellar diaspore, the presence of which can be traced to a retrograde metamorphism. E.S.

Schmetzer, K., Medenbach, O., 1988. Examination of three-phase inclusions in colorless, yellow and blue sapphires from Sri Lanka. *Gems & Gemology,* **24,** 2, 107-11, 3 figs (2 in colour).

Thin tabular negative cavities parallel to basal pinacoid found in 20% of 300 stones examined. Liquid and gas phases identified as CO_2, while solid phase is diaspore, a hydrated form of corundum.

R.K.M.

Schwarz, D., Hänni, H.A., Martin, F.L., Fischer, M., 1988. Die Smaragde fer Fazenda Boa Esperanca bei Taua, Ceara, Brazilien: Vorkommen und Charakteristika. (The emeralds of Fazenda Boa Esperanca, Tauá, Ceará, Brazil: occurrence and characteristics.) *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* **36,** 3/4, 134-47, 1 map, 3 diagrams, 4 tables, 10 photomicrographs, bibl.

A German version of the article published in the *Journal of Gemmology,* **21,** 3, 168-78. E.S.

Sersen, W.J., 1988. Corundum type categories. *Gemmological Digest,* **2,** 1/2, 3-9.

An attempt is made to classify the colour of rubies and sapphires to take into account the individual colour of each specimen. The attempt is made for grading rather than gemmological purposes. M.O'D.

Spencer, L.K., Dikinis, S.D., Keller, P.C., Kane, R.E., 1988. The diamond deposits of Kalimantan, Borneo. *Gems and Gemology,* **24,** 2, 67-80, 14 figs in colour.

One of the earliest known sources of diamond, Kalimantan has two main alluvial areas. Landak in the west is largely inactive, but the swamps of Banjarmasin in the south-east are now being investigated. The region is equatorial, wet and very hot, mining methods are mostly primitive, but a sampling project at Banjar Baru used sophisticated equipment. Sample pit yielded more than 1000 carats of small gem quality diamonds, 470 grams of gold and 178 grams of platinum. Diamonds are cut locally at Martapura. 15% of stones are one carat or more, mostly white or yellowish with some fancy colours. Almost no bort. Hoped that Indonesia can become a small but consistent producer of high quality diamonds. R.K.M.

STOCKTON, C.M., 1988. Pastel pyropes. *Gems & Gemology*, **24**, 2, 104-6, 2 figs in colour.

Pure pyrope is colourless and very rare, but has been found in Western Alps. Pastel shades of orange, or pink, are being found in parcels from East Africa. Low RI, between 1.734 (colourless grossularite) and 1.714 (colourless pyrope), identifies. [Confusion might occur with some spinels?] R.K.M.

THEMELIS, T., 1988. Intersecting folds in hydrothermal emerald. *Lapidary Journal*, **42**, 4, 19, 1 fig. in colour.

A fold-like effect can be seen in some hydrothermally produced emerald; these growth phenomena can best be seen by dark-field illumination. M.O'D.

ZEITNER, J.C., 1988. The Proctor beryls. *Lapidary Journal*, **41**, 10, 42-7, 4 figs in colour.

The Keith Proctor collection of fine minerals contains many items of gem quality. The article describes a selection of beryl crystals displayed at the 1988 Tucson Mineral and Gem Show. M.O'D.

ZEITNER, J.C., 1988. Louisiana's agatized palm. 42, 4, 43-6, 2 figs in colour.

Agatized palm wood, the state fossil of Louisiana, is fashioned into ornaments. It has a fine-grained texture and is hard enough to take an adequate polish. M.O'D.

ZWAAN, P.C., 1987. Orthopyroxene from the Embilipitya area in Sri Lanka. *Schweizerische Mineralogische und Petrographische Mitteilungen*, **67**, 119-25, 5 figs.

Colourless to deep brown orthypyroxenes with colourless specimens having RI 1.650, SG 3.194, are described from the Embilipitya area of Sri Lanka. All have a strong absorption band at 506nm. The intensity of the band deepens with the depth of the brownish colour though even colourless specimens show the band. M.O'D.

Book Reviews

BLAKEMORE, KENNETH, 1988. *The retail jeweller's guide*. 5th edn. Butterworths, London. pp 412. 166 black-and-white illus. £30.00.

This is the latest book in a long line that started with *The retail jeweller's handbook* by Selwyn in 1945. The seven editions of the *Handbook*, followed by five of the *Guide* have all attempted to cover the full range of goods dealt in by the retail jeweller.

Following this tradition, the current edition has been expanded to include chapters on glass and pottery; products increasingly handled by the modern jeweller. This material has been condensed from the same author's *A retailer's guide to glass and pottery*, which is unlikely to be reprinted.

Other chapters deal with precious metals, gemstones, silverware, boxes, jewellery and its manufacture, hallmarking, and clocks and watches. There are also five glossaries and five appendices. The book ends with a comprehensive index.

The gemstone section has additional material on modern synthetics and methods of enhancement. This chapter, although seeming somewhat compressed to a gemmologist, nevertheless contains an amazing amount of information. It is, however, unfortunate that of the two books recommended by further reading, one is *Gemstones for everyman* by B.W. Anderson. This has been out of print for many years, and is extremely scarce.

The hallmarking chapter has also been expanded to include details of the regulations concerning mixed metals (there is some confusion here between the 1975 and the 1986 amendments) and of international marks.

The author, who has been Editor of the *Watchmaker, Jeweller and Silversmith* since 1947, is to be congratulated on this excellent book that cannot be too highly recommended to anyone connected with the jewellery trade. Gemmologists not in the retail trade should consider it as essential reading. It will enable them to gain some knowledge of the many various sides to the modern jeweller's business, helping them to appreciate that gemstones are only a part (albeit a vital part) of that business. N.B.I.

Culme, J., Rayner, N., 1987. *The jewels of the Duchess of Windsor.* Thames & Hudson in association with Sotheby's, London. pp.224. Illus. in black-and-white and in colour. £30.00.

The sale of the personal jewellery of the late Duchess of Windsor in April 1987 attracted a level of publicity rarely given to jewellery and gemstones. Though it has been said by many that some of the pieces were not particularly important from the standpoint of the jewellery historian, they are still of high quality and the stones they contain are often large and beautiful.

Readers who have the sale catalogue itself should get this book too as it contains additional biographical material and a list of the prices paid for each item as well as all the pictures and descriptions used for the sale. M.O'D.

Hoskin, J., Lapin, L., 1987. *The Siamese ruby.* World Jewels Trade Centre, Bangkok. pp.119. Illus. in colour. US$27.00.

This is a very attractively produced book designed to raise the image and status of the Siam ruby with the trade and the general public. The ruby is introduced as a gemstone with some gemmological detail and there are sensible notes on the vexed topic of colour and clarity alteration. A good deal of information is given in what is quite a small book – present- day marketing is described and illustrated with scenes of dealing. Other photographs show Bangkok and Chantaburi street scenes but those which really catch the eye are those depicting the stones themselves. Most appear to be of Burmese quality at least.

The book was published to commemorate the 60th birthday of His Majesty the King of Thailand and it deserves to be widely purchased. M.O'D.

Krashes, L.S., 1986. *Harry Winston, the ultimate jeweller. 2nd revised edn.* Harry Winston, Inc., New York, and GIA, Santa Monica. pp. xiii, 218. Illus. in colour. £50.00.

Perhaps the most unusual picture in the book is that of Harry Winston himself who was said to be wary of publicity! The book contains an account of both the man and the firm with particular emphasis on his glittering clientèle and even more on the jewels and individual stones that he created and handled. The central section of the book describes and illustrates some of the most celebrated stones Winston created (mostly by re-cutting) with notes on their previous history. The standard of the illustrations is very high indeed and I was pleased to see the occasional painting as well as photographs. There is a short bibliography.

This is not a cheap book but of very high quality. M.O'D.

Liddicoat, R.T., 1987. *Handbook of gem identification.* 12th edn. GIA, Santa Monica. pp.362. Illus. in colour. £25.00.

This new edition of a famous old classic breaks new ground. The text, though arranged in the same sections as in previous editions, has been entirely re-set and the illustrations are all in colour. As before, after some introductory matter on gem testing in general, the bulk of the text deals with gemstones in chapters each covering a different colour. Many species are illustrated as are a number of the more important inclusions. The standard of the reproduction is high and the book concludes with a set of identification tables. Not many of the really rare species are omitted though I failed to find clinohumite. But such a search is expected of a reviewer and it is more interesting to look at the book as a whole and, of course, to compare it with *Gem testing*.

The *Handbook* is clearly aimed at the integrated residential gem testing classes so well run by the GIA; *Gem testing* constantly wanders from the point under discussion to refer to some aspect of mineralogy in general – this distinction seems to me to reflect in a rather pleasing way the most valuable and productive differences between the two approaches to gem testing. Readers of this review should already have *Gem testing* and should get the *Handbook* as soon as possible. Two small criticisms, one more important than the other. There is no bibliography (this is the more serious criticism); from a distance the dust jacket with the genial face of the author upon it rather resembles a Slavonic political or historical work. M.O'D.

Marcum, D., 1986. *Dow Jones-Irwin guide to fine gems and jewellery.* Dow Jones-Irwin, Homewood, Illinois. pp. xxii, 213. Illus. in colour. US$25.00.

There are many books on gemstones aimed at the potential investor and as Western economies recover and consumer confidence surges it is not surprising that the genre is gaining new members. This is quite a good example of its kind with most of the gemstone information quite accurate and including interesting data on price rises and maintenance (there are few recorded falls). At the price this is worth buying if you want a quick insight into the commerce of gemstones. M.O'D.

MORRILL, P., 1981. *Maine mines and minerals*. 2nd part. Winthrop Mineral Shop, Winthrop, MA 04343. US$18.00.

This is a useful guide for the field collector, giving alphabetical lists of locations followed by mineral lists. There are several maps and directions are given to most places, together with occasional references to the literature in outstanding examples. M.O'D.

MÜLLER, G., 1988. *Convection and inhomogeneities in crystal growth from the melt*. Springer Verlag, Berlin. pp.138. Illus. in black-and- white. DM128.00.

The text of this book is based on a German original published in 1986 but incorporates a number of emendations and additions. It forms volume 12 of the series *Crystals, growth, properties and applications* which has provided a very large amount of useful information over the years. It is also worth noting that this volume contains an author index for vols. 1-12. The crystals described are mainly those of semiconductor materials but the techniques of growth and characterization are well worth getting to know by anyone with an interest in the crystalline state.

The book begins with a discussion of fundamentals of process modelling for semiconductor crystal growth and then devotes a number of chapters to the topic of inhomogeneity and how it can be detected and avoided. There is a good bibliography and a list of symbols. M.O'D.

RAMSEY, J.L., RAMSEY, L.J., 1985. *The collector/investor handbook of gems*. Boa Vista Press, San Diego, California. pp.300. Illus. in colour. $16.95.

An interesting book giving a full if idiosyncratic account of world economic trends as they have affected and might affect the gemstone investment trade. There are also extensive notes, accurate for the most part, on individual gem species, courses of instruction and hints to buyers. It is reasonably priced and gives a good insight into contemporary thinking on this often vexed topic. M.O'D.

SEIM, R., 1981. *Minerale*. (Minerals.) GLB, Köln. pp. 408. Illus. in black-and-white and in colour. DM19.80.

This is a well-produced general guide to minerals, some of which are illustrated in colour in a central section. Each species has been chosen with European localities in mind and many have crystal diagrams. There is a short section on the gem minerals and on the history and properties of the chemical elements. The locality information is valuable and the book is completed by a short bibliography. M.O'D.

SHUVALOV, L.A., 1988. *Modern crystallography IV*. Springer, Berlin. pp. xviii, 583. Illus. in black-and-white. DM198.00.

With this volume, which carries the subtitle *Physical properties of crystals*, the set *Modern crystallography* comes to a distinguished conclusion. The translation from the Russian is very effective (the original work is entitled *Sovremennaja kristallografija*). The book opens with a discussion of the fundamentals of tensor and symmetry description of the physical properties of crystals and continues with the mechanical properties of crystals. Then come sections on the electrical and magnetic properties of crystals.

The next chapter, on semiconductors, gives a very useful introduction to metals, semiconductors and insulators, but many readers will turn first to the next chapter but one which deals with the optical properties of crystals. Many familiar concepts will be found concisely explained and I recommend readers who can get hold of the book to study this section. The final chapter covers liquid crystals and is followed by an extensive reference section. M.O'D.

SOPWITH, T., 1984. *An account of the mining district of Alston Moor, Weardale and Teesdale*. Davis Books, Newcastle-upon-Tyne. pp. viii, 183. Illus. in black-and-white. Price on application.

This is a reprint of the book first published in 1833. It describes in a fairly scientific and gossipy way the lead mining districts of the north-east of England which extend over approximately 400 square miles. Included in this area are a great number of mineral-producing sites, including some which gave the world's finest fluorite. I warmly recommend this book (which is in a larger format than the original) to all those with an interest in field work. M.O'D.

STOWE, C.W., 1987. *Evolution of chromium ore fields*. Van Nostrand Reinhold, New York. pp. xii, 340. Illus. in black-and-white. $40.80.

The book contains a series of papers on the development of chromium minerals and of other minerals in which chromium acts as a replacement element. This is a useful work for anyone interested in the way in which chromium is formed and how it behaves. Each chapter has its own references.

M.O'D.

VERE, A.W., 1988. *Crystal growth.* Plenum, London and New York. pp. xiii, 258. Illus. in black-and-white. US$47.00.

This book will be found useful at several levels. It gives an always welcome state-of-the-art report and provides a large section of abstracts on seminal topics – a feature I have not previously encountered in the crystal growth field. The book forms part of the series *Updates in applied physics and electrical technology* and after a general introduction goes on to describe transport, nucleation and growth, growth from the liquid phase, vapour phase epitaxy, current trends in crystal growth, an extensive set of references and the abstract section which extends to over 100 pages.

Readers interested in the growth of ornamental materials will find a good deal to interest them.

M.O'D.

WHARTON-TIGAR, E., 1987. *Burning bright: the autobiography of Edward Wharton-Tigar.* Metal Bulletin Books, London. pp. vii, 280. Illus. in black-and-white. Price on application.

The subject of this adventure has been connected with mining for most of his life and the story reads like an Edwardian or Victorian boys' yarn. Mr Wharton-Tigar was for some time the thorn in the side of the Central Selling Organization (of diamonds) and began his mining career at the classic Yugoslavian lead-zinc mine of Trepca. After a colourful career in the war he became involved in the production of diamonds from West Africa and with their introduction to world markets. It was due to the prices paid for his goods by the CSO that he began to challenge their policies and price manipulation. At one time he challenged the Oppenheimers personally. This is a most interesting account of how part of the CSO worked at one period. The whole book is clearly written and the central character engagingly drawn. M.O'D.

Achat – Das farbige Geheimnis. (Agate – the colourful secret.) Münchener Mineralientage Fachmesse GmbH, West Germany, 1987. pp. 96. Illus. in black- and-white and in colour. Price on application.

Published by Münchener Mineralientage Fachmesse GmbH on the occasion of their special exhibition 'Idar-Oberstein as guest'. Many beautiful colour photographs as well as numerous black-and-white ones, a number of reproductions of historical prints and photographs. The booklet deals with many aspects of the stone: its geology, with many occurrences detailed; how agates are worked, with special emphasis on and local history of the Idar mills; and various types of agate are discussed. E.S.

Crystals, growth, properties and applications. Vol. 11. Springer, Berlin, 1988. pp. 196. Illus. in black-and-white. DM168.

This volume is devoted to superhard materials, convection and optical devices. The three major papers are 'Shock- induced growth of superhard materials', 'Surface- tension-driven flow in crystal growth melts' and 'Electrooptical effects, crystals and devices'. The first paper, recognizing that the growth of diamond is expensive and that diamond tends to react with oxygen at much lower temperatures than boron nitride, discusses the growth of the latter material. Diamond's other tendency, to form carbides at elevated temperatures with transition metals, is also less of a problem when BN is substituted. The first synthesis of diamond by the shock wave method was carried out in 1961; Alder and Christian subjected compressed graphite powder to shock pressures of about 30GPa (300kbar) and a few per cent of the graphite were converted to very fine grained cubic diamond.

The paper on electrooptical crystals discusses lithium niobate, tetragonal bronzes, perovskites, KDP and semiconductors with sphalerite structure. Recent progress in device fabrication is reviewed, including bulk modulators, deflectors and lumped and travelling wave modulators made from wave guides. Electrooptic bistability and the photorefractive effect (the basis of holographic storage) are also discussed. Both papers have extensive lists of references and contain much useful data on transparent crystals of ornamental dimensions.

M.O'D.

Musée Cartier. London, 1988. pp.95. Illus. in black-and-white and in colour. Price on application.

Catalogue of an exhibition held in London during June 1988. The text and illustrations are taken largely from Nadelhoffer *Cartier – jewellers extraordinary**, Thames and Hudson, London 1984.

M.O'D.

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*Reviewed in *Journal of Gemmology*, **XIX**, 8, 734. – Ed.

Proceedings of the Gemmological Association of Great Britain and Association Notices

OBITUARY

Mr Neville Deane, FGA (D.1954, Tully Medallist), Bewdley, died on 1 March 1987.

After a very unpromising childhood, being an orphan with severe deafness which was not diagnosed until his early teens, he rapidly gained qualifications in metallurgy and analytical chemistry.

He joined the Institution of Metallurgists as one of its earliest members in 1946 and was elected to the grade of Fellow in 1959. His earliest experience was as Junior Chemist to the Patent Shaft & Axletree Co., Wednesbury (1915-1917), and Works Chemist to J. & J. Siddons, Ironfounders, West Bromwich (1917-1919). In 1919 he was appointed Works Chemist to the Incandescent Heat Co., Smethwick, and remained there until 1923 when he set up his own business, principally concerned with aluminium and gun metal castings, and also as a consulting chemist and metallurgist.

After 1941 he was involved mainly with consulting work, and began to develop an increasing interest in gemmology and lapidary work, taking up serious study of this subject as a student under R. Keith Mitchell. He was one of the few students of gemmology who gained the Rayner Prize for first year work (1953) and the Tully Metal and the Rayner Diploma Prize (1954).

I first made contact with Neville through his metallurgical work, when we exchanged a few letters dealing with a problem just after the War, little knowing that we both were to meet several years later with an entirely different mutual interest.

After gaining my Diploma in the Association's examinations and being primarily interested in lapidary work, I was advised by the late Sid Tisdall to try to meet a fellow named Neville Deane, who at that time had a reputation for being very blunt and difficult to deal with. Having had earlier contact with Neville I had no such problems and found him a friendly and kind fellow, much in need of someone with whom to discuss his interests since he had only recently lost his wife.

He had a well equipped workshop for gem cutting and general lapidary work, and was a pioneer amateur and semi- professional cutter. Almost all of his information on this subject was American based, and he was an expert in the use of the Willems Dop for faceting. He willingly passed on information on his methods, and had much patience with struggling amateurs.

His great pride was in showing his 'bragging pieces' as he called them. These were large, faceted, colourless topaz stones of various design, including the famous Portuguese cut, and the notoriously difficult Varna star. The time spent with him went all too quickly – if he decided he had had enough he would switch off his hearing aid!

His other skill was in gardening, and he delighted in supplying flowers for his church. During the latter part of his life his Christadelphian fellow church members gave him much help and support, as he had no surviving relatives and he and his wife Nellie had had no family.

While he was still able, he attended most of the meetings of the Midlands Branch of the Gemmological Association and his blunt comments given in his strong 'Black Country' accent will be remembered by us for many years. A.D. Morgan

Mlle Dina Level, Hon. FGA, died at the age of 85 in a nursing home at Nimes in the south of France. She had been living there for the past few years; although no longer able to write, she continued to enjoy reading.

Dina Level is world renowned as a practical gemmologist, having spent a lifetime at the Paris Chamber of Commerce Laboratory. She started there under the direction fo Georges Göbel and upon his retirement there followed a period of co-operation and accord with the present director, J.P. Poirot. A dexterous exponent of the endoscope, she had, above all, a love of and an enthusiasm for the hidden subtler beauties of gemstones. Intrinsic beauty rather than monetary worth mattered most to Dina Level. Although she had at times the privilege of entrée to the treasures of the Louvre Museum, she could nevertheless steep herself in the delicate fronds of moss agates, the convolutions of banded agates and the softer charms reflected by the flame structures of pink pearls.

She was an Honorary Fellow of the Gemmological Association of Great Britain. In her own country she was awarded the Gold Medal of Industry in recognition of her work at the Paris Laboratory. Those who were privileged to listen to her lectures at international conferences will remember the enthusiasm she projected for her subject. She contributed many articles for the *Revue de Gemmologie*, the French equivalent of our *Journal of Gemmology*. She wrote in a manner which combined a poetic touch with a gemmological approach almost of intimacy with the gems she was describing.

An anglophile with a considerable knowledge of our history, she was nevertheless a truly gallic personality, diminutive in stature but a giant in her world of gemmology. France has lost a truly great lady, we too share in that loss *Loin les yeux mais non loin du coeur.* A.E. Farn

GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to the following for their gifts:

Mr A.G. Flewelling, FGA, Ontario, Canada, for a large quantity of rough sapphire from the USA and Australia. The samples will be used for study purposes.

Mr M.G. Pickford of the Laboratory of Molecular Biophysics for an SP500 Unicam Spectrophotometer which will remain at the Association until it may be put to good use either at a university or a laboratory.

Dr Yan Weixuan of the China University of Geosciences, Wuham, China, for two books entitled *Chinese arts and crafts* and *Xinjiang's gems and jades.*

NEWS OF FELLOWS

On 30 January 1988 Mr Peter Read was invited to give the Doug Page Memorial Lecture following the AGM of the Brisbane Branch of the Gemmological Association of Australia. The subject of the lecture was 'Cumputer-aided gem identification' and included a demonstration of Peter Read's GEMDATA computer program and the use of his GEMSTORE program contained in a miniature pocket-sized computer.

On 14, 22 and 23 June 1988 Mr Michael O'Donoghue, with Messrs Peter Read and Roy Huddlestone, gave two courses on behalf of Precious Stone Trading Services Ltd for preliminary and diploma students entering for the Association's examinations.

On 8 to 11 July 1988 Mr Michael O'Donoghue participated in a field study of some aspects of the mineralization of the northern Pennine orefield.

Following the series 'Gemmologia Europa I' in Milan in the autumn of 1986, when E. Alan Jobbins was invited to lecture, a second series 'Gemmologia Europa II' was arranged to present the theme of 'Treasures of the World'. This series commenced on 19 September 1988 when a lecture/video film on 'The British Crown Jewels' was presented by Dr Roger Harding, Alan Jobbins and Kenneth Scarratt. This lecture series was conceived by Dr Margherita Superchi of CISGEM (Centro Informazione e Servizi Gemmologici) under the aegis of the Chamber of Commerce, Industry, Handicraft and Agriculture of Milan (Camera di Commercio, Industria, Artigianato e Agricultura di Milano). The presentation in the series by Dr Superchi described the 'Treasures of Milan Cathedral' which includes the magnificent XVII century Airoldi chalice of Sicilian workmanship; it is illustrated on the front cover of this issue.

MEMBERS' MEETINGS

London

On 10 October 1988 at the Flett Theatre, Geological Museum, Exhibition Road, South Kensington, London SW7, Mr Clive R. Burch, Senior Lecturer in Gemmology and Geology at the Sunderland Polytechnic, gave an illustrated presentation entitled 'A review of inclusions in synthetic gemstones'.

Midlands Branch

On 16 September 1988 at Dr Johnson House, Bull Street, Birmingham, Mr David Wilkins gave an illustrated talk on the *Retail Jeweller's* study tour to the African sub-continent. He gave accounts of arduous trips to various mining operations.

North West Branch

On 21 September 1988 at Church House, Hanover Street, Liverpool, Mr Stanley Hill, FGA, gave a talk on jewellery design. Mrs Valerie Duke was also present and members were able to view various Brazilian gemstones that she had brought along.

EXECUTIVE MEETING

At a meeting of the Executive Committee held on 31 August 1988 at Saint Dunstan's House, Carey Lane, London EC2V 8AB, the business transacted included the election to membership of the following:

Fellowship

Baker, Sylvia V.J., Seoul, Korea. 1987
Marazzi, Roberto, Lugano, Switzerland. 1986
Ng, Li N., Penang, Malaysia. 1986

Ordinary Membership

Ashby, Steward M., Floyds Knobs, Ind., USA.
Bernadotte, Charlotte, Stockholm, Sweden.
Carrott, C.I.C., London.
Cho, Ki S., Seoul, Korea.
Cohen, Stanley P., Fort Worth, Tex., USA.
Combotis, Marianna, Athens, Greece.
Daly, John H., Glasgow.
D'Alessandro, Martha A., Houston, Tex., USA.
Dowdell, Jonathan, Hampton.
Flett, Robert S., London.
Fong, Chan K., East Molesey.
Galopim de Carvalho, Rui, Lisbon, Portugal.
Gunawardane, Leonard, Colombo, Sri Lanka.
Gupta, Ashwani, Slough.
Hagemann, Claus, Eunepetal, West Germany.
Harrison-Smith, Rosemary A., Benfleet.
Kaufman, Bradley S., Moweaqua, Ill., USA.
Khalil, Julie A., Bristol.
Mason, Susan E., Nottingham.
Matthews, Pauline, Cottesloe, Western Australia.
Pettit, Brian B., Cambridge.
Pring, Amanda L., Birmingham.
Rawat, Mohamed S., London.
Sirio, Alfonso, Madrid, Spain.
Siviter, David J., Worcester.
Stimler, Harvey J., London.
Sundin, Conny S.I., Solleftea, Sweden.
Tayara, Mona D., Athens, Greece.
Thomson, Sybelle M.F., Edinburgh.
Towns, Geraldine A., Naperville, Ill., USA.
Wainwright-Sundin, Manuela, Solleftea, Sweden.
Warrington, David, Queensland, Australia.
Weldon, Martin, Dublin, Eire.
Willis, Gaynor E., Austin, Tex., USA.
Wood-Cordilia, Ilse J., Farnborough.

COUNCIL MEETING

At a meeting of the Council held on 13 September 1988 at the Royal Automobile Club, Pall Mall, London SW1, the business transacted included the following: (1) the subscription rate for 1989 for Fellows and Ordinary members was increased to £30 for UK members and $80 for those overseas. (2) the following were elected to membership:

Fellowship

Bramham, Kathleen J., London. 1988

Ordinary Membership

Blacoe, James B., Athlone.
Kitchen, Peter J., Lusaka, Zambia.

CORRIGENDA

On p.43 above, second column, 2nd line, for 'cross- filter method of' read 'cross-filter method to'

On p.181 above, second column, Fig. 9, the photomicrograph has been printed upside down

Letter to the Editor

From R. Keith Mitchell, FGA

Dear Sir,

I wonder how many gemmologists have noticed the quite extraordinary optics attributed by TV and Press Advertising to the well-known prism shaped Toblerone chocolate made by the Swiss firm of Chocolat Tobler.

This remarkable sweet is apparently made in three differently coloured types [does that make it trichroic?] which are, of course, no less opaque than any of their competitors, and are depicted refracting light away from the normal and bending red wavelengths more than violet ones.

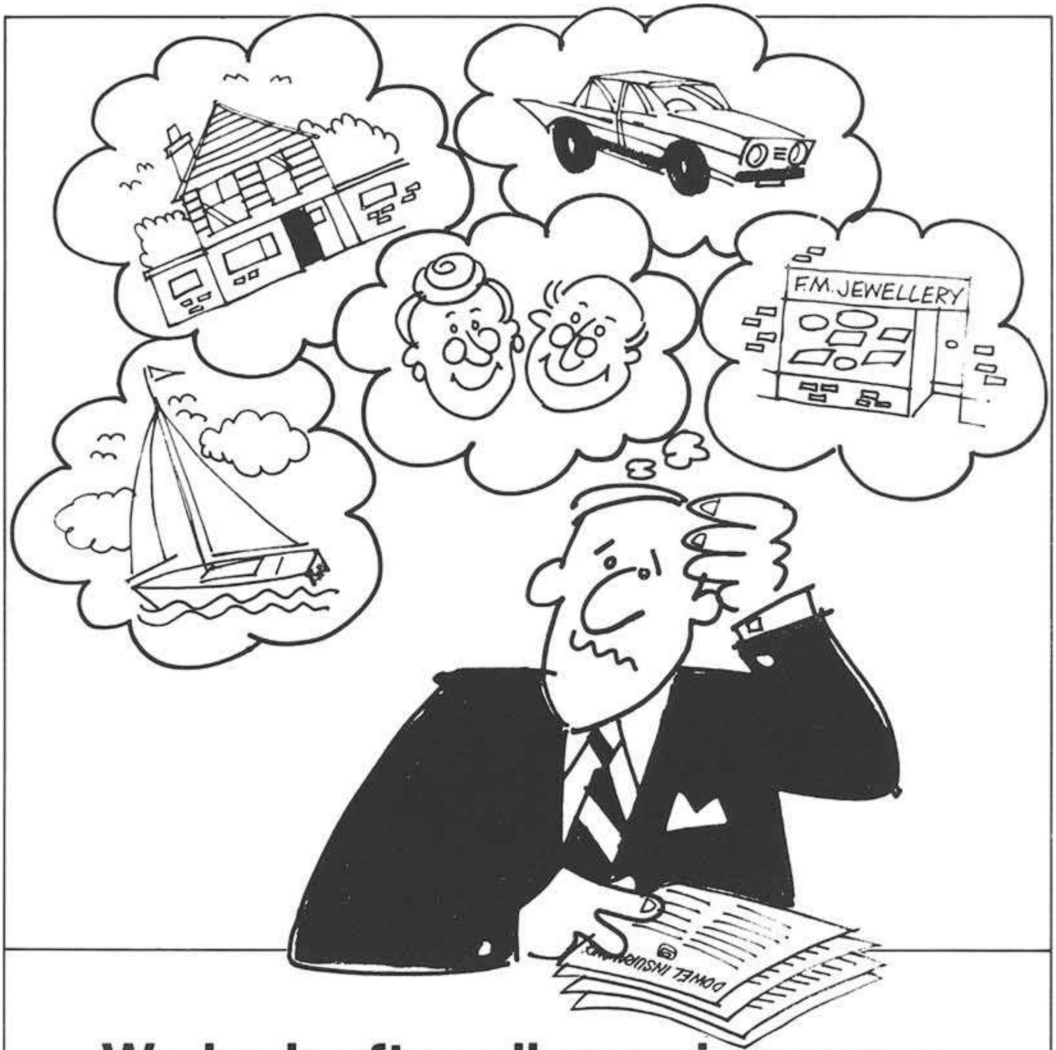
The three chocolate packs are shown reflecting in a polished surface, but the remarkable spectrum does not reflect! Can it therefore be assumed that this spectrum is not only entirely contrary to normal optics, but that it is also plane polarized?

Dare one ask what such an advertisement is supposed to convey to the sweet-eating public?

It is perhaps worth noting that the chocolate contains NUTS! Which could possibly explain everything!

Yours etc.,
R. Keith Mitchell

30 August 1988
21 Bark Hart Road, Orpington, Kent BR6 0QB.


F.M. JEWELLERY

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The Editors of the *Journal* invite advertisements from gemstone and mineral dealers, scientific instrument makers, publishers and others with interests in the gemmological, mineralogical, lapidary and jewellery fields.

Rates per insertion, excluding VAT, are as follows:

Whole page	£180
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Saint Dunstan's House,
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GEMDATA

A computer program for gem identification

The GEMDATA Package by Peter Read (see p.221 for full details) is available through the Gemmological Association at £75.00 plus postage, packing and VAT* (*UK only at £11.25). Postal rates are as follows: £3.50, UK and Eire; £4.00, Europe; £6.00 rest of the world.

To order your Package use the form below.

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Signature .... Date ....

*Delete as applicable

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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.

Volume 21 No. 4. October 1988

The Journal of
Gemmology

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Registered Office: Saint Dunstan's House, Carey Lane, London EC2V 8AB

ISSN: 022-1252

Produced by Green Belt Studios: Printed by Quadrant Offset, Hertford, England.