ISSN: 0022-1252 XIX (4) 293-388 (1984)

Vol. XIX No. 4 October, 1984

THE JOURNAL OF GEMMOLOGY

and

PROCEEDINGS OF THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

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Vol. XIX No. 4 **October 1984**

GLASS INFILLING OF CAVITIES IN NATURAL RUBY

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Towards the end of April 1984, a rounded triangular-shaped ruby weighing 8.84 cts was brought into the L.C.C.I. Laboratory by a dealer, who having purchased it in Bangkok had since become worried that it had been treated in some way. He was particularly disturbed about a large area on the pavilion of the stone which contained bubbles visible to the naked eye and then recalled that while in Bangkok he had heard that a new process was being used to infill unsightly cavities in natural rubies. The laboratory examination confirmed that an unnatural substance filled what was once a very large open cavity on the pavilion of an otherwise perfectly natural ruby.

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ISSN: 0022-1252 XIX (4) 293 (1984)

In this instance the dealer was satisfied with the knowledge that the stone had indeed been 'treated' and was not concerned with a positive identification of the type of artificial substance used as the infill. We were, however, in the time permitted, able to establish that the infill had a hardness of less than 6 and a refractive index of 1.512. We were also able to observe a weak greenish fluorescence given off by the infill when the stone was placed under short wave ultraviolet light.

The size of the stone and the extent of the infill material suggested that the first observation to be made during an appraisal would involve the infilled cavity. This being so, it is very unlikely that it would ever be sold for anything more than it was—a treated ruby. What was slightly disturbing to us was the thought of the same process being used on smaller stones with proportionally smaller cavities—especially if the substance was bubble free.

It was not long before our fears were justified. Less than four weeks after our first encounter, one of the participants in a gem identification course being held at the L.C.C.I. Laboratory brought with him two rubies which his firm had recently purchased in Bangkok. Both stones weighed between one and two carats, and when examined on the microscope both were found to have a number of 'infilled cavities' in the pavilion and girdle areas. One of the stones contained three infilled cavities, and in two of these there were bubbles present, but the third was bubble free. In the second stone the infilled cavities were all free of bubbles. It was also noted that a cavity in one of the stones had been left unfilled in its natural state.

Fortunately the owner of the two latter stones was not in a hurry to have one of them returned and as a result (although we were still not allowed to carry out destructive testing) we were able to carry out microprobe analyses of the ruby itself and of the infill material.

The stone analysed weighs 1.21 ct and is an oval modified brilliant/mixed cut. There are two infilled cavities near the culet, but the third and largest lies just below the girdle midway along one long edge of the oval. The latter (see Figure 1) was chosen for analysis because it is the largest and shows a clear junction between the infill material and the host ruby in the middle of a facet. Three analyses of the ruby and five of the infill material were made and the means are given in Table 1.

TABLE 1. Electron microprobe analyses of ruby and infill material

wt%	1	2
SiO_2	<0.2	59.0
Al_2O_3	98.4	28.4
Fe_2O_3	0.5	—
FeO	—	0.7
MgO	<0.2	0.5
Na_2O	<0.2	2.6
K_2O	<0.2	5.4
Cr_2O_3	0.5	<0.2
Total	99.4	96.6

Notes. A Geoscan electron microprobe with Link Systems energy-dispersive attachment and data handling program were used, with an accelerating voltage of 15 kV, a specimen current of 5×10^{-9} amps and an electron beam focused to approximately 5 μm. Elements of atomic number 11 (Na and above) can be measured by this method and the limit of detection for each of the oxides is about 0.2 wt%. Total iron was assigned to Fe_2O_3 in corundum, and to FeO in the infill material.
1. Mean of 3 analyses of ruby. 2. Mean of 5 analyses of infill material.

Although only a small area of the ruby proper was sampled, the three analyses indicate that there was some variation in the minor contents of iron and chromium. The Fe_2O_3 values range from 0.3% to 0.6% and those for Cr_2O_3 from 0.4-0.6%. No other minor elements, with atomic number greater than 11, were detected above the 0.2 wt% level.

Again, although the infill material is small in volume its composition is very consistent. It was found to be essentially an alkali alumino-silicate glass with minor amounts of iron, magnesium and possibly other elements of low atomic number. The low total of about 97% indicates that up to 3% of H_2O, Li_2O or B_2O_3 may be present. Glasses of this composition are generally very viscous and this is consistent with the presence of bubbles in two of the infilled areas.

This new form of ruby treatment may be overlooked quite easily if, firstly, the stones examined are small (*c.* 1.00 ct), and,

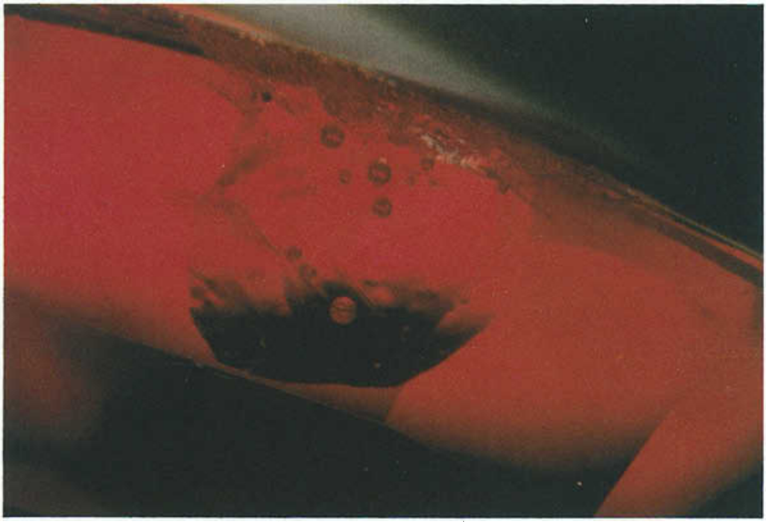

FIG. 1. A cavity in a natural ruby infilled with a glass. Transmitted light.

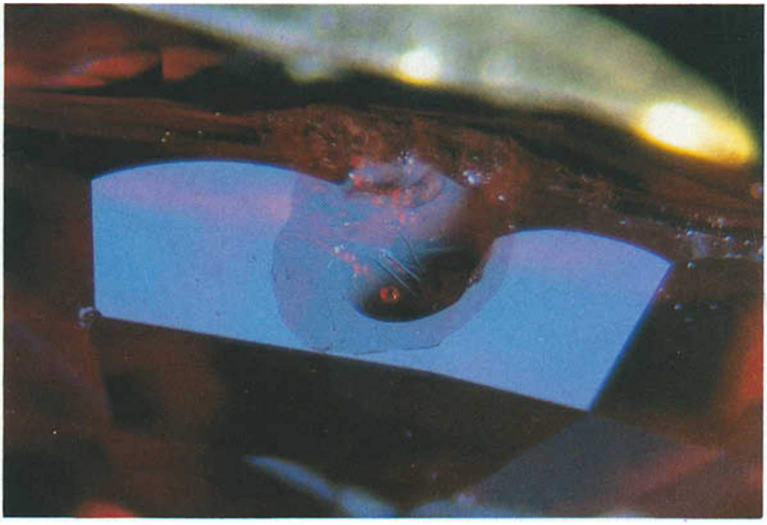

FIG. 2. The same infilled cavity as that in Fig. 1 seen in this case in reflected light. Note the change in lustre between the ruby and the glass.

secondly, if the glass infill is bubble free. When examining rubies it is now recommended that the surface of the stone is examined in reflected light and any changes in lustre (see Figure 2) similar to those seen between the garnet top and glass base of a garnet topped doublet, noted. If seen, then these areas of poor lustre should be more closely examined for evidence of cavity infilling.

[*Manuscript received 23rd June, 1984.*]

CONTRIBUTION TOWARDS THE IDENTIFICATION OF TREATED CORUNDUMS: HEAT AND DIFFUSION TREATED RUBIES

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ABSTRACT

Heat and diffusion treatment of rubies are detailed. Even though their identity in certain instances, particularly in heat treatment only, cannot be disclosed to the trade, the aspects mentioned are of useful aid in separations. The dangers of such treatments are discussed. Methods employed in Thailand and Sri Lanka in this connexion are given. Detections of treated rubies by gemmological methods are detailed.

INTRODUCTION

Processes of artificial coloration of corundum varieties have taken a primary position among various improvement operations. The latest to be discussed in this respect is the diffusion treatment of rubies. Following the successful coloration of light blue sapphires from Sri Lanka and lightening of the dark blue of Australian sapphires, the pioneers of 'cooking' corundums, the Thais, operate another heating system on their rubies, and the process has taken a noteworthy position at present.

During a recent visit to the famous gemfield in Thailand, Chantanburi, the author was shown by some dealers how the rubies are subjected to treatment and various steps of the operation. The same practice is also carried out in Sri Lanka today, much more sophisticatedly than previously. Another, recent introduction gaining interest in the trade is the diffusion-treated ruby. Series of research done in this connexion in identifying heat or diffusion treated rubies are detailed.

Under high temperature inducements the colour of blue sapphire is improved and is known to the trade. The technical and gemmological aspects of blue sapphire treatments were described by Jobbins (1971), Harder (1980), Sasaki (1980), Tombs (1980), Nassau (1981), Crowningshield & Nassau (1981), Hänni (1982 a & b) and Gübelin (1982). Further, colour improvement of yellow sapphire and its colour instability were detailed by Schiffman (1981), Schmetzer *et al.* (1982) and Keller (1982). However, only

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very little was mentioned of colour enhancement of ruby (Hänni, 1982 b; Abraham, 1982 and Ohguchi, 1982) during these analytical procedures. Nowadays, the subject is often encountered in identification certificates issued by various gemmological laboratories. Among these two treatment procedures the diffusion treatment needs to be disclosed to the customer according to the rules introduced by the C.I.B.J.O. Coloured Gemstone Commission (1981) here in Europe and the proposals made by Federal Trade Commission Guides for the Jewellery Industry (1981) in U.S.A. Heat treatment, however, does not require disclosure if the detection cannot be made by a gemmological laboratory.

HEAT TREATMENT OF RUBIES

In Thailand the rubies are discovered in an iron-rich basaltic terrain, and the colour is influenced by iron giving a dark brownish-violet hue to the stone. According to the process described by Nassau (1981) the colour can be improved by converting the Fe^{2+} to Fe^{3+} after heating in an oxidizing atmosphere at a temperature between 1000 °C and 1700 °C for many hours. In this conversion ($4FeO + O_2 \rightarrow 2Fe_2O_3$) the darker hue is removed and the stone appears lighter red in colour.

Modern methods are used by Thais in their long noted experiences on the subject. As the first step, suitable stones, with less cracks and fissures, are selected. Rubies with heavy cracks are trimmed by the cutters. Any water concentration within cracks is allowed to evaporate on a preliminary heating process where the material is kept on heated iron trays. The corundums are afterwards packed into a crucible filled with alumina powder (Figure 1). Many of these crucibles, often in different sizes, are then introduced to the main heat treatment utilizing modern ovens. The author was informed by some experienced operators that the use of sophisticated heating plants is more economical and the results are satisfactory. An extensively used electrical furnace is shown in Figure 2. The temperature is gradually increased, followed by periods of raising or lowering the heat which vary among different operators, depending also on the nature and original colour intensity of the stone. An average 8 to 10 hours

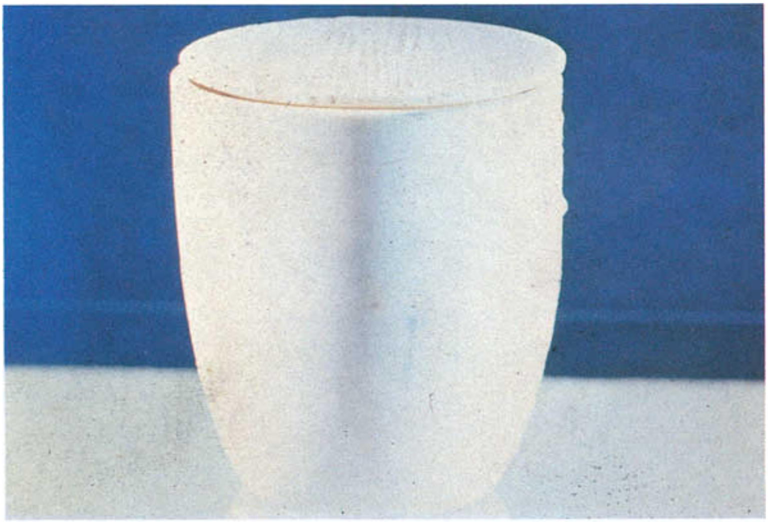

FIG. 1. A crucible extensively used in the heat treatment of ruby.

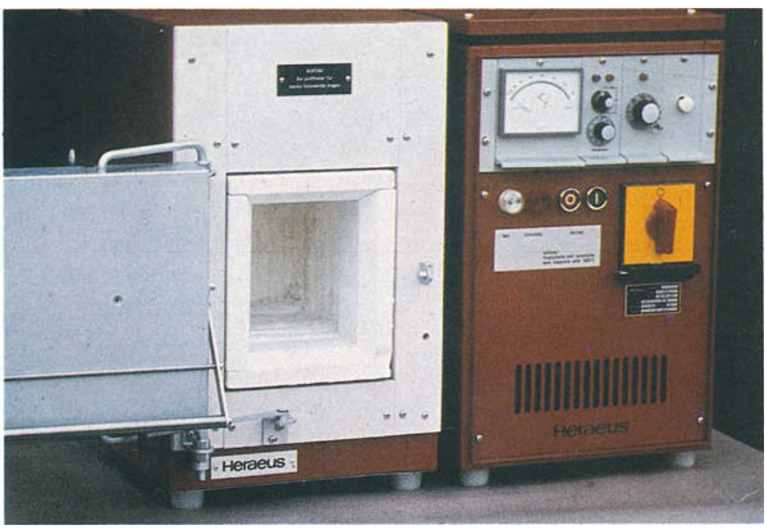

FIG. 2. High temperature chamber furnace manufactured by Hearaeus in West Germany. Owing to rapid heating system it is used in the heat treatment of corundum (after Hearaeus, model number K 1700/1).

FIG. 3. Sorted rough ruby lot weighing 3000 grams just after heat treatment.

FIG. 4. The author, examining rubies after the heating process.

treatment is common. Figure 3, illustrates a lot of 3 kg of heated rubies in the rough state. If the desired colour is not achieved, the process can be repeated several times. In many instances even faceted rubies are heated, if the owner is dissatisfied with the colour. These stones are then sorted out according to various hues of colours and sizes and are marketed in Chantaburi gem market in the Sunday auction (Figure 4).

Frequently encountered colours of corundum in Sri Lanka are the pinkish-violet or pinkish-yellow varieties. These less-priced sapphires are heated to obtain a better pink or, rarely, a reddish hue. The original sapphires of these particular colours often contain rutile within them. It is probable that some titanium causes the violet tinge in such gemstones (see Nassau, 1980; Schmetzer & Bank, 1981). Without disturbing the Cr^{3+}, a heat treatment in reducing atmospheric conditions, at a temperature of 1000 °C to 1500 °C, may result in the removal of rutile.

$$4TiO_2 \rightarrow 2Ti_2O_3 + O_2$$ (after Nassau, 1981)

This effects the removal of the blue tinge in the stone, and they appear pink or red in colour after the operation. However, the results of such 'cooking' methods are not very successful. The result is more pink (75% to 85%) than ruby coloration (which may be 5% to 7%).

Only a few dealers in Sri Lanka have adopted Thai methods of heat treatment. The higher temperatures required are achieved by using natural gases or oil (Gunaratne, 1981). Such common oil and gas ovens are sketched in Figures 5a and b respectively. The heat treatment in Sri Lanka is shown to be much more successful than at early stages. According to the discussions had with one of the largest operators the author was informed that only very little treatment is carried out which succeeds in obtaining the 'pure' ruby colour. The attempts made mostly ended up with pink colour as mentioned before. A more primitive process of altering the colour of corundum varieties is the so-called blow-type heating (Gunaratne, 1981). As shown in Figure 6, it is done by coating the gems with clay and by heating, which is obtained by blowing charcoal, in a sand bath. However, this is practised by those dealers who are able and willing to risk the uncertain results of this method.

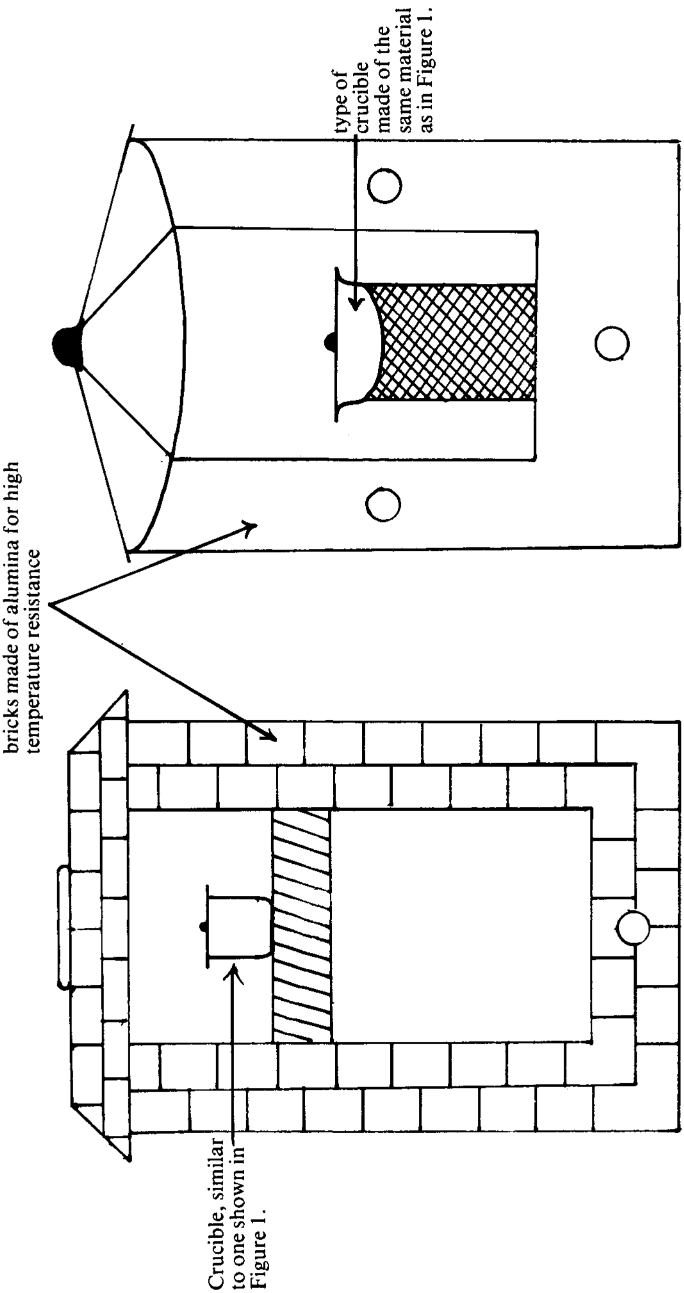

FIG. 5. Typical (a) oil and (b) gas furnaces used in the heat treatment of corundum in Sri Lanka.

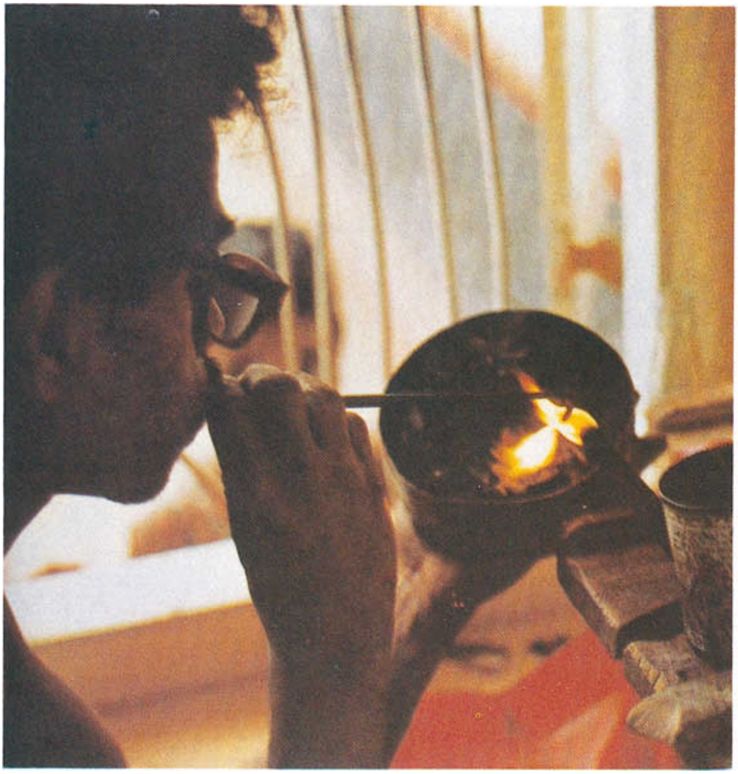

FIG. 6. A historically famous mode of colour alteration—blow type heating—used in Sri Lanka.

DIFFUSION TREATMENT OF RUBIES

The patents introduced by Carr & Nisevich (1975, 1976, 1977) and assigned to the Astrid Corporation Ltd, of Hong Kong, describe glossing of colour in natural or synthetic corundums. Commercially important diffusion treatments related to blue sapphires were mentioned by Nassau (1981) and Crowningshield & Nassau (1981). Those U.S. patents assigned to the Hong Kong company also mention the possibility of diffusion by using oxides other than iron and titanium as in the case of blue sapphires. Nickel, chromium or nickel + chromium oxides are used to give different surface coatings (Carr & Nisevich, 1976 & 1977).

Recognizable amounts of chromium can be induced into pink or colourless sapphires under heat. The mechanism of this is to move the chromium atoms into the stone under heat. This 'skinning' method, however, is dependent on the temperature and the period of treatment. The process after Carr & Nisevich (1976, 1977) is now practised on most of pink Sri Lanka sapphires, and such colour-coated violet sapphire was detected by Ohguchi (1982). The colour-coated ruby examined by the author was also of Sri Lankan origin. This was confirmed by the inclusions (mentioned below) and the results measured by a UV spectrophotometer (λ 339 nm; λ/W 4.75), a method introduced by Bosshart (1982).

GEMMOLOGICAL IDENTIFICATIONS

The corundum gems now need to be examined with much more intensive gemmological identification methods. The question for gem labs is not only whether the ruby is natural or synthetic but also, if it is natural, whether heat-treated or not. Several investigators provided conclusive answers in this connexion (Crowningshield & Nassau, 1981; Scarratt, 1981; Schiffmann, 1981; Hänni, 1982 a and b; Gübelin, 1982; Schmetzer *et al.,* 1982; Ohguchi, 1982). Some of the characteristics described can be used simultaneously in separating treated rubies.

The most characteristic discrimination features of 'cooked' rubies can be recognized through intensive microscopic studies. These characteristics can be divided as *internal* and *external* alterations. The extensive work done by Gübelin (1973) on the origin of inclusions in coloured gemstones must be taken as a comparison in detecting the epigenetism caused on those treated rubies. This means an alteration of protogenetic and syngenetic inclusions under high temperature conditions. Such syngenetically trapped scenery change to an appearance of epigenetism is shown in Figures 7 and 8 respectively. The liquid droplets of Figure 7 are absent in Figure 8. On some occasions the crystal matter is revealed partly dissolved with surrounding healing feathers. This distinction was made by observing nearly 800 rubies from Thailand before and after heating. However, this is not the only discriminatory criterion for the separability of heat-treated rubies. Also observed were various forms of disc-shaped fissures (Figure 9). Similar healed feathers were observed by Hänni (1982 a and b) and Gübelin (1982) in treated blue sapphires.

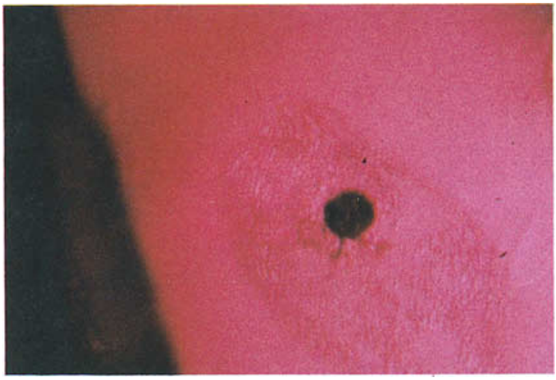

FIG. 7. Locality typical inclusion in Thai ruby; a circular feather with a pyrrhotite crystal at the centre. 25 ×

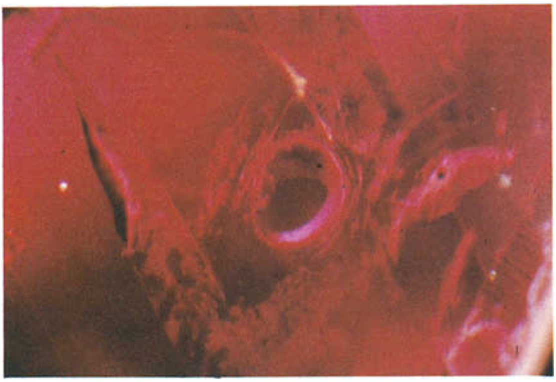

FIG. 8. Epigenetism caused to the inclusion in Fig. 7 under high temperature. The crystal, after melting, has created a void with a healed feather around. 40 ×

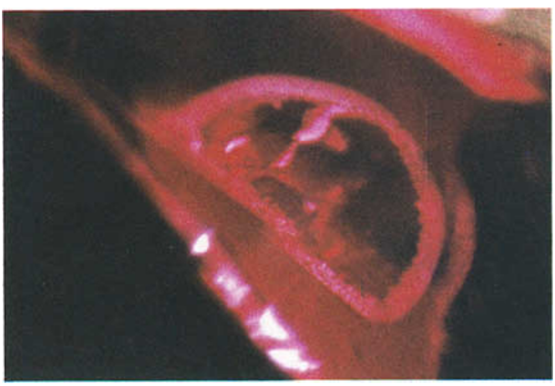

FIG. 9. Healed fissure, often encountered in 'cooked' rubies from Thailand. 60 ×

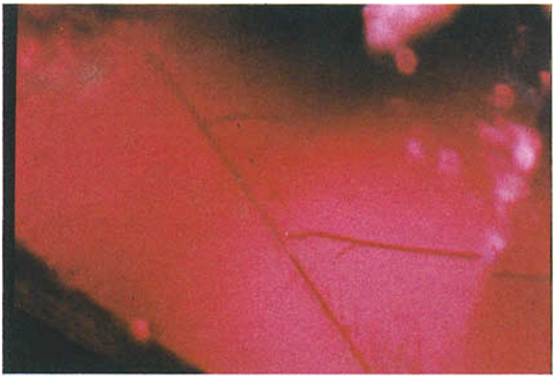

FIG. 10. 'Fire marks' with adjoining hair fine cracks detected as a typical external feature in heat treated Thai ruby. 40×

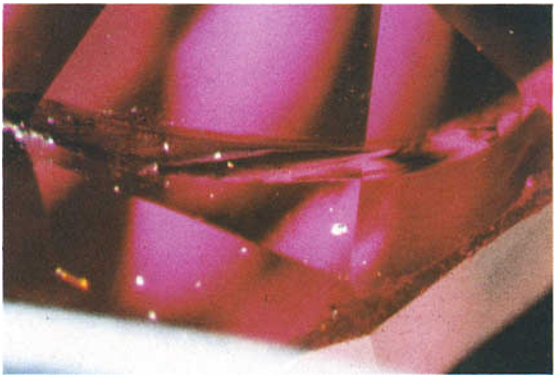

FIG. 11. A fire crack penetrating into the ruby after several repeated heat treatments in Thailand.

FIG. 12. Often seen 'injuries' on the surface of a ruby after high temperature inducement. 30×

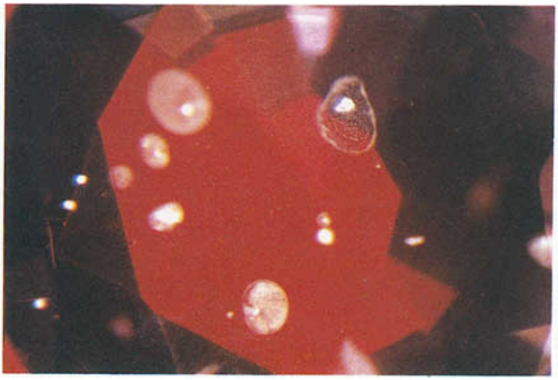

FIG. 13. Typical circular discs of healed fissures seen in a diffusion treated ruby from Sri Lanka. 25 ×

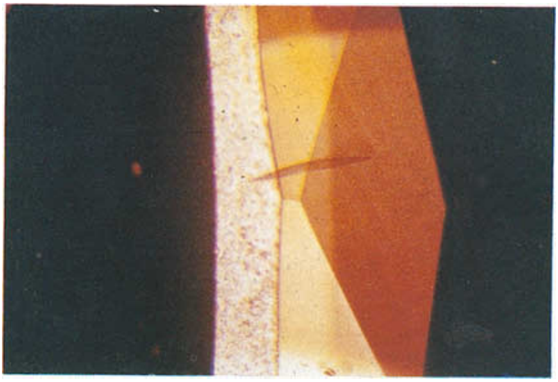

FIG. 14. Different thicknesses of the coating on the two facets and typical 'pock marks' on the inpolished girdle of the diffusion treated ruby investigated. 40 ×

During many observations made it has become apparent that corundum gems need to be examined internally as well as externally. Some noteworthy marks are now encountered on most rubies of Thai origin upon careful surface examinations. Similar surface marks were reported on synthetic corundums made by Verneuil and termed as 'fire marks' (Webster, 1975). The observed rubies from Chanthaburi-Trat province revealed some fire marks (Figure 10), which were, however, dissimilar in appearance to those seen in flame-fusion made rubies. Such fire cracks may penetrate into the stone in repeated heating and appear as in Figure 11. Other features worth mentioning are the strongly damaged surface 'injuries' (Figure 12). These surface markings are caused by multiple reheating at high temperatures. However, they can be minimized, and the stones will present a better surface appearance if repolished before they reach the market.

With the belief of its treated origin in Hong Kong, the author revealed few characteristics in a diffusion treated ruby. The disc shape (the discs were round in this connexion rather than the oval contour of Thai ruby, see Figure 9) and healing fissures (Figure 13) were a common indication in this stone confirming its origin to be Sri Lanka. Under immersion microscopic observation, using methylene iodide ($n_D = 1.74$), the colour concentration on different facets showed (Figure 14) variable thicknesses. The typical 'pock-marks' were present on the unpolished girdle (Figure 14). Recently Ohguchi (1982) mentioned the identification of colour-doped ruby by the use of x-ray fluorescence chemical analysis. He noted different outputs of transmission curves for synthetic, natural and natural colour-coated rubies respectively. It showed that the doped sample contained a higher percentage of colouring material than the non-treated samples.

Concluding Thoughts

The colour of ruby can be enhanced by heat or diffusion treatment. The former can occur in nature and may be difficult to detect. The methods introduced by previous investigators can be used simultaneously with the criteria mentioned in this work. However, a steady practical knowledge of internal and external features of rubies is a necessity in such separations. Even though the colour may remain stable, the durability may be disturbed by repeated heating.

Diffusion-treated rubies must be disclosed to the trade. This colour coating procedure is detectable under various gemmological observations by microscope. During the preparation of this paper only very few stones were available in the trade. However, one can expect them to flood the market in future, especially when in those ruby occurring localities they find the best way for them to reach the jeweller.

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[*Manuscript received 18th July, 1983.*]

ON THE IDENTIFICATION OF A LIGHT PINK PYROPE GARNET AND A KORNERUPINE

By J. M. DUROC-DANNER, F.G.A., G.G.

INTRODUCTION

Recently the writer acquired a parcel of a number of faceted stones. These were mostly sapphires, spinels, and zircons. Some of the stones were not what they were marked, but were easily identified . . . A small brilliant-cut orange 'spinel' turned out to be a tourmaline, and a deep blue 'zircon' with no double refraction, but with angular markings, was in fact a magnificent blue spinel. Two however were more troublesome and needed a more thorough investigation.

A LIGHT PINK PYROPE GARNET

A light pink stone of 2.46 carats, marked as spinel, was surprisingly clean when viewed under the microscope, except for a few angular-like oriented needles. Since these inclusions are not diagnostic for spinel,[1,2,3,] the stone's identity had to be confirmed.

Anomalous double refraction similar to that seen in some glass imitations was observed under the polariscope, and this according to literature is not at all characteristic of spinel.[1,4]

The refractive index of 1.737 and the specific gravity of 3.738 were much higher than the normal values for a pink spinel.[1,4,5]

No fluorescence could be detected, while pink spinels are said to show a crimson glow under ultraviolet light.[1]

The spectroscope revealed a strong line centred at 432 nm, a broad band at 490-505 nm, two lines at 525 and 570 nm, and weak chromuim lines at 650 and 670 nm. This also is not very characteristic of a pink spinel . . .[1,6]

The strange 'spinel' was in fact a very nice specimen of a light pink pyrope garnet, which was ascertained by its chemical analysis (Table 1).

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TABLE 1

Analytical data and derivation of formula

Chemical analysis wt%			number of ions	
SiO_2	—	45.20	Si	3.04
Al_2O_3	—	25.33	Al	2.00
MgO	—	28.50	Mg	2.88
TOTAL	—	99.03	O	12.00

Empirical formula : $Mg_{2\cdot88}\,Al_{2\cdot00}\,Si_{3\cdot04}\,O_{12}$

Ideal formula : $3MgO.Al_2O_3.3SiO_2$

A KORNERUPINE

Zircons were checked under the microscope for doubling of the facet junctions. All except one, a 3.49 carats oval-cut saturated green stone, showed this effect. It should be mentioned here that, if strong doubling of opposite facets is characteristic of zircons due to their high birefringence, this effect is seen in most varieties except perhaps the green and the very rare orange metamict zircons.(1) Microscopic examination of this green stone with dark-field illumination revealed some very long thin needles (rutile ?) oriented in two directions forming an angle of approximately 147°. Since rutile needles are present in numerous gemstones, and therefore alone are not diagnostic, it was decided to check the physical properties of this stone.

PHYSICAL PROPERTIES

The stone was examined table down in a Gem Illuminator Polariscope, set to its dark position, where the vibration directions of the polarizer and analyser are perpendicular to one another. The stone was rotated in this position, and instead of the typical blinking reaction of anisotropic stones, it remained light with only a slightly darker band moving across the stone as it was turned.

To confirm the anisotropy of this stone, without changing its orientation, and with the polariscope kept in its dark position, the stone was rotated to the position that permitted the maximum of light to pass—a position where the dark band had completely disappeared. Next, the analyser was quickly turned to its light position, and, since simultaneously the stone appeared darker, double refraction was indicated.(7)

The fact that this stone remained light, while rotated between crossed Polaroids suggested that the table facet was probably cut perpendicularly to an optic axis.

To visualize this, and determine whether the stone is uniaxial or biaxial, the polariscope was set to its dark position, and a glass sphere placed on the stone's pavilion. The entire biaxial interference figure could be seen inside the glass sphere (Figure 1).

FIG. 1. Biaxial interference figure made visible by a glass sphere between crossed polars.

By rotating the stone a few degrees, the two brushes corresponding to the two optic axes could be brought closer to each other, and gave rise to a cross-like pattern similar to that of the uniaxial interference figure.

From this test, the stone was proved biaxial, with a very small 2V angle (axial angle), and it was clear that it could not be a green metamict zircon.

The refractive indices determinations were carried out by using a Rayner Dialdex critical angle refractometer with monochromatic sodium light. Only the stone's table facet could be tested to obtain all the refractive indices, since the unsymmetrical narrow step-cut

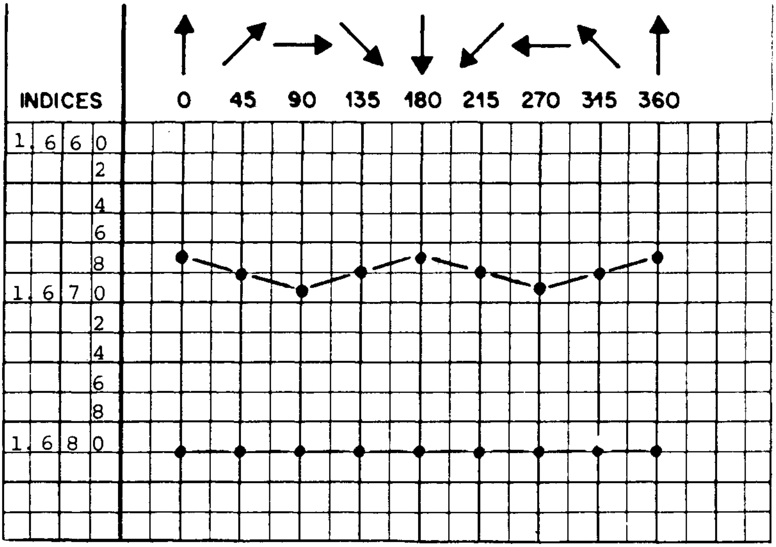

FIG. 2. Refractive indices graph.

faceting of the off-centred pavilion did not permit the stone to sit properly on the refractometer. The stone was rotated every 45° and its indices recorded until a rotation of 180° was obtained, since beyond this point the reading repeats itself. The indices obtained are shown in Figure 2. From these readings it is impossible to tell whether the stone is uniaxial negative, in which case $\omega = 1.680$, $\varepsilon = 1.667$, or biaxial positive with $\alpha = 1.667$, $\beta = 1.669$, $\gamma = 1.680$ (table facet cut perpendicularly to the acute bisectrix), or biaxial positive ? or negative ?, with $\alpha = 1.667$, $\beta = ?$, $\gamma = 1.680$ (table facet cut perpendicularly to the axes planes)[8]. Since the biaxial interference figure was obtained, the stone had to be analysed from another direction to find the value of β and the optic sign. This was done with a minute crystal taken from the stone's girdle and revealed under the polarizing microscope the following indices:

$$\alpha = 1.667 \quad \beta = 1.676 \quad \gamma = 1.680$$

giving a birefringence of 0.013, optic sign (-). By consequence, the table facet of this stone is cut *more or less* perpendicularly to the optic axes planes[8].

The stone remained suspended in methylene iodide of specific gravity 3.32, and hydrostatic weighing of the stone in distilled water at 4°C using a Mettler PL 300c balance (accuracy ± 0.001 carat) indicated a specific gravity of 3.314.

The pleochroism observed through the pavilion with a Rayner dichroscope was distinct; light green, medium green, and brownish-red (tobacco leaf colour).

The absorption spectrum seen through a Gem Beck Spectroscope Unit, showed only vague indistinct lines in the blue portion of the visible spectrum.

No fluorescence could be seen with a Multispec combined LW/SW Unit (G.A.A.J.).

These physical properties correspond to the complex magnesium iron aluminium boro-silicate, kornerupine.[9,10,11] X-ray powder diffraction and qualitative chemical analysis were undertaken to confirm the identification.

Qualitative Chemical Analysis

The stone was analysed with a P.G.T. energy dispersive analyser coupled to an electron microscope. This showed major contents of Mg, Al, Si, with very little iron. Boron was not detected due to its very light atomic weight, so a final test was undertaken.

X-ray Powder Diffraction

A scraping of the stone's girdle was submitted to a beam of monochromatic x-rays (Cu/Ni) in a cylindrical Gandolfi Camera of diameter 114.6 mm. After an exposure time of approximately 7 hours, under working conditions of 40 Kv, and 20 mA, the most important lines were found to be lying at:

d (Å)		I (vis.)
10.35	—	40
6.85	—	35
3.349	—	50
3.003	—	100
2.617	—	100
2.100	—	40
2.080	—	30

and could be matched in the Powder File (J.C.P.D.S. 29-852) to those diagnostic for Kornerupine.

Conclusion

With x-ray powder diffraction the identification of kornerupine was confirmed. The physical, optical, and chemical properties are consistent with the range of data quoted in gemmological literature for this mineral.

The main difficulties in the identification of the light pink pyrope garnet and the kornerupine lay in the many possibilities to be considered and the correct interpretation of the information gained from the different tests.

The origin of these two stones, the pyrope and the kornerupine, is unknown to the writer, but according to the cutting style of the kornerupine, this stone could originate from Sri-Lanka.

Acknowledgements

The writer is indebted to the Natural History Museum of Geneva, and in particular to Dr H. Sarp, for carrying out the chemical analysis and x-ray powder diffraction, and for confirmation of the physical properties by the polarized microscope.

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[*Manuscript received 24th February, 1984.*]

CHELSEA, PAWNBROKING AND GEMMOLOGY

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

Frinton-on-Sea

I stopped smoking just after the War, not for health reasons, but simply because with a mortgage, smoking was a luxury I had to jettison.

I remember, as a youngster long before the War, a childish interest in collecting 'cigarette cards'. These were issued by the various manufacturers to attract sales. Series such as the 'Flags of the League of Nations', 'The British Army Regiments', were very popular.

One such series I believe was entitled 'Do you know?'. On each card was illustrated in colour a bird, a tower, a symbol, a building, a bridge, and on the other side would be a brief succinct résumé of the details. Some to a small boy would be fascinating, others not so interesting. One which stays in my memory showed three round flat golden-coloured discs. These were said to be three gold bezants representing the 'arms' of money lenders from Lombardy and were said to be the origin of the pawnbrokers' sign of the three golden balls.* Certainly Lombard Street in the City of London is associated with money lending and banking. The three balls mounted two above and one below were facetiously said to signify the odds of two to one against the ultimate redemption of a pledge. In pawnbroking parlance a pledge was something left in pawn against a loan.

Perhaps my continuing memory of the three gold bezants on a cigarette card is due to the fact that my father managed a pawnbroker's shop in inner London, and we lived above the shop. Outside my bedroom window hung three brass balls and later a clock with the name of the shop plus 'Established in 1796'. As a small boy I lay in bed at night unable or unwilling to go to sleep; below me in the main shop a succession of strikes, chimes and cuckoos emanated from the mechanisms of the stock of clocks which in those days were Westminster and Whittington wooden mantel clocks, alarms, cuckoo clocks and sometimes a sonorous grandfather clock.

*'Supposed by some to be derived from the ensign of the wealthy Medici family.' (*O.E.D.*)—Ed.

ISSN: 0022-1252 XIX (4) 317 (1984)

Somewhat reluctantly, upon leaving school I started working in the shop as a 'warehouse boy'. This entailed carrying up parcels of clothing, shoes, which had been pawned that day, and stacking or arranging them in date and type order. One room was entirely boots and shoes; the basement was blankets and sheets, and in the loft musical instruments and miscellaneous goods of a very weird and varied nature.

Jewellery was kept downstairs in a compartmentalized safe. The jewellery was usually wedding rings and watches—we didn't live in a wealthy district. After an altercation with my father, who was anxious that *no one* could accuse him of favouring his son, I left and went to yet another pawnbroker in the west of London. Here I lived in as a member of staff. The food was poor. The accommodation consisted of one bedroom shared with two other lads as well as various gramophones, wireless sets, fishing rods and a bicycle—all being pledges.

After a fairly short period I left to join yet another pawnbroking establishment in Chelsea, in the Kings Road near to a now popular pub called 'The Worlds End'.

At the Chelsea shop I heard that my predecessor 'knew all about stones', because according to my junior (17 years) he had been to the polytechnic for stones. Sad to say that at that time Chelsea, its polytechnic and stones meant nothing to me. I was too busy cycling the difficult twelve miles across London daily to think of evening classes.

The employer, a most lugubrious individual, told us all one day that he was going to retire and close the shop—he couldn't sell it and the pawnbroking department had to run down over a year to allow the full term for pledges to elapse.

I found yet another job, this time in the retail jewellery department of a West End pawnbrokers named Jay Richard Attenborough—there were at that time three firms of pawnbrokers carrying the name Attenborough; one only remains in Fleet Street.

At my particular shop I soon found how little I knew—least of all about gemstones. My immediate senior was one George Ratcliffe, F.G.A. (1934): he told me in no uncertain terms that I was extremely ignorant and ought to go to gemmology classes. 'Gemmology, whats that?' was my query, and in practically no time I was at Chelsea Polytechnic with one or two other young chaps, one named Harry Wheeler and another Sam Redknap.

We had an instructor named B. W. Anderson, and another named Thorold Jones. The war years interrupted us for a while, but in September 1946 I enrolled again with others, among whom were Sam Redknap and Harry Wheeler, Bert Clark, Dr Rutland, Dr Stern, all ex-army types.

I never wanted to go into the pawnbroking business, and I didn't expect to get a job in the Laboratory. I felt very much at home though when I made the acquaintance of Robert Webster; he too was ex-army (both wars), still quite young, and equally had an ex-pawnbroking beginning—and strangely enough just outside the Chelsea boundary. There may not be a strong link between Chelsea, pawnbroking and gemmology but at least an interesting one started by George Ratcliffe, who incidentally after the War joined yet another pawnbroking firm.

[*Manuscript received 28th November, 1983.*]

AUSTRALIA'S FIRST EMERALDS

By GRAHAME BROWN, Dip.D.T., F.G.A., F.G.A.A.

University of Queensland, Australia

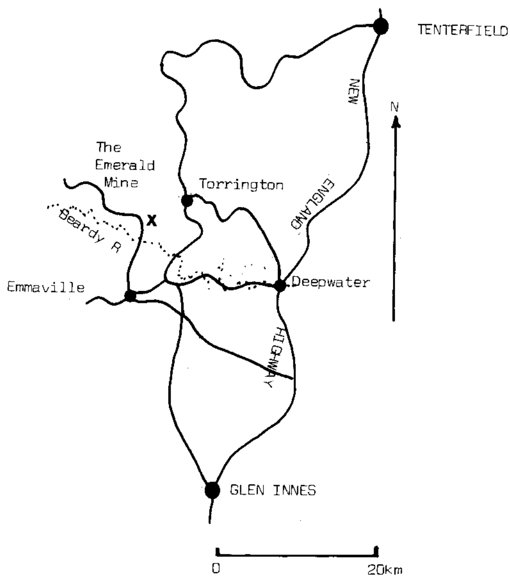
Well respected gemmological texts[1,2,3,4] record that Australia's first commercial emerald deposit was discovered, in 1890, just 9 km to the north-north-east of the small northern New South Wales tin mining town of Emmaville. Emmaville (Figure 1) or Vegetable Creek—to use the original town name, that was derived from the many Chinese market gardens that lined the town's water-course—is located (Map 1) on the western edge of the New England Batholith. Twenty miles to the east of Emmaville lies Deepwater—a country town on the New England Highway, which joins Brisbane to Sydney.

FIG. 1. The town of Emmaville, from the Gulf Road that leads to the Emerald Mine.

HISTORY OF THE EMERALD MINE

David[5], Wynn & Loudon[6] and Mumme[7] have between them provided a relatively complete history of emerald mining at The Glen or Glen Creek area. This history is briefly summarized below.

ISSN: 0022-1252 XIX (4) 320 (1984)



MAP 1. The location of the Emerald Mine at the Summerville (formerly Dakalbin) pastoral property, near Emmaville, N.S.W.

1881 A deposit known locally as De Milhou's Reef or Cleary's Lode was hand mined for cassiterite.

1890 D. A. Porter, an Inspector of Public School Buildings, and an amateur mineralogist, discovered ?emerald, while prospecting the abandoned tin lode at De Milhou's Reef. Porter submitted a small parcel of these green crystals to T. W. E. David—then a Geological Surveyor with the N.S.W. Department of Mines & Agriculture. A report on these samples, by David, concluded: 'they are beryls, of a colour sufficiently emerald green to entitle them to be termed emeralds.'
Porter's find was taken up by the Emerald Proprietary Company, who named the mine they developed on De Milhou's Reef, the Emerald Proprietary or the Emerald Mine. In this same year, the mine was sunk to a depth of 15 m, and an 18 m long drive was completed along the line of the emerald-bearing lode.[8] A parcel of 2250 ct of marketable emerald (both rough and cut) was sent to

London for valuation. Some of the faceted emeralds were sold for £4 per carat.[9]

1891 The Emerald company had sunk two shafts on their lease: the original mine to 15 m, and a new shaft to 30 m. From both of these mines, 25 000 ct of emeralds were recovered. Of the emerald mined, only 0.01 to 0.02 per cent was of gem quality.[10]

1892 About 25 000 ct of emerald, of unknown value, were mined. Due to the hardness of the rock enclosing the emeralds, recovery of emerald, in an undamaged state, proved very difficult.[11]

1893-4 Unprofitable returns for emeralds, sent to London, caused the mine to cease production.[12]

1897 Mining was recommenced, and the main (15 m) shaft was deepened to over 90 m. The purpose of this extension was to test the deposit at depth. No emeralds were recovered at depth.[13]

1898 Sporadic mining was attempted, but no financial return was obtained. The mine again ceased production.[14]

1908-9 The mine was again reopened, and 1000 ct of emerald (valued between £1,600 and £1,700) were recovered from the old drive. The largest emerald rough recovered weighed 60 ct. Of a parcel of rough, that was cut in Europe, the largest stone weighed 6 ct, while the other 49 cut emeralds were determined to be of fair quality, but of pale colour.[15]

1909-63 Only minor prospecting occurred at the Emerald Mine.

1963 A winze was sunk in the drive, at a point 12 m from the main shaft. Unknown quantities of supposedly good quality emeralds were recovered during this mining phase.

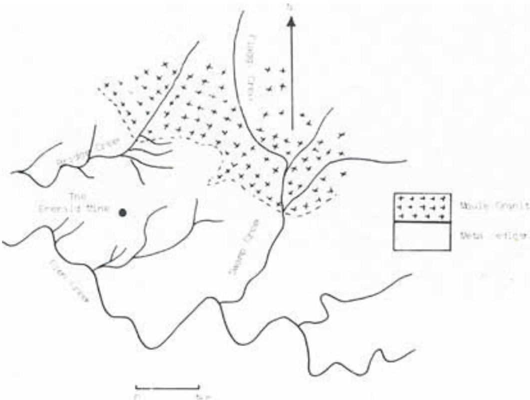
1964 The Emerald and its associated mines were surveyed by Wynn & Loudon.[6]

1965-80 No mining activity occurred. The mine was occasionally visited by fossickers.[16]

1981 The main shaft of the Emerald Mine was dewatered and cleaned of accumulated debris. Exploration of the old workings revealed that the mine had a main shaft, 98 m deep, and that two separate drives had been established in a north-easterly direction: a 23 m long drive at the

9 m level, and a 9 m drive at the 37 m level. Plans are believed to be currently in hand for recommencing mining in the drive at the 9 m level.[17]

Recorded emerald production from this mine is incomplete at 53 225 ct,[18] and is most likely to be underestimated.



MAP 2. The geology of the emerald deposit at the Emerald Mine, near Emmaville, N.S.W. (*after Wynn & Loudon (1965).*[6]).

GEOLOGY OF THE DEPOSIT

The emeralds occur (Map 2) in a Permian sedimentary sequence that had been intruded by pegmatite and aplite from the nearby Moule Granite.[6] The Emerald Mine (Figure 2)—GR 46693622 Grafton 1:250 000—is sunk into an irregularly shaped lode which dips from the north-east to the south-west from the Moule granitic stock. Although this lode tends to bifurcate, only one emerald-bearing lode has so far been discovered. The emerald-bearing lode is the one that intersects the main shaft of the Emerald Mine at its 9 m level.[19]

The emerald-bearing lode is a quartz-topaz-feldspar-mica pegmatite, that varies in width from 50 mm to 1 m and is a late phase derivative of the nearby Late Permian Moule Granite. This pegmatite has intruded into the surrounding meta-sediments (Permian siltstones, slates, quartzites), along north-east to south-west trending joints.[8]

In the pegmatite, emeralds occur irregularly, as 'bunches', usually firmly embedded in flattened cavities in the quartz-topaz

FIG. 2. The headframe at the Emerald Mine (1982).

vein rock (Figure 3). In these cavities, the generally small (< 1 ct) emeralds are often surrounded by an uncommon kaolin-group mineral—dickite.[20] Minerals frequently associated with the emeralds in the lode are cassiterite (SnO_2), fluorite (CaF_2), arsenopyrite (FeAsS), wolframite (an intermediate member of the series huebnerite $MnWO_4$ and ferberite $FeWO_4$), and rarely quartz.

A recent mineralogical investigation of this emerald-bearing lode[20] indicated that:

- The wall rock was formed from a hard, fine-grained quartz-topaz rock, with a ratio of quartz to topaz of 80:20;
- The narrow alteration zone of the pegmatite was produced by dickitization-type hydrothermal alteration of the topaz content of the host rock; and,
- The lode consisted of major fluorite, beryl, quartz, topaz; with minor cassiterite and arsenopyrite.

Additionally, Mumme[7] has observed that the very small ionic size of the chromophore in this particular emerald prevented its entry into the early stage minerals, that crystallized from the Moule Granite; but this small ionic size allowed the ion to be concentrated in those minerals formed in the late stage pegmatitic veins.

FIG. 3. Emerald crystals in a flattened vugh, in the lode at the Emerald Mine. Note the presence of the minerals that are associated with this lode: fluorite (purplish), dickite (opaque white), arsenopyrite (silvery), quartz (glassy grey).

FIG. 4. Typical habits displayed by the emeralds from the Emerald Mine.

FIG. 5. Specimen of Emerald Mine emerald penetrating quartz.

FIG. 6. Specimen of Emerald Mine emerald penetrating fluorite.

FIG. 7. Specimen of Emerald Mine emerald intergrown with topaz.

FIG. 8. Specimen of Emerald Mine emerald enclosed in its host rock.

GEMMOLOGY OF THE EMERALD

Emerald crystals, from the Emerald Mine, display a decidedly acicular habit (Figure 4), with the hexagonal prism and basal pinacoidal forms dominant. The emerald crystals, which vary in dimension from 1-10 mm in width and up to very rare 3 cm lengths, are found as attached crystals in collapsed dickite-filled cavities within the lode (Figure 3), as well as occurring as crystals penetrating quartz (Figure 5), fluorite (Figure 6), topaz (Figure 7), or the host rock (Figure 8). These mineral associations for the emerald of the Emerald Mine are supported by Stevens's suggested paragenetic sequence,[20] of:

Topaz
Beryl
Quartz
Fluorite ↓

Colours observed in the emeralds, from the Emerald Mine, vary from the faintest greenish hue to a light bright emerald green shade—with a yellowish rather than bluish secondary hue. Stevens's spectrographic analyses clearly attributed the greenish hues of the emerald from the Emerald Mine to their 1000 ppm vanadium and perhaps their 450 ppm copper content, rather than their 350 ppm chromium content. Rather surprisingly no iron was detected in these emeralds.

GEMMOLOGICAL PROPERTIES

Gemmological properties were established for representative samples of gem qualtiy emerald from the Emerald Mine. These properties are listed in Table 1.

CHARACTERISTIC INCLUSIONS

Microscopic examination (×20 and ×50 magnification) of these emeralds revealed a rather common pattern of inclusions, that readily confirmed the pneumatolytic origin of these particular emeralds. The Emerald Mine emeralds displayed many inclusions that could be considered to be typical for beryl—irrespective of its variety.

The inclusions recorded in this investigation into emerald from the Emerald Mine, include:

TABLE 1. The gemmological properties of emeralds from the Emerald Mine, near Emmaville (N.S.W.).

SPECIFIC GRAVITY	2.68
DIAPHANEITY	Transparent
LUSTRE	Vitreous
REFRACTIVE INDEX	ω 1.575, ε 1.57
BIREFRINGENCE	0.005
OPTIC SIGN	U^-
PLEOCHROISM	ω Yellowish green, ε Green
CHELSEA FILTER	Very pale pink
FLUORESCENCE	Inert
ABSORPTION SPECTRUM	A broad absorption band centred at 610 nm, with absorption of the ε ray wider than that of the ω ray. General absorption below 454nm.

..................................as Liquid Inclusions[21]

- * Two-phase primary tubes oriented parallel to the *c*-axis of the crystal (Figure 9);
- * Two-phase primary 'daggers' oriented parallel to the *c*-axis. These inclusions have been produced by a crystal interrupting the rapid growth of the emerald crystal in the direction of its *c*-axis. (Figure 10);
- * Partly resorbed parallel oriented tubes, the original two-phase contents of which have been replaced by an epigenetic cavity filling (Figure 11);
- * Irregularly outlined two-phase primary polycuspate inclusions oriented parallel to the *c*-axis or the crystal (Figure 12). Occasionally, these inclusions appear to be three-phased (Figure 13);
- * Two-phase secondary partly healed incipient cleavages, or 'veils', that are oriented in the basal plane at right angles to the *c*-axis of the crystal (Figure 14). When viewed down the *c*-axis, these secondary inclusions display a net-like form (Figure 15); and

FIG. 9. Photomicrograph of two-phase liquid tubes parallel to the *c*-axis of an emerald crystal from the Emerald Mine. (×20 magnification)

FIG. 10. Photomicrograph of a two-phase primary 'dagger' inclusion included in an emerald from the Emerald Mine. This inclusion has been initiated by an included cassiterite crystal. The 'dagger' is oriented parallel to the *c*-axis. (×20 magnification)

FIG. 11. Photomicrograph of trichite-type inclusions in an emerald from the Emerald Mine. This inclusion has been formed by epigenetic mineral infiltration of resorbed parallel oriented tubular inclusions. (×20 magnification)

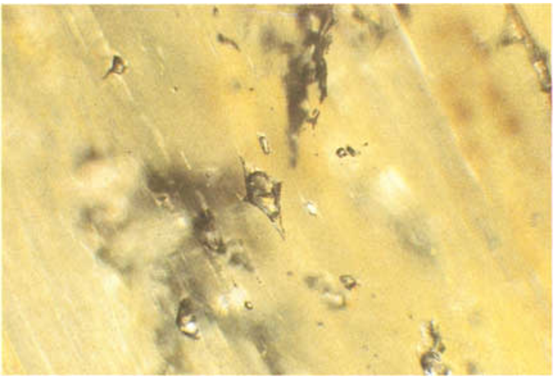


FIG. 12. Photomicrograph of a two-phase polycuspate liquid inclusion, that is oriented parallel to the *c*-axis in an emerald from the Emerald Mine. (×20 magnification)

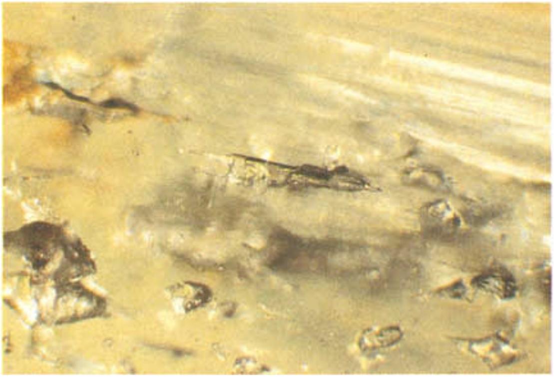


FIG. 13. Photomicrograph of a three-phase (solid phase arrowed) polycuspate inclusion in an emerald from the Emerald Mine. (×20 magnification)

FIG. 14. Photomicrograph of partly healed cleavages in the basal plane of an emerald from the Emerald Mine. Note that these partly healed cleavages are at right angles to the two-phase tubes that parallel the *c*-axis. (×20 magnification)

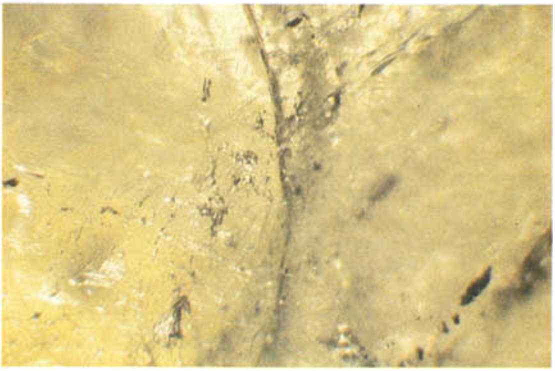


FIG. 15. Photomicrograph of the net-like appearance of the two-phase partly healed basal cleavages in an emerald from the Emerald Mine. (×20 magnification)

FIG. 16. Photomicrograph of randomly oriented partly healed cracks in an emerald from the Emerald Mine. Note the angulation of these cracks to the basal plane of the crystal. (×20 magnification)

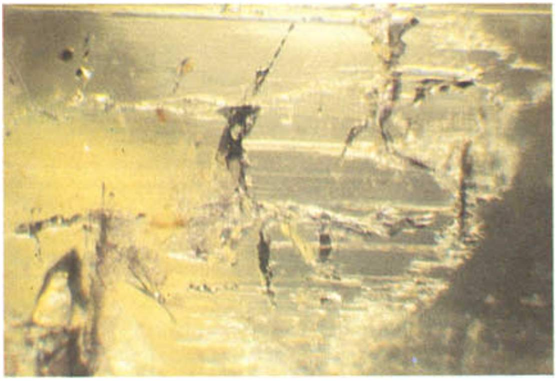


FIG. 17. Photmicrograph of randomly oriented two-phase partly healed cracks in an emerald from the Emerald Mine. (×20 magnification)

FIG. 18. Photomicrograph of a very irregularly outlined thin film-like partly healed crack in an emerald from the Emerald Mine. (×20 magnification)

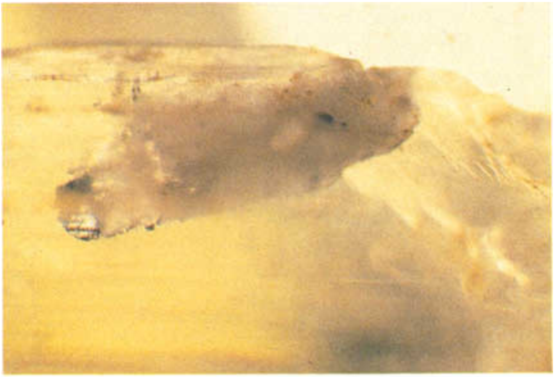


FIG. 19. Photomicrograph of a mass of fluorite that is included in an emerald from the Emerald Mine. (×20 magnification)

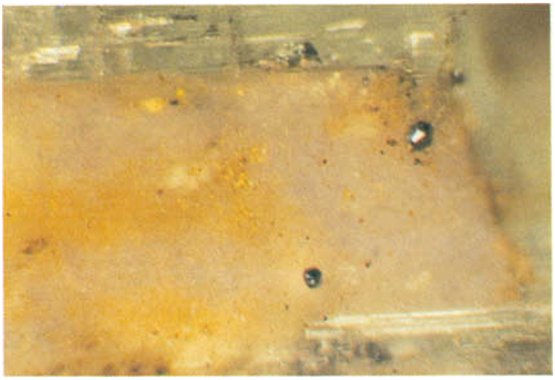


FIG. 20. Photomicrograph of included cassiterite crystals in an emerald from the Emerald Mine. Note the close association between the cassiterite and the fluorite. (×20 magnification)

FIG. 21. Photomicrograph of an included silvery white mineral, of unknown constitution, in an emerald from the Emerald Mine. (×20 magnification)

FIG. 22. Photomicrograph of an epigenetically precipitated brownish orange mineral that has infiltrated a crack in a completely grown emerald from the Emerald Mine. (×20 magnification)

* Randomly oriented secondary partly healed syngenetic internal fractures, the contents of which may be either single-phase (Figure 16) or two-phased (Figure 17). Also in this category are irregular outlined, very thin films, of the trichite-type (Figure 18).

..................................and as Mineral Inclusions[21]

* Masses of fluorite (Figure 19);
* Occasional crystals of cassiterite (Figure 20), that were always closely associated with the masses of included fluorite;
* Irregular masses of an unknown silvery white mineral (Figure 21); and,
* Epigenetically precipitated minerals that acted as cavity fillings in cracks that developed after the emerald crystal had formed (Figure 22).

Having completed this microscopic examination, before access was obtained to Stevens's 1971 thesis, it is gratifying to note that the observations recorded above in Figures 9-22 substantially confirm Stevens's[20] classification of inclusions in the emeralds from the Emerald Mine as:

Primary Inclusions

* colour banding
* two-phase hydrosaline tubes parallel to the *c*-axis
* negative crystals
* spherical randomly oriented two-phase inclusions
* very rare three-phase inclusions, and

Secondary Inclusions

* solid inclusions of fluorite, and
* dendritic two-phase striae oriented roughly parallel to the basal plane.

CONCLUSIONS

The emerald-green coloured beryls from the Emerald Mine, near Emmaville, contain vanadium, copper, and chromium as possible chromophores. To classify this beryl as an emerald would seem correct; in spite of its 350 ppm* chromium content.[22,23,25]

*Wood & Nassau (1968) suggest that a minimal 1000 ppm Cr^{3+} content should be present in a beryl before it should be classified as an emerald.

Emeralds from this deposit display a rich suite of liquid and mineral inclusions, that support the hypothesis that these emeralds are late phase derivatives of the nearby Moule Granite. Although the comparatively low refractive indices (1.57-1.575) and specific gravity (2.68) of this emerald fit the existing data[24] for vanadium-rich emeralds, of moderate water and alkali content; these data await ultimate confirmation by subsequent analytical results.

After almost a century of gemmological indifference, it is pleasing to report that at last this historically important emerald deposit has been described in the gemmological literature.

ACKNOWLEDGEMENTS

I wish to express my appreciation to Tony Cope, for allowing me access to his lease at the Emerald Mine; and to Hylda and Harold Bracewell for providing specimens for examination.

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[Manuscript received 10th February, 1984.]

SAPPHIRE FROM LOCH ROAG, ISLE OF LEWIS, SCOTLAND

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PREAMBLE

Occurrences of sapphire in Scotland have long been known (Heddle, 1901; McCallien, 1937; Firsoff, 1971); however, the sizes of all the specimens described to date have been small, mainly in the order of 1 or 2 mm, with thin platelets only rarely attaining a maximum size of 25 mm in diameter. The sapphires from Loch Roag represent a significant find as the crystals are all much larger, reaching 46 mm in diameter.

OCCURRENCE

The sapphires occur as megacrysts in a xenolithic dyke at Loch Roag, Isle of Lewis, Outer Hebrides, Ross and Cromarty, Scotland. The dyke, which varies in width from 0.5 m to 1.5 m, is exposed in a 4.5 m (maximum) vertical section for a length of 24 m, and intrudes almost vertically through rocks of the Lewisian Complex. The dyke is a monchiquite of lamprophyric affinities, and the xenoliths are coarse-grained rocks of presumed mantle and deep crustal origin (Upton *et al.,* 1983). There is a marked variation in the lithology of the dyke. Chilled margins (approx 25 cm wide) characterized by large corroded biotite crystals in a fine-grained matrix grade into a coarser central core containing, in addition to larger corroded biotite crystals and the ball-like xenoliths, corroded megacrysts of augite, apatite, sanidine, anorthoclase and corundum. Biotite and augite megacrysts are abundant, feldspar and grey opaque apatite much less so, whilst corundum megacrysts are scarce.

DESCRIPTION

The corroded sapphire megacrysts occur mainly as striated, distorted, truncated hexagonal pyramids and bipyramids (Figure 1) and occasionally as hexagonal tabular prismatic crystals (Figure 2). The size of the crystals varies, but few are less than 1 cm; the average size is 2-3 cm. All crystals are of gem quality, but the colour is variable even within individual crystals.

ISSN: 0022-1252 XIX (4) 336 (1984)

FIG. 1. Pyramidal sapphire crystal, 28 mm long, in matrix.

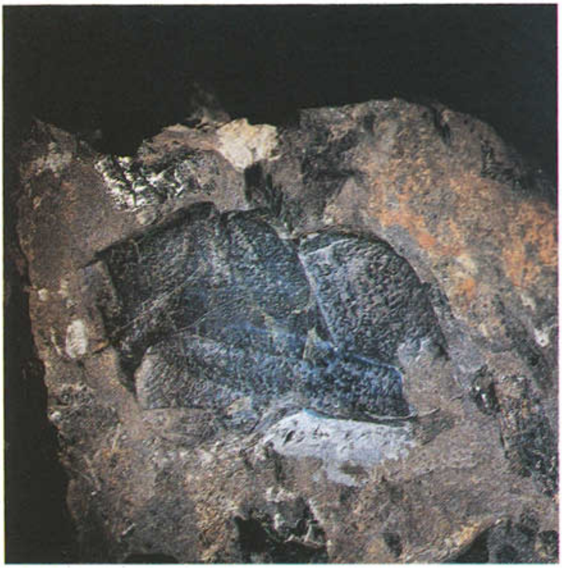

Fig. 2. Tabular sapphire crystal, 43 mm × 27 mm, in matrix.

FIG. 3. Pronounced colour zoning in crystal fragment.

FIG. 4. Hexagonal radial structure with sector zoning in a 22 mm × 27 mm polished crystal cross-section.

FIG. 5. Brilliant cut (8.5 mm dia × 4.5 mm) 2.7 ct dark blue stone with pronounced colour zoning and many fractures.

On balance the smaller crystals are of a fine blue colour, whilst the larger crystals are patchy with areas of blue, green and occasionally yellow. Colour zoning can be seen in some specimens (Figure 3). All of the sapphire crystals show fractures which have in many cases been filled with thin films of secondary iron staining. Some crystals also show well developed parting parallel to {0001}. One specimen in the possession of Edinburgh University Geology Department shows a hexagonal radial structure (Figure 4), with sector zoning. This is caused by symmetrical deposition of exsolution lamellae of haematite micro-inclusions (Upton *et al.*, 1983). As almost all the sapphires are being kept as fine crystal specimens, it was not possible to give a detailed examination of inclusions. Those few polished fragments which were examined proved to be inclusion-free. The single cut stone (Figure 5), 2.7 ct, did however show a large feldspar grain (approx 1 mm) exposed on the crown, and a profusion of micro, opaque breadcrumb-like inclusions and dark wispy veils, the latter two being intimately associated with the large amount of fracturing. Some specimens include grains of a niobium-rich rutile with up to 38% Nb (Aspen P., personal communication).

PROPERTIES

Refractive index:-	ε 1.762—1.767
	ω 1.772—1.775
	δ 0.008—0.010
Specific gravity:-	3.95—4.05
Absorption spectrum:-	All samples examined showed a medium diffuse broad band centred on 450 nm. No other lines were seen even when using a copper sulphate filter.
Pleochroism:-	Pronounced
	Because of the patchiness of the colour it is difficult to give the twin colours; suffice to say that they range from violet-blue to yellow-green.
Fluorescence:-	The sapphires exhibited no fluorescence under both long and short-wave ultraviolet.

DISCUSSION

This type of occurrence has similarities with the source rocks of the ruby and sapphire gemfield at Pailin, Kampuchea [Cambodia] (Jobbins *et al.,* 1981) and the sapphire deposit at Chanthaburi-Trat, Thailand (Keller, 1982). Not only are the host basalts of a similar composition, but they also contain nodules and corroded megacrysts of like types. The origin of the sapphires from these SE. Asian localities is regarded as of probable mantle origin (Barr *et al.,* 1978, 1979) as are the Loch Roag sapphires (Upton *et al.,* 1983). The major difference between the deposits is that whilst the Pailin and Chanthaburi-Trat deposits are derived from source rocks formed as a result of outpourings of Tertiary basaltic lavas from volcanic vents and dykes, the Loch Roag deposit is the result of late Palaeozoic intrusive igneous activity and apparently confined to a small area producing *in situ* crystals. A summary examination of the surrounding area revealed one other dyke, but this was not wide enough to have a coarse central core. Because of glaciation, some 10 000 years ago, there can be little likelihood that gem-bearing gravel deposits will exist. Examination of gravels in a nearby burn did not indicate that gem concentrates had formed in the post-glacial period.

Similarities also exist with the 'nodule province' alkali basalts found in Australia at Chinaman Peak, Queensland, and Hill End, New South Wales (Wass *et al.,* 1976). There, corroded corundum (sapphire) megacrysts have been found in Tertiary volcanic plugs and flows respectively. These Australian sources are not worked for sapphires because of the relative rarity of *in situ* crystals, the commercial sources being limited, as with the Kampuchea and Thailand deposits, to alluvial concentrates such as those at Anakie, Queensland, and Inverell, New South Wales.

At Yogo, Montana, U.S.A., sapphires are mined from a Palaeozoic alkali basalt dyke. This is the only mine of its type and one of the very few mines where sapphires are actually extracted from the source rock. The Yogo dyke, whilst being similar in composition to the Loch Roag dyke, does not show the same lithological features. There are no ultra-basic nodule xenoliths, and the rock is essentially fine-grained without megacrysts of the types found in the previously described areas. Most of the sapphires from the Yogo deposit are small; crystals or fragments weighing more than a few carats are extremely rare and the majority of the cut stones weighed less than one carat (Clabaugh, 1952). The origin of the sapphires differs from those at Loch Roag in that it is attributed to the recrystallization of aluminous rich mudstones picked up at depth by the intrusion (Blodgett, 1981). The Yogo sapphires have a characteristic tabular habit similar to that of the Loch Scridain, Mull, Scotland sapphires, which are derived from baked high alumina shales (Richey, 1961). Yogo sapphires also have a very thin dark spinel coating not found on Loch Roag sapphires.

CONCLUSIONS

The Loch Roag sapphire occurrence strongly resembles those in SE. Asia and Australia, the major difference being the age and type of emplacement; however, the paragenesis is probably the same for them all.

For Scottish mineralogists and gemmologists this is an exciting find, providing as it does gem crystals of cuttable size. However the limited amount of sapphire-bearing rock in this pinch and swell dyke and the scarceness of the sapphires within it suggest that this will be relegated to the 'other occurrences' section in textbooks.

If, as Upton *et al.,* (1983) suggest, these gems are derived from the break-up of peraluminous pegmatoids in the upper mantle or lower crust, then, bearing in mind the loch, rock and bog topography, it is not inconceivable that other similar, and perhaps wider, dykes may lie hidden beneath the thick peat overburden waiting to be discovered. It was only by chance that this dyke was exposed while cutting an access track to peat diggings, for there is no trace of it on the surface.

ACKNOWLEDGEMENTS

I am very grateful for the help given to me by Mr Peder Aspen, of the Geology Department, Edinburgh University, both for the loan of specimens and for his useful comments during the preparation of this paper. Thanks are also due to Mr Hugh Crawford, F.G.A., for faceting the cut stone.

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[*Manuscript received 26th March, 1984*]

COMPOSITION, PROPERTIES AND ORIGIN OF A NEW TYPE OF HAEMATITE

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ABSTRACT

A new type of haematite which has recently come into use in the gem cutting industry is mineralogically characterized. The new type of haematite ore consists of granular haematite as a main constituent and of magnetite, martite and gangue minerals as minor constituents. The new type of haematite rock originating from Brazil has an Fe content of 69% Fe. Iron ores similar or identical in chemical and mineralogical composition are known and were mined as 'high-grade haematite' for a long time from different localities, e.g., from Quadrilátero Ferrífero area near Ouro Preto, Minas Gerais, Brazil.

INTRODUCTION

In recent months cut and rough material of an obviously new haematite type appeared on the market. Some of the properties of this new type of haematite are different from those of the material used up to now in the gem cutting industry, and, therefore, the attention of the trade was attracted to the new material. The haematite from England or from Morocco, which commonly was used up to now by the gem cutting industry, has a reddish or reddish-brown streak and does not show magnetism. In contrast to this old type, the new type of haematite is bluish grey in colour with a dark brown streak and an evident reaction to the magnet. In addition, the new type of haematite has a granular texture and does not show the radial fibres of orbicular haematite (glaskopf) used in the past.

Due to the properties of the new haematite material mentioned it was assumed by some dealers that the new product might not be haematite but magnetite or even an artificial product. In addition, in some certificates, the new material was indicated as an 'artificial product with a silicon-like binder' or as 'reconstructed haematite' (sintered product of magnetite and haematite as mentioned by Schlossmacher (1969)). In contrast to this certification, the new material was described by Fryer *et al.* (1984) as pure granular haematite. However, no additional details of the properties and composition of the material and no information on its origin are

ISSN: 0022-1252 XIX (4) 343 (1984)

available. In the present paper the investigations performed at Heidelberg of this new material are described, which make a more detailed description of the composition of this new haematite ore available.

Materials and Methods

For mineralogical characterization of the new haematite type, several cut and polished beads were supplied from different firms in Idar-Oberstein, and occasionally also rough samples of the ore were made available.

For the determination of present phases a great number of samples were investigated by x-ray powder diffraction techniques (Debye-Scherrer cameras, powder diffractometer). Qualitative and quantitative chemical analyses were carried out by electron microprobe, and, for ore microscopy in reflected light, some polished sections were prepared.

Results

All samples investigated, which were assigned to the new type of haematite, consist of granular haematite as a main constituent (Figure 1), which is distinctly different from the orbicular type of haematite (glaskopf) with radial haematite needles or fibres as used by the gem industry in the past. A chemical iron determination of the rough haematite ore resulted in an iron content of 69% Fe, which corresponds to an extremely pure type of iron ore. In all samples investigated by ore microscopy a typical metamorphic fabric with granular haematite and various amounts of minor constituents as magnetite, martite (an alteration product of magnetite with haematite lamellae) and gangue minerals was observed (Figure 1). However, the main constituent in all samples was haematite, which was highly predominant over the content of magnetite, martite and gangue minerals. In one sample, goethite also was determined. By qualitative investigations of the gangue minerals by electron microprobe the rock samples were found to contain Al silicates and K-Al silicates (presumably clay minerals), and Ca phosphates (presumably apatite). The minerals mentioned and their intergrowths are shown in Figure 1.

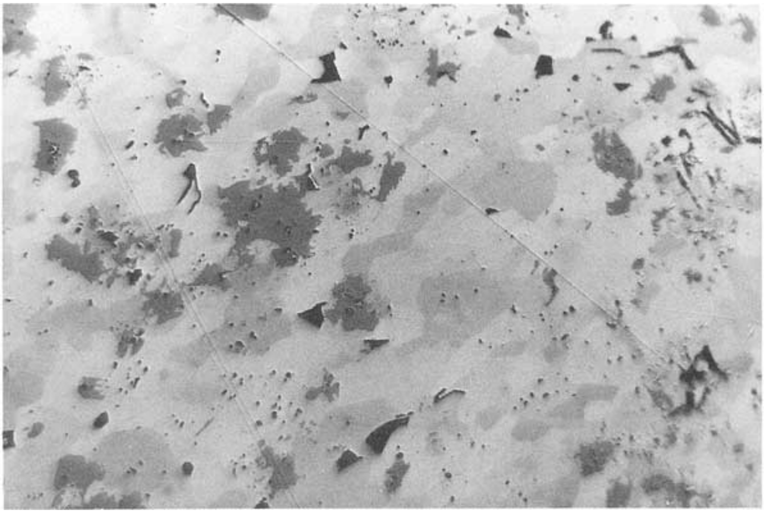

FIG. 1. Photomicrograph of polished section of high-grade haematite ore from Brazil. Greyish-white and light grey: haematite; dark grey: magnetite; black: gangue minerals and voids. (Oil immersion, not exactly crossed nicols, width of the photo approximately 0.35 mm.)

Discussion

As we were informed by the trade, the rough iron ore of the new haematite type originates mainly from two mines in Brazil; however, the exact locations of the mines were not given. In a communication of the Paris Chamber of Commerce, the localities Itabirito and Mariana are mentioned. Both are situated in the mining district of the so-called Quadrilátero Ferrífero near Ouro Preto, Minas Gerais, Brazil. In this mining area, a massive type of haematite ore is known and has been mined for a long time. Due to its mineralogical composition (predominantly granular haematite with admixtures of magnetite, martite, and gangue minerals), its fabric and iron content of 69%, the new type of haematite ore used in the gem industry is similar to, or almost identical with, a massive haematite ore described by various authors from Quadrilátero Ferrífero (e.g., Dorr & Barbosa, 1963; Dorr, 1964, 1965; Reeves, 1966; Eichler, 1976). Therefore, the information of the trade about the origin of the new type of haematite (Brazil) is consistent with the literature about the massive haematite rock, which is mined in large quantities from various localities in Brazil. For these iron ores with an iron content that averages more than 66% Fe the term 'high-grade haematite' is used in literature (Dorr, 1965).

The magnetic properties of the new type of haematite have to be assigned to the haematite constituent of the ore itself or to its magnetite admixture. On one side, pure haematites without magnetite admixtures are known from different localities, which are distinctly magnetic (Ramdohr, 1980). On the other side, the magnetite constituent of the ore is sure to produce a distinct magnetism.

Though in the samples supplied up to now for investigation purposes no artificial product was found, the use of various materials under the trade name 'hemetine' or 'hematine' as a haematite substitute has been known for a long time. Therefore, materials of unknown origin with questionable properties should be given to one of the gem testing institutes for investigation.

In summary, it could be established that in all properties and composition the new type of haematite ore used now in the gem industry corresponds to a high-grade haematite ore as described from various localities in the world, e.g., from different mines in Quadrilátero Ferrífero, Brazil. The presence of an artificial product was not proven in the material supplied up to now for investigation.

In the last meeting of the nomenclature commission of CIBJO in March 1984 in Milan, Italy, it was decided that for the new type of haematite with 'distinct content of magnetite and martite' the name haematite may be used without any additional remarks (K. Wild, personal communication).

Investigations of a Haematite Imitation

During the investigations of haematite ore from Brazil described in this paper, a haematite substitute of unknown composition was also supplied. Using electron microprobe and x-ray powder diffraction, the material was determined as elemental silicon. From this result, the low density of 2.33 g/cm^3 of the substitute as compared with 5.2—5.3 g/cm^3 for haematite is understood. As learned from further inquiries, the material was occasionally cut during the past 10 years. The rough material is thought to be an impure by-product of the semiconductor industry.

ACKNOWLEDGEMENT

The authors are grateful to Mr E. Bunn, of R. Jerusalem & Söhne, Idar-Oberstein, for information about the problems discussed.

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[*Manuscript received 12th June, 1984.*]

SIBERIAN DIAMONDS

By R. V. HUDDLESTONE

(being the substance of a lecture delivered to the Gemmological Association of Great Britain at the Central Electricity Generating Board Theatre, Sudbury House, Newgate Street, London, EC1, on 19th October, 1983.)

Diamonds from the Ural Mountains in Russia have been found in small quantities since 1829. Dramatic discoveries by Larisa Popugayeva near Daaldinsk on the Siberian platform in August, 1954, were to prove the opening of a new chapter in the history of the diamond world.

In just 29 years the Soviet Union has become the world's largest diamond producing country. I estimate the total production of diamonds since the Yakutalmaz (Yakutdiamond) company was formed in 1957 to be in excess of 169 million carats, and it is now running at about 10.5 million carats annually—around 25% of total world production. Some observers claim production is 16/17 million carats. I have never seen any evidence for more production than is quoted in my Table 1.

Who were the people involved? What were the difficulties encountered? What were the milestones along the way? How has the market been affected and what of the future? With the aid of some interesting statistics I intend to show new insight into the subject of Siberian diamonds and the amazing developments that I have seen unfold in the last quarter of a century.

In the early 1700s stories were circulating that 'fire stones' had been found in Siberia. In 1736 an early scientist, M. W. Lomonsov, said in St Petersburg that diamonds existed in Siber (Mongolian for sleeping land) and would be found in quantity if men sought with diligence.

The first properly documented diamond in Russia was found on July 5th, 1829, near Krestovozdvizhensk in the Ural Mountains. Between 1829 and 1939 only about 100 stones were found. Alluvial deposits were later found in the River Vishera (1939), Basin of lower Tungusska (1948), River Vilyuy (August 1949), River Markhi (1950/51 Bear Expedition), River Malaya Botuobiya (1953) and Rivers Shugra and Northern Kolchin (early 70s). But what the geologists were seeking was a primary deposit (pipe).

ISSN: 0022-1252 XIX (4) 348 (1984)

TABLE 1. Estimated Production

Year	Total Carats	Gem Carats
Year: 1959	800000	Approx 20%
1960	950000	,,
1961	1100000	,,
1962	N.A.*	,,
1963	N.A.*	,,
1964	4000000	,,
1965	5000000	,,
1966	6000000	,,
1967	7000000	,,
1968	7000000	,,
1969	7500000	,,
1970	7850000	,,
1971	8800000	,,
1972	9200000	,,
1973	9500000	,,
1974	9800000	,,
1975	9500000	,,
1976	9500000	,,
1977	10300000	,,
1978	10550000	,,
1979	10700000	,,
1980	10850000	,,
1981	10600000	,,
1982	10600000	,,
Total	169300000	33860000

Average size of rough just over half a carat. Production Agreement 1960 (De Beers). 1972 Modified. Mir pipe exploitation costs paid off and profitable after 12/13 years from opening.

*Figures for 1962 and 1963 are not available but are assumed to be the same as for 1961 (a conservative assumption).

As long ago as 1937 Vladimir Sobolev (Figure 1) at the 17th International Geological Congress in Moscow had predicted that primary deposits would be found on the Siberian Platform between Lake Baikhal and the Arctic Ocean over 1600 km from Moscow and near the Arctic Circle. In 1941 Sobolev made a full report to Gosplan, the organization responsible for all the five year plans for development of the country. World War II stopped further development.

During 1948 some alluvial deposits were found in the basin of the lower Tunguska river, and Sobolev's plan started to work.

FIG. 1. Vladimir Sobolev.

Gregory Finstein, a Jewish geologist, panned six diamonds on August 12th, 1949, in the 2500 km long Vilyuy river, but dredging did not commence on a commercial scale until 1957. Under the over-all development plan, each year would see a fresh expedition in the search for diamonds, which had now become of strategic importance to Russian industry.

During the Amaka (Bear) expedition in 1950/51, alluvial deposits were found in the Markhi tributary of the Vilyuy river. Under the guidance of A. P. Burov and Professor A. A. Kukharenko, two female geologists Natalya Sardatskikh and Larisa Popugayeva were prospecting, when with great excitement they established that pyrope garnets had been found in their samples (1953)—one of the indicator minerals for primary deposits of diamonds.

During the three to four month summer period in the province of Yakutia the ground unfreezes to a depth of two metres and the tundra becomes a mosquito infested swamp, but this is the only time when conditions are good enough for exploration work, so in that period of 1954 Larisa went out to the new expedition near Daaldinsk. Her painstaking work was rewarded with the find of the first pipe, named Zarnitsa (Thunderflash).

In June 1955 the authorities learned of their success when Yuri Kabardon radioed the message 'HAVE STARTED SMOKING PIPE OF PEACE, TOBACCO GOOD'. The first primary source (pipe) had been discovered not far from where Larisa Popugayeva had walked a few months before. This pipe was named Mir (Peace). I frequently refer to this find as the big hole of Siberia and predict that history will rate this find as being as important as the big hole at Kimberley. There was talk of the Mir pipe production being expected to level off after a decade, yet the mine was only a few years into production. Some pipe mines have operated for a century or so and I expect that the Mir pipe will be a prolific producer for decades to come. In the same year Udachnaya (success or lucky) was discovered and there followed Sputnik 1959, Aikhal (glory) in 1960 (see Figures 2 & 3) and Internationalnaya 1969.

Some geologists began to wonder how the Siberian mine could produce five times more than a comparable mine in South Africa. Geologists now know that there are 450 specific kimberlite pipes on the Siberian platform and that a number of these pipes and some alluvial (secondary) deposits are being worked. Kimberlite is the host material for diamond in the pipe. There are thousands of volcanic pipes in the world. Hundreds contain kimberlite and a few contain diamond in economic quantities—see Tables 2 & 3 and Map.* From this information we see that size of pipe is not

FIG. 2. Workers at Aikhal (Glory) Mine about 1960.

*The Map is printed on the back of Table 6, inserted between pp. 356 and 357.

FIG. 3. The Diamond Road from Aikhal to Mirny.

necessarily an indicator of yield from the pipe, Mir being 23 in the size league while Kimberley ranks 26.

By assessing the age of kimberlite using the method either of U.Pb (Uranium-Lead) dating of zircons or of Rb-Sr (Rubidium-Strontium) dating of micaceous kimberlite matrix, it is possible to arrive at an approximate age of the host materials in a particular pipe and from this deduce that the diamond content is as old as the host material, and probably on current thinking the diamonds are older than the kimberlite. The age of some Siberian deposits, along with comparisons from other continents, can be found on Table 4.

In 1957 Yakutalmaz Trust Company was formed, and in the same year they began to build the town of Mirny. Later a road was built to the town from the Lena River—1958 saw the commencement of construction of a hydro-electric power station on the Vilyuy River, 100 km upstream of Mirny (peaceful). Victor Tikhonov was appointed as the manager of the Mirny diamond administration. Under his guidance production started at Mir in 1958, three years after discovery (see Figures 4, 5 & 6). Udachnaya started producing in 1968 some thirteen years after discovery.

The gestation periods appear to be very long, but when the operating conditions are considered the achievement at Mir (three years) was a heroic feat of man's tenacity in the face of seemingly

TABLE 2. The world's largest known diamond pipes

Order	*Name*	*Country*	*Hectares*	*Acres*
1.	Mwadui	Tanzania	146	360.77
2.	Orapa	Botswana	106.6	261.93
3.	Pipe, Ellendale B	Australia	84	207.48
4.	Camafuca Camazambo	Angola	67.5	166.73
5.	Catoca	Angola	66.2	163.51
6.	Jwaneng	Botswana	54	133.43
7.	Talala	Zaire	50	123.50
8.	Pipe A, Ellendale	Australia	46	113.62
9.	AK1, Argyle	Australia	45	111.15
10.	Pipe C, Ellendale	Australia	36	88.92
11.	Premier	S. Africa	52	79.07
12.	Zarnitsa	Siberia	21.5	53.13
13.	Udatchnaya	Siberia	20	49.40
14.	Kao	Lesotho	19.8	48.90
15.	Massif I	Zaire	18.6	45.94
16.	Finsch	S. Africa	17.9	44.23
17.	Letsang-la-Terai	Lesotho	15.9	39.27
18.	Pipe D, Ellendale	Australia	13	32.12
19.	Koffie-fontein	S. Africa	11.1	27.43
20.	Jagers-fontein	S. Africa	10.0	24.71
21.	Camatue	Angola	9.3	22.98
22.	Leningradkaya	Siberia	9.0	22.23
23.	Mir	Siberia	6.9	17.05
24.	Dainyaya	Siberia	5.4	13.34
25.	De Beers	S. Africa	4.8	11.86
26.	Kimberley	S. Africa	3.6	8.90
27.	Nevidimka	Siberia	2.5	6.18
28.	Dolgodjdannaya	Siberia	2.5	6.18
29.	Ossennyaya	Siberia	1.6	3.95
30.	Molodenjnaya	Siberia	1.5	3.71
31.	Blaauwbosch	S. Africa	1.5	3.71
32.	West End	S. Africa	1.4	3.46
33.	Geophysitchskaya	Siberia	1.2	2.97
34.	Polyarnaya	Siberia	1.0	2.47
35.	Spsuedmmyaya	Siberia	0.5	1.24
36.	Malyutka	Siberia	0.4	0.99
37.	Roberts Victor	S. Africa	0.4	0.99

impossible odds. Yakutia, the coldest province in Siberia, has winter temperatures down to minus 70 °C, rising to 60 °C in the short summer—a range of about 130 °C from one extreme to the other. Under winter conditions iron bars snap like matchsticks, ordinary machinery becomes unusable, and rubber tyres break like brittle crockery (Figures 7 & 8).

TABLE 3.

Relative sizes of some Kimberlite Pipes

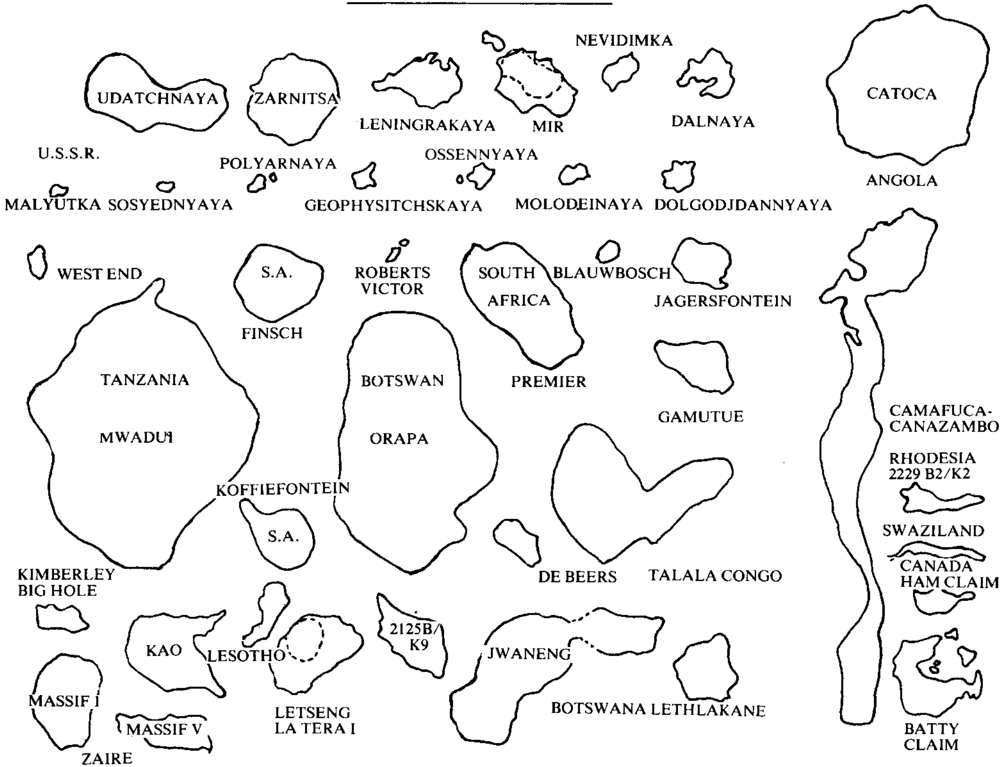


TABLE 4. Ages of diamond deposits

Using an age assessment technique based on U.Pb (uranium-lead) dating of zircons, G. Davies, of Geophysics Laboratory, Carnegie Institute, Washington, D.C., and other scientists, estimate the age of some of the Siberian kimberlite as follows:

	Million years
Slyudyanka	148
Pozdnyaya	220
Internatsionalnaya	360
Mir	362
Druzhba	411
Amakinskaya	451
Brazilian Conglomerates	1000
Indian Conglomerates	500
Tanzanian Kimberlites	60
West African Kimberlites	1100
Witwatersrand Conglomerates	2600
Premier Mine	1700
Kimberley Area	90

Using another dating method Rb-Sr (rubidium-strontium) used as the base for dating micaceous kimberlite matrix—the two methods do not always produce the same result:

Premier and National (Transvaal)	1250 and 1180 my respectively	
Finsch (Cape Province)	130-170 my	
Swartruggens (Transvaal)	150 my	
Njoio and Tchivira (Angola)	130 my	
Colossus (Central Rhodesia)	490 my	
Wesselton (Kimberley)	83-84 my	similar to U.Pb ages for these pipes
Monastery (South Africa)	90 my	
Roberts Victor (South Africa)	127 my	

My files contain similar data on another 40 locations whose ages range from 33.9 million years to 2600 million years.

They have since developed special tyres made of polystyrol isoprendivinyl. Buildings have triple doors to preserve internal heat. Some steels shatter or lose hardness, so when building a bridge over the Lena river they used metal pipes filled with kerosene. When working under such extremes of cold it seizes the throat, covers the face with hoar frost and sticks the eyelids together. The first geologists even had to chop their bread with an axe.

According to the 'Institute of Permafrost' in Yakutsk the ground is frozen down to a depth of 5000 feet, which the scientists call 'permafrost' but the locals call 'frozen cement'. There are 22 hours of sunshine during the three summer months, which melts the top six or seven feet and melts the swamps down to about thirty feet. This brings out millions of large *gnoos* (mosquitoes) so that protective clothing (netting) has to be worn (Figures 9 & 10).

The permafrost is so intense that in March 1983 when a 10 000 year old Woolly Mammoth carcass was uncovered, it was so fresh that it was fed straight to the sled dogs after de-icing. The nearest railway, the Trans-Siberian, is over 1000 km away. Supplies first came in by hydroplanes fitted with skis and later by helicopters from the railway depot.

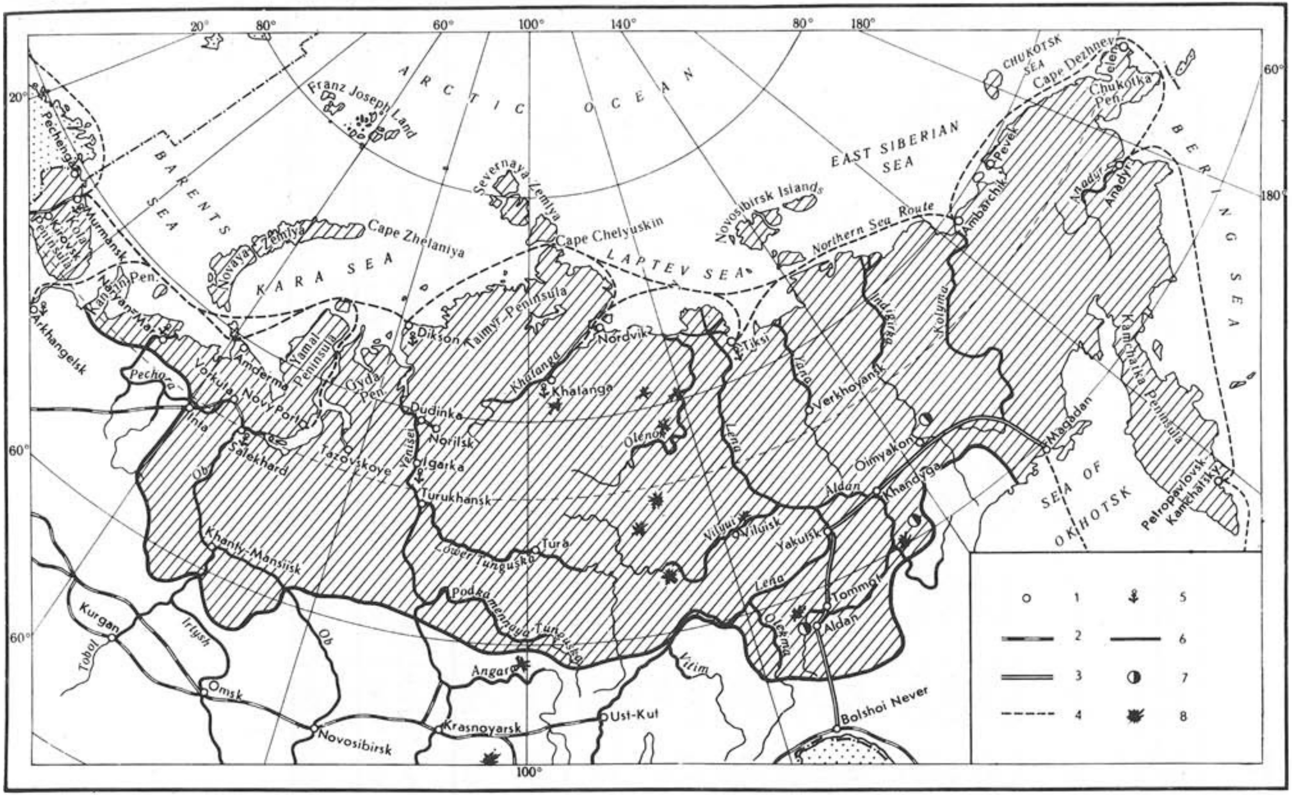
The area is forest (tundra) and swamp. Rivers are ice-free only for about three months of the year. There is now an anchorage at Lensk, and great truck caravans follow the highway that has been constructed. Consider the sheer size of Siberia and the inaccessibility of the mines, which are further than London is from Moscow. The U.S.S.R. has eleven time zones, and there is about ten hours time difference between East and West. The Siberian peoples have over thirty languages. Yakutia has an average of two people for each square kilometre.

FIG. 4. Mirny town, Yakutia, about 1969 (built for the diamond workers).

TABLE 6. World Production of Diamonds
(Thousands of carats)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Zaire	14752	12504	12432	13155	13140	13423	14087	12520	13390	12940	13000	12000	12000	11213	9683	8734	10235	7500	7500
South Africa	4450	4945	6135	6803	7433	7863	8112	7031	7395	7565	4926	3900	4000	8033	7726	8384	8520	9546	9194
Namibia (S.W. Africa)	1541	1646	1759	1701	1722	2013	1865	1648	1596	1600	1570	1600	1600	2001	1898	1653	1560	1248	1014
Ghana	2668	2273	2819	2537	2447	2391	2550	2562	2659	2317	2573	2000	2000	2300	1950	1253	1258	836	836
Sierra Leone	1463	1489	1462	1400	1410	1989	1955	1935	1800	1404	1670	1500	1500	450	707	885	592	486	485
Angola	1148	1156	1268	1289	1667	2022	2396	2413	2155	2125	2100	2100	2100	353	400	841	1480	1400	1400
Central African Rep.	442	537	540	520	609	535	482	437	524	380	450	450	450	301	284	315	342	312	277
Ivory Coast	200	198	184	175	187	202	213	326	334	300	320	320	320	65	**65***	48	—	—	—
Tanzania	664	828	947	987	683	777	703	837	652	501	550	550	550	375	2293	314	274	217	220
Liberia	571	540	555	543	750	746	812	809	890	817	636	650	650	326	308	302	298	336	335
Guinea	72	72	72	50	50	72	74	74	80	80	80	80	80	**80**	80*	85	39	38	40
Botswana	—	—	—	—	—	200	464	822	2403	2416	2718	2500	2500	2691	2785	4394	5101	4961	7769
Venezuela	115	91	85	69	114	194	509	499	456	778	700	750	750	700	738	803	721	490	500
Brazil*	175	175	150	160	160	160	150	150	155	160	160	250	352	200	200	620	667	1089	1150
Guyana	109	113	96	97	66	52	61	48	49	52	50	50	50	17	17*	16	10	10	9
China	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N/A	1800	1900	2000
Australia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	48	205	557
Other W. World	100	110	120	130	140	150	160	170	180	190	190	190	190	65	65*	83	83	84	71
Total W. World +	28470	26677	28624	29616	30578	32589	34593	32281	34718	33625	31693	28890	29092	29170	29399	28730	33027	30658	33357
U.S.S.R.*	4000	5000	6000	7000	7000	7500	7850	8800	9200	9600	9800	9500	9500	10300	10550	10700	10850	10600	10600
Total World	32470	31677	34624	36616	37578	40089	42443	41081	43918	43125	41493	38390	38592	39470	**39949***	39430	43877	41258	43957

Source: USBM, IGS
N/A = Figure not available
*Estimate
+ Including statistical discrepancies



(after S. Pokshishevsky, "Geography of the Soviet Union").

Map showing Siberian Diamond Localities.

1—towns; 2—railways; 3—main motor roads; 4—sea routes; 5—some important arctic ports; 6—navigable sections of rivers; 7—gold deposits; **8—diamond deposits**

FIG. 5. Workers' flats at Mirny (summer): about 1980.

FIG. 6. Mirny township (winter): about 1980.

FIG. 7. Building one of the recovery plants in permafrost conditions at Mirny.

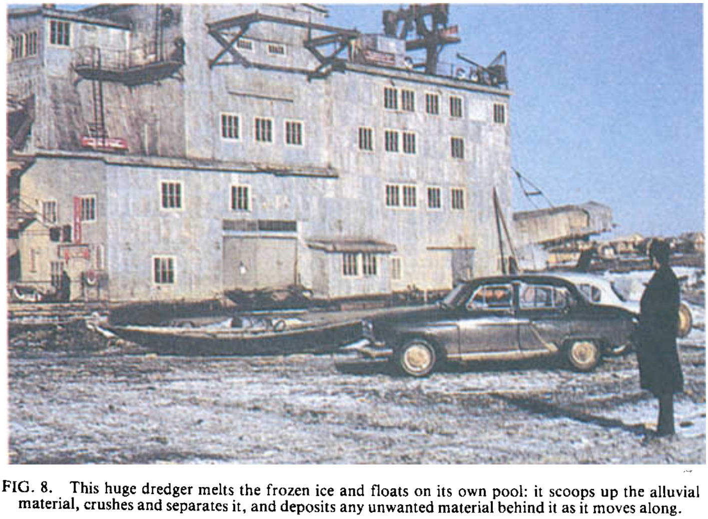


FIG. 8. This huge dredger melts the frozen ice and floats on its own pool: it scoops up the alluvial material, crushes and separates it, and deposits any unwanted material behind it as it moves along.

FIG. 9. Geologists prospecting for diamonds in the short summer period.

FIG. 10. Geologist prospector on the tundra (normally frozen waste) in summer: note the mosquito net.

J.Gemm., 1984, XIX, 4

FIG. 11. Mir pipe, the big hole with opencast galleries.

FIG. 12. Taiga (deciduous forest), Lena River, Lower Yakutia.

The Siberian platform contains three of the world's longest rivers, the Ob/Irtysh at 5410 km, the Yenisi/Angara/Selenga at 5075 km and the Lena at 4400 km. There are over one million lakes, and Lake Baikhal as well as being the deepest in the world at 6365 feet contains 20% of the world's fresh water. During the winters, one of the main motor-roads in the diamond areas crosses this lake on the ice.

In this remote and harsh environment, where it is colder than the North Pole and where snow shoes and reindeer sleds are still the normal mode for personal travel, one Yakut man claims he saw aircraft before he saw his first car and the telephone before there was a mail service. There is no scheduled service to the mines; it takes two hours to fly from Yakutsk to Mir. When drilling holes for blasting they use steam and heat funnelled from the engines of Concordski to prepare the rock for blasting.

It has been said that the mine lacked the facilities necessary to sort and separate large quantities of diamonds. Some years ago Alexei Nicolaievich Stepanov helped to build pilot plant no. 1 at Mirny. Because of his proven skills he was appointed Designer/Manager of plant no. 2 and subsequently became Director of plant no. 3.

The diamond processing/separating plant has been described as the world's largest and is a monstrous, aluminium sheathed, windowless fourteen storey high monolith. The cavernous interior houses gigantic unbelievably noisy machinery which is almost totally automated. The separating processes operate round the clock day and night and sometimes produce enough diamonds in one day to pay the annual operating costs of the plant.

There are now at least seven processing plants in the Mirny area, all of which use vast quantities of water which has to be heated and kept hot in order for the machinery to work. A steel structure built into permafrost ground warms up during the 22 hour days of sunshine in the summer, the metal structure gradually melts the ground and the building slowly sinks. Sometimes they build on stilts to allow biting Siberian wind to take the heat away from the steel.

Due to the problems of constructing, operating and maintaining the engineering plant at the Aikhal (Glory) mine, they decided to build a 'Road' through the tundra from Aikhal in the arctic circle to Mirny, and they set up a team of rugged 30-ton trucks to carry the diamondiferous material on an all year, round-the-clock relay between the two camps, in order to process it in the relatively better environment at Mirny. The really remarkable fact is that the trip is 250 miles each way. The truck drivers really earn their £1000 plus per month! (see Figures 3, 11 & 12).

By 1972 there were probably about 60 000 people employed in the Mirny area, over 50% of them being female, which sounds like a good arrangement to me! The diamond town of Mirny has forty-six nationalities amongst the workers. The fully electrified town has its own T.V. and radio station and a daily paper. There is a hospital, a brewery and a Vodka distillery, sixteen schools of one type or another and the technical college has about 1000 students. The people live in five to seven storey blocks, which are tinted in differing colours on the outside (see Figures 5 & 6).

There were plans to build a microtown at Udachny, and the planners were thinking of a dome or pyramid structure to cover the whole town but eventually this became a conventional set of structures with a sealed-in environment.

Generally wages are about two and a half times more than equivalent jobs nearer Moscow. Because of the harsh conditions there are bonuses to be earned: 40% extra if North of latitude 58°, 50 and 60% for the Arctic Circle, and 70-100% for the high Arctic. A bonus is paid for remoteness from cities and there is an extra 10% for each year that a worker stays beyond the original agreement.

There are many more facets to producing diamonds in Siberia, where the slang term ice takes on a new meaning.

The world average size of rough diamond produced when I entered the trade in 1944 was about 0.75 to 0.80 ct and gradually dropping. Russian rough diamonds appear to average about 0.50 to 0.55 ct. However, as with all deposits some large Russian stones do turn up. See Table 5: the (unnamed) stone of 120 ct I handled a number of times in my capacity as a technical consultant. That stone was of a good colour, but it exhibited optical stress haloes in the heart of the stone which caused the owner to consult with me. In due course the stone was successfully cut into a number of unnamed stones.

Diamond statistics are notoriously difficult to obtain. Most diamond mining statistics do not include precise gem and industrial production figures, but a generally accepted ratio is 20% gem, 80%

TABLE 5. Large Named/Unnamed Rough Siberian Diamonds

Carats	*Name*	*Comments*
37.56	"Toktogul" (Person's Name)	Found at Mirny
38.72	"Zlata Praga" (Gold Splendour)	Found at Mirny
44.62	"Gornyak" (Miner/Mine-worker)	Found at Mirny
46.36	"Letni" (Summer)	Found at Mirny
51.66	"Valentina Tereshkova" (First Woman Cosmonaut)	Found at Mirny 1963
71.50	"50 Let SSSR" (Fifty Years of the U.S.S.R.)	Found at Mirny
80.66	"Progres" (Progress)	Found at Mirny
105.98	"Mariya" (Name of the best worker at Mirny)	Found at Mirny 1966
114.37	"Bolshaya Medveditsa" (Big/Great Bear)	Found at Mirny
119.55	"Professor Odintsoy"	Found at Mirny 1981 Colourless/Transparent
*120.00	Unnamed	Found at Mirny 1974/5
135.12	"Vetki Pochin" (Great Initiative/Beginning)	Found at Mirny
171.15	"Revolyutsioner I. Babushkin" (I. Babushkin, Revolutionary)	Found at Mirny
200.00+	"50th Anniversary of Aeroflot"	Found at Mirny 1973
232.10	"Svezda Yakuti" (Star of Yakutia)	Found at Mirny 1973/4 Brownish, transparent, slightly convex facets and rounded edges, no visible inclusions

All the stones (except*) are in the Chamber of Diamonds of the U.S.S.R. in the Treasury at the Kremlin in Moscow.

25.52	"Brilliant"	Found at Mirny Polished—an unusual shape of emerald cut

industrial. The decision as to a specific stone being classed as gem is more commercial than technical. Some of the factors being the obvious one of colour, clarity and shape. However, as the value of gems has risen over the years the dividing line between gem and industrial has been sinking. Many rough stones now sold as low quality gems used to be classed as good industrial. If we take the estimated 'Russian production' from 1959 to 1982 as 169 300 000 ct, then 20% of that gives us a figure of 33 860 000 during that 24 year period. (See Table 1).

Using other statistics, gathered over the years: during the 19 year period 1964 to 1982 world production of gems was estimated at about 150 007 400 ct, and Russian production of gems was estimated at about 32 850 000 ct or 21% of world production of gems (Table 6*).

During 1982 an article by Edward J. Epstein in *The Sunday Times* made some startling claims about Russian diamonds. He claimed that the Russians were making synthetic diamonds in Moscow and the Ukraine and selling them through the normal channels in London. The newspaper did not allow a reasoned riposte to these claims, which appeared to give them more credence, causing a furore in the trade. His claims are based on the fact that Russian stones have a greenish tint, sharp angular edges, uniform shape and size, and that Soviet scientists had succeeded during the late 1960s in making synthetic gem diamonds up to half a carat in size, yet they were still buying some industrial stones from the West.

Rough diamonds from all deposits can be classified in three basic colour ranges. Cape series (yellow), brown series and green series. Some deposits tend to have a preponderance of one colour: this has no significance to synthetic gem diamonds. Rough diamonds from pipes (primary sources) commonly have octahedrons with sharp angular edges 'brightly polished': they are called glassies and have no significance to synthetic gem diamonds. They are uniform in shape and size; so are the productions from some other mines (Figures 13, 14, 15, 16, 17 & 18).

If the Russians were able to control the manufacturing process to such a degree as implied, then they would also know that the perfect octahedron is not the best shape to make because there is more weight loss when cutting the rough of that shape because of its sharp angular edges. I believe that the ever rising tide of Russian diamonds should not therefore be viewed with such apprehension as has now been generated, and in years to come there could be comforting signs of relief that there will be enough gem stones there, to sell, when the demand returns to the market place.

*Inserted between pages 356 and 357.

FIG. 13. Siberian 'glassy' diamonds (with scale in centimetres).

FIG. 14. Octahedral 'glassies' from Mir.

FIG. 15. Octahedral 'glassy' diamond (about ¾ ct) in kimberlite, from Mir pipe. (Author's collection).

FIG. 16. Chrome diopside inclusion in Siberian diamond.

FIG. 17. Diamond-bearing eclogite with graphite, from Mir (specimen 2 cm long).

FIG. 18. Striated diamond-bearing eclogite from Udachnaya pipe (specimen 3.5 cm long).

Synthetic industrial diamonds were first synthesized by A.S.E.A. of Sweden in 1945 and shortly after that by G.E. of America and De Beers in South Africa and much later by the U.S.S.R. Such stones are now made in most industrialized countries including Russia and China. The Russian factories are based in Kiev, Leningrad, Moscow, Yerevan and Tashkent. There are still some processes in industry where the natural industrial diamond is far superior to the synthetic industrial, and this is why the Russians like everyone else still need to buy on the open market. Even today there are some industrials that are in short supply from natural sources.

In 1970 G.E. of the U.S.A. announced the successful production of synthetic gem diamonds and just a few years ago a story came out that the Russians had made gem diamonds prior to that date. I have never seen this story scientifically substantiated and for the moment it must lie along with a number of similar claims that the Russians were the first in other spheres of endeavour, whereas I believe the Siberian diamond endeavours are to be congratulated.

During 1974/5 I was offered the opportunity to test two of the G.E. synthetic diamonds, which had been cut and polished by Lazare Kaplan of New York. The (D.G.L.) laboratory in Hatton Garden, of which I was the director, carried out exhaustive non-destructive tests on the stones and in the report published were able to demonstrate differences between the synthetic and natural gem diamonds. One of the tests showed rod-like inclusions in the synthetic that we had not, ever, observed in natural stones, and the spectral response on our spectrophotometer was quite unusual: it also exhibited an extremely long phosphorescence decay time after exposure in a dark room to a 365 nm UV light source, which was then extinguished in order to observe the effect.

In 1982 on behalf of another laboratory I borrowed via the Royal Institution one of the stones, that was tested in 1974, and retested the stone for a programme on Télévision Française, (T.V.L.) with the same results. When perusing the records of both laboratories, I found that not one other diamond since 1974 has shown any of these features.

To create a synthetic industrial diamond in the laboratory needs pressures of over 7 million kPa simultaneously with a temperature of 1353 °C. These conditions must remain stable for many hours, which is not easy to achieve.

To create a synthetic gem diamond in the laboratory needs a pressure of over 21 million kPa and a temperature of 3020 °C. These conditions must be kept stable for nearly one week to produce one rough stone of about one carat. Recently I have spoken with a senior person at G.E., who confirms the view that even today the cost of producing a sythetic gem diamond is at the very least ten times greater than to dig it out of the ground.

As gemmologists will be aware every major gemstone has been synthesized—in the case of ruby and sapphire for over 80 years—and in each case it has increased the market awareness of the natural stone and created a secondary lower-priced market. So there should be no cause for alarm when synthetic gem diamonds do eventually come onto the market.

The diamond cutting and polishing industry in Russia has grown tremendously in recent years and there are cutting factories at Kiev, Moscow, Sverdlovsk near the Vishera River, and Mirny; this last factory is built of ferroconcrete and glass. It has been 'guestimated' that there are up to 10 000 diamond polishers in Russia, which is on a par with Antwerp and Israel for numbers, but it seems more probable that the numbers are in the region of 6000 polishers. One of the plants is so large that it employs about 2000 polishers under one roof. Traditional polishing techniques are used. The average size of polished diamond produced is between 25 and 30 points. Quality control appears to be very strict, and only the well made stones are sorted for export.

A number of times it has been rumoured that the Russians were dumping their polished diamonds on the market, because of the large quantities of Russian diamonds available. From the statistics it can be seen that for every five diamonds in the market place one of them could well be of Russian origin. When Lev Soldatov, a Muscovite who is the Director of the Yakutian Diamond Combine, was asked about dumping, he replied 'If we flooded the market, the ladies of the world would find that their diamonds would lose some of their value. We would not wish to raise the fury of womanhood. I am not sure that even the Soviet Union could cope with that'.

It is also probably fair to say that the marketing of the U.S.S.R. stones does not appear to be fine-tuned to the ebb and flow of normal market supply and demand and does not act quickly enough to reduce the flow when the market turns down. Of course external currency needs sometimes dictate selling policies.

Moscow appears to market the stones in a number of ways. Originally all output was sold through colleagues of mine. At other times (1960-1972) it was sold by contract through the Central Selling Organization. From 1972 that contract was modified. At the present time there are no contractual agreements. Due to the complex nature of our industry, substantial quantities of Russian rough still appear to find their way by devious routes through the C.S.O.

For a number of years now the Russians have retained substantial quantities of selected sizes of rough for their own polishing operations. The marketing of Russian polished stones is done through Russalmaz in Antwerp, Frankfurt and Geneva. Whatever else may be said, Russian diamonds have mostly been marketed in an orderly fashion, so much so that they have not upset or damaged the industry.

[*Manuscript received 9th March, 1984.*]

GEMMOLOGICAL ABSTRACTS

ALEKSANDROV (V. I.), BATYGOV (S. Kh.), VISHNYAKOVA (M. A.), VORORIKO (Yu. K.), KALABUKHOVA (V. F.), LOMONOVA (E., E.), OSIKO (V. V.). *Optical properties of strontium titanate crystals grown by the Czochralski method from a cold container.* Inorganic Materials, **19**, 2, 238-42, 4 figs, 1983.

Direct high frequency heating of the nonmetallic melt in a cold container has made it possible to grow $SrTiO_3$ by the Czochralski method in air. The colour of the crystals before annealing is determined by the thermal conductions of the growth process. M.O'D.

BAKOŃ (A.), SZYMANSKI (A.). *Morphological qualitative classification of synthetic diamond microcrystals.* Mineralogia Polonica, **13**, 2, 61-8, 30 figs, 1982.

A morphological classification is attempted for synthetic diamonds of different commercial brands, produced by static methods. Five distinct forms were determined for each of two parameters, and three typical grains representing each of the forms is illustrated. These photographs serve as a basis for the qualitative evaluation of diamond grains and allow the selection of an appropriate diamond abrasive for tools with different binders. R.A.H.

BROWN (G.). *Gem feldspars.* Wahroongai News, **18**, 4, 7-14, 1984.

A comprehensive account of all the gem varieties of this the largest group of rock-forming minerals. R.K.M.

BROWN (G.). *The Kashmir sapphire.* Wahroogai News, **18**, 4, 15-16, 1984.

A compilation of facts drawn from several sources on a sapphire often named but very rarely seen or authenticated. R.K.M.

BROWN (G.). *The Cowell nephrite province.* Wahroongai News, **18**, 5, 18-19, 1984.

Describes provenance and material of this large commercially viable deposit of nephrite on the Eyre Peninsular, S. Australia. Occurs in shades from yellow-green to dark green and black, the latter apparently the most valued. There is an estimated 4 million tonnes, 2% of which is thought to be of prime gem quality. R.K.M.

COLE (B.). *Collecting the unusual.* Lapidary J., **38**, 3, 412-3, 7 figs in colour, 1984.

Brief account of the travels and collection of Lowell Jones, a Missouri gemstone dealer. M.O'D.

FRYER (C. W.), ed., CROWNINGSHIELD (R.), HURWITT (K. N.), KANE (R. E.). *Gem Trade Lab Notes.* Gems & Gemology, **XX**, 2, 106-12, 23 figs (19 in colour), 1984.

A 'galaxy' of star inclusions of red goethite in amethyst and a piece of rock with one polished face, found to be partly cummingtonite-grunerite, are described and illustrated; coated diamonds have recently been arriving for test at G.I.A. labs despite legislation which prohibits the practice; natural dendritic holes in diamond resembled laser drilling; a greyish-lavender stone identified as diopside despite unusual colour, constants were normal; nephrite ducks had carved lines enhanced artistically by brown stains resistant to acetone but lifted by 10% HCl solution bead nephrite dyed green by substance similar to that used to dye green jadeite—all are described and illustrated. Realistic imitation 'mabe pearls' proved to be made from some kind of plastic; large flat bouton pearls, x-rayed on edge, showed lentil shaped cavity(?) nuclei, fluoresced strongly in x-rays and were therefore of fresh-water origin; other button pearls fluoresced weakly and were salt-water; a dimpled pearl x-rayed to show that a drilled nucleus had been used—possibly a product of experiments to produce a spherical Biwa pearl, or a Mississippi equivalent.

A fine multiple star quartz of 22 ct and another giant of 170 ct are illustrated, and a heat treated ruby cabochon had patches of blue fluorescence under short UV light; a Verneuil synthetic sapphire showed grain reflection planes similar to grain in diamond, possibly due to heat treatment, not typical of synthetic material—curved colour zoning was also seen; a black stone supposed to be from a meteorite proved to be spinel and not meteorite; a remarkable yellow-brown zircon cat's-eye is illustrated. R.K.M.

GUNAWARDENE (M.). *Identification characteristics of synthetic ruby made by Knischka.* Lapidary J., **37**, 12, 1700-6, 30 figs (29 in colour), 1984.

Translation into English of a paper first published in *Gold & Silver, Uhren & Schmuk,* **36**, 2, 1983. M.O'D.

HÄNNI (H. A.). *Die Echtheitsuntersuchung von Korund-Methoden und ihre Grenzan.* (The true understanding of corundum-methods and limits). Schweizer Uhrmacher und Goldschmiedezeitung, **106**, 5, 17-23, 10 figs (6 in colour), 1984.

Compares the various methods of testing natural and synthetic corundum with illustrations of inclusions and reference to the Ramaura synthetic ruby. M.O'D.

KOIVULA (J. I.). *The first-order red compensator: an effective gemological tool.* Gems & Gemology, **XX**, 2, 101-5, 6 figs (4 in colour), 1984.

An aid to microscopy now available in durable plastic sheet form. The red compensator either enhances of subtracts wavelengths according to its orientation relative to the subject examined. In polarized light this alters intensities of low order interference colours and makes inclusions, etc., more easy to locate. It can shorten exposure times in photomicrography and reduce vibration risks. R.K.M.

KOIVULA (J. I.), ed. *Gem News.* Gems & Gemology, **XX**, 2, 121-2, 1984.

Diamonds: a 260 ct yellow diamond found at Coromandel, Minas Gerais; India implements nationwide diamond exploration starting in Andhra Pradesh; diamond cutting starts in Philippines; Singapore opens own diamond exchange.

Coloured stones: Pakistan reports new emerald deposits found, aquamarine and topaz production continues; someone has rediscovered gem quality amethyst on Rhode Island and gem chrysoberyl at Greenfield, New York State; Zambia consortium is recruiting mining personnel to prospect for emerald and other gems; Tanzania announces easing of government restrictions on individual prospecting; beryllium found in Canadian North West Territories; opal, chalcedony and onyx found at Mt Rudnik, Serbia.

Gold: reported in Ontario and Quebec; mud slides make gold production difficult in Papua, New Guinea; exploratory drilling at Reid Mine, northern California shows up to 1.5 oz per ton, together with silver. R.K.M.

LAURENCE (C.). *Fabled diamond on sale for £5 million.* Daily Telegraph, No. 40, 164, p.11, 1 photo, 4th August 1984.

Put on the market for £5 million by Graff's, Knightsbridge, a 47.29 ct diamond, Golconda 'D', 'has been hailed as the largest "flawless brilliant" in the world'. It is said to have come from Golconda in the seventeenth century, to have disappeared in the eighteenth century, and to have been found recently in Bombay. J.R.H.C.

LOOCK (G.). *Anakie, Zentral Queensland, Australien.* (Anakie, Central Queensland, Australia). Magma, **3**, 36-9, 13 figs (12 in colour), 1984.

The sapphire mines of Anakie are described and some typical crystals illustrated. M.O'D.

NASSAU (K.). *Heat treatment used on gemstone materials.* Lapidary J., *part 1,* **38**, 1, 18-42, 11 figs (7 in colour); *part 2,* **38**, 2, 288-90, 12 figs in colour; 1984.

In part 1 the author outlines the history of heat treatment of gemstones before discussing the methods and equipment used. The mechanisms by which colour is altered are explained with particular reference to quartz and corundum. Part 2 deals with oxidation-reduction in blue sapphire, silk and asterism in corundum, diffusion of colour and asterism into corundum, heat-induced cracking and the reconstruction and clarification of amber. M.O'D.

NIŚKIEWICZ (J.). (Geological setting of the occurrence of chrysoprase and related gemstones in the Szklary massif, Lower Silesia). Geologia Sudetica, **17**, 1/2, 125-39, 3 figs, 1982. (Polish with English summary).

Chrysoprase, chalcedony and opal occur sporadically in serpentine of the Szklary massif in SW. Poland. These minerals are generally found in steeply dipping veins and in irregular lenses a few centimetres in size. They are most often developed in yellowish brown to reddish brown altered serpentine; the chrysoprase is invariably associated with earthy weathered serpentinite relatively rich in Ni, whereas the chalcedony and opal occur in all types of altered serpentinite. On the basis of Ni grades [not given], the author has indicated areas of the least probable occurrence of chrysoprase in the massif. R.A.H.

NOOR DEEN (M.). *Rare gemstones of Sri Lanka.* Lapidary J., **38**, 1, 238-40, 1984.
Brief account of the gem materials found in Sri Lanka. M.O'D.

O'DONOGHUE (M.). *The dealer looks at gemstones—12.* Gems, **15**, 4, 29.
A brief account of the present state of the diamond investment business and of the perils of appraisal related to tax deduction (with reference to some recent cases in the U.S.A.). (Author's abstract) M.O'D.

O'DONOGHUE (M.). *Industrial review: gemstones.* Britannica book of the year, 1983.
The investment boom was fading and the prophesied decline in influence of the Central Selling Organization did not come about. Pakistan emerged as a major gem exporter. Emerald from Brazil was being exploited and some qualities finer than normal were found. Sales at the major auction houses continued to flourish.
(Author's abstract) M.O'D.

PROCTOR (K.). *Gem pegmatites of Minas Gerais, Brazil: exploration, occurrence and aquamarine deposits.* Gems & Gemology, **XX**, 2, 78-100, 17 figs (16 in colour), 1984.
A very full account of the granitic pegmatites of NE. Minas Gerais and, in this paper (the first of a projected series), of the aquamarine, morganite and heliodor production of the region. Early exploration, development, geology, mining methods and sociological effects are explained. All varieties of gem beryl other than emerald are found in these pegmatites, but aquamarine is by far the most important. Different valleys and mines described in detail. Little mining at present, but potential of region is still very great. All aquamarines are heat-treated to change sea-green, or yellow, to fine blue. R.K.M.

REBAN (J.). *Moldavite—the gemmy tektites.* Lapidary J., **38**, 1, 30-6, 10 figs (7 in colour), 1984.
The original author gives a résumé of moldavite from Czechoslovakia, and two other writers describe tektites found in other countries. M.O'D.

ROLANDI (V.). *Edelsteine aus dem Tierreich: Eine gemmologische Untersuchung über das aus Cnidaria (Korallen) stammende Schmuckmaterial.* (Gemstones from the animal kingdom; a gemmological study of Cnidaria (corals) branches used as gem material). Aufschluss, **35**, 251-65, 15 figs (1 in colour), 1984.
The various coral-producing creatures and the structures of the coral are described. M.O'D.

SCANDALE (E.), LUCCHESI (S.), GRAZIANI (G.). *Optical anomalies of beryl crystals.* Physics and Chemistry of Minerals, **11**, 2, 60-6, 7 figs, 1984.
Basal plate sections of natural beryl crystals showed optical anomalies when examined by optical microscope, x-ray topography and electron microprobe analysis. The anomalies were found to be linked with growth history and variation in impurity content. Optical axial plane orientation and 2V values depend on minor element concentration differences in growth sectors. M.O'D.

SHIGLEY (J. E.), KAMPF (A. R.). *Gem-bearing pegmatites: a review.* Gems & Gemology, **XX**, 2, 64-77, 13 figs in colour, 4 tables, 1984.

A good account of these important rock types which are the most prolific sources of many gem minerals, with theories on their formation, the significance of crustal depth and of pneumatolytic solutions. A well-considered paper. R.K.M.

TAGLIAMONTE (N.). *History of shell cameos.* Lapidary J., **38**, 2, 288-90, 13 figs in colour, 1984.

The author gives personal reminiscences of the cameo-making industry of Naples. M.O'D.

ZEITNER (J. C.). *Collect emeralds, diamonds, rubies and more for a fee. Part 1,* Lapidary J., **38**, 1, 62-77, 20 figs (9 in colour), 1984.

Collecting for a fee is common in many parts of the United States. The areas in the states of Maine, New York, Pennsylvania, North Carolina, Arkansas, Missouri and Ohio are listed and described. M.O'D.

Tsumeb. Lapis, **9**, 7/8, 13-63, 85 figs (65 in colour), 1984.

A survey of all the minerals so far found at the copper-lead-zinc mines at Tsumeb, Namibia, with descriptions and notes on occurrence. Some, including malachite, azurite, smithsonite and cuprite, have gem potential. M.O'D.

BOOK REVIEWS

BARNETT (F.). *Opal and how to work it.* Gemcraft Publications Pty Ltd, East Malvern, Victoria, Australia, 1981. pp. iv, 60. Illus. in black-and-white. $3.95.

A useful guide for the amateur prospector and opal cutter. M.O'D.

DAVIES (G.). *Diamond.* Adam Hilger Ltd, Bristol, 1984. pp. x, 255. 81 Illus. in black-and-white. £17.50.

The author has set out with the stated intention of describing the properties and uses of diamond without employing excessive scientific detail, and in doing so he gives us a lively account of the achievements and reports of the various scientists and philosophers down the ages who have become involved with this intriguing gem mineral. The book is certainly not written for the expert, and in over-simplifying some of the more complex aspects of his subject, Dr Davies may occasionally offend both the physicist and the gemmologist.

The opening chapter, entitled 'Fantasy', deals with the use and misuse of the word 'diamond' in ancient manuscripts ranging from the bible to Pliny's 'Natural History'. The curative and magical properties of diamond are also described together with the mineral's early use as an engraving tool for inscribing other gemstones.

The second chapter covers the chemistry of diamond, including an account of Lavoisier's tentative identification of the gas (which resulted from vaporizing diamond) as carbon dioxide, and Tennant's confirmation of this and of the charcoal or carbon composition of diamond. It is amusing to read that Humphry Davy, in attempting to explain away the enormous difference in hardness between charcoal (graphite) and diamond, suggested that this was due to an impurity constituent in diamond. It took another six years before Davy became converted to Tennant's idea that this difference was caused by their differing crystalline structures. Similar insights into the personalities of other scientists who have added to our knowledge of diamond are a feature of subsequent chapters, which include coverage of the structure, synthesis, use and impurity content of diamonds.

A whole chapter is devoted to the diamond stability diagram, which forms the starting point for modern synthesis methods, and this is preceded by a chapter which relates the early unsubstantiated attempts at synthesis, including a graphic report of Hannay's 'explosive' experiments, and the controversy surrounding the later validation of his 'synthetic' diamond specimens. In the chapter on modern synthesis, it is satisfying to see that the Swedish company ASEA is credited with the first confirmed synthesis of diamond (rather than General Electric of America), a fact missing from some books, particularly those by American authors!

In the chapter dealing with diamond impurities, a concise description is given of paramagnetic resonance and other techniques used in the determination of the trace elements present in diamond. In the case of nitrogen impurities, there are clearer descriptions to be found in other textbooks of the differences which exist between Type Ia/b and Type IIa/b diamonds.

The final chapter in this fascinating book is entitled 'Natural gemstones', and briefly covers the history of diamond occurrences, mining, separation techniques, the optics of diamond cuts, and artificial colour enhancement. In the optics section it is disappointing to see the term 'sparkle' in use (as originated in Dodson's PhD Thesis) rather than 'scintillation'. Also disappointing is the scanty coverage of diamond simulants and their detection. Cubic zirconia is produced in top white colour grades as well as yellow, and its dispersion at 0.06 (compared with diamond's 0.044) does not cause its refractive index to change 'rapidly' with the colour of light (there must be some confusion here with strontium titanate which has a dispersion of 0.190; this error is also repeated in the comments on using reflectivity as a test, where it is predominantly the difference in refractive index and *not* dispersion which separates cubic zirconia form diamond).

The final paragraph in this chapter states that the emphasis throughout the book has been on the 'scientific' aspects of diamond, and this is evident from the references given at the end of each chapter, only one of these being taken from a textbook on gemmology.

Despite the minor gemmological inconsistencies, the book is most readable and helps to make a physicist's view of diamond more understandable to the gemmologist. P.G.R.

HOLMES (R. W.), KENNEDY (M. B.). *Mines and minerals of the Great American Rift.* Van Nostrand Reinhold, New York, 1983. pp.xii, 332. Illus.in black-and-white and in colour. £28.60.

The Great American Rift runs from Mexico to Alaska but the states with which the book is concerned are Colorado and New Mexico. Individual mines have been located physically and in the literature, and although some of the descriptions are submitted in a style reminiscent more of the shovel than of the pen a good deal of information can be found. Notes on such minerals as rhodochrosite and fluorite will be interesting to the gemmologist; the bibliography is very comprehensive, the index a little less so (flüorspar and fluorite have separate listings) and the colour photographs are very good. M.O'D.

JACKA (J. D.), HAMMACK (N. S.). *Indian jewelry of the prehistoric southwest.* University of Arizona Press, Tucson, 1975. pp. 48. Illus. in colour. $5.00.

Brief but well-illustrated guide to Indian jewellery with turquoise prominent. M.O'D.

KNEIDL (V.). *Hunsrück und Nahe.* Franckh'sche Verlagshandlung, Stuttgart, 1984. pp. 128. Illus. in colour. DM29.50.

This excellent book covers the geology, mineralogy and fossils of the forested Hunsrück and the Nahe valley of West Germany. Since Idar-Oberstein is in the

Nahe valley the importance of the book to those interested in gem materials is obvious. Lists of specimens, a bibliography and a workable index are provided.

M.O'D.

LEVINSON (O.). *Diamonds in the desert.* Tafelberg, Cape Town, 1983. pp. 172. Illus. in black-and-white and in colour. R24.00.

Set against the background of the discovery of diamonds in the former German South West Africa is the biography of one of the first diamond discoverers and traders, former railway worker August Stauch. A great deal of information is lucidly presented and well researched. Much of the account deals with personalities of the day and their subsequent history; some, though by no means all, made fortunes. Stauch did both but accepted life with admirable equanimity. M.O'D.

NASSAU, (K.). *Gemstone Enhancement.* Butterworths, London, 1984. pp.220. Illus. in black-and-white, with 27 coloured plates. £20.00 (US$34.95 in North America).

In his introductory chapter, Dr Nassau makes the point that the technical details of a number of treatments were discovered during the development of gemstone synthesis. Knowledge of the reversibility of treatments can also be of practical importance where heat is applied during jewellery repair and results in the inadvertent loss of colour in a stone. These opening remarks set the style of the book, which is not only very readable but also achieves a nice balance between theoretical and practical information.

In Chapter 2, 'The History of Treatments', mention is made of Pliny's book written around A.D. 40 to 75, which contains references to gemstone alteration methods, including foiling, oiling, dyeing and the production of composites. Recorded instances of foiling, for instance, go back to at least 2000 B.C. Perhaps the most extensive source of recipes for the falsification of gems is represented by the handwritten 'Stockholm Papyrus', which dates from around A.D. 400. Many examples of these ancient treatments are reproduced, together with extracts from such famous historical gem books as 'The Mirror of Stones' by Camillus Leonardus. The chapter ends with a summary of twentieth-century irradiation techniques.

In Chapter 3, the heat treatment of gems is traced from its very early application in pre-Christian Grecian and Roman times to the sophisticated methods used in the 1970s and 80s. Details of these treatments are given with an explanation of the probable mechanisms of enhancement. Despite the complexity of the associated chemical and valency equations, these mechanisms are easily understandable in Nassau's lucid text.

Chapter 4 deals with 'Irradiation Treatments' and reminds us of the wavelengths in the electromagnetic spectrum and the various sub-atomic particles which are put to use in the service of gemstone enhancement. As with the previous heat treatment chapter, the relevant gems are listed together with their resulting colours and the mechanism of the change (in this case due mainly to the creation of colour centres in the atomic structure).

The simpler processes of chemical staining, bleaching, dyeing and oiling are covered in some detail in Chapter 5, which ends with a description of composites and synthetic overgrowths (e.g. the Lechleitner and Nacken processes).

Of prime interest to the gemmologist and jeweller is Chapter 6, 'The Identification of Treated Gems and the Question of Disclosure', although the author only claims that this contains a brief outline of the subject. The importance of visual inspection is stressed, either by using a 10× hand lens or a modern microscope, and the benefit of using the immersion technique of inspection is also mentioned, as is the possibility that some oils employed for sapphires and rubies may exhibit fluorescence. The chapter ends with a discussion of disclosure regulations applicable to the U.S.A. and to Europe.

The final chapter, 'Specific Gemstone Treatments', contains an alphabetic listing of gems and their various treatments from amber to zoisite. This constitutes nearly 40% of the book, and the author warns that the descriptions of treatments should not be taken as recommendations. The reader should always first try any procedure out on a small fragment of little value!

In this most valuable final chapter, the paragraphs in each alphabetic section are letter-coded to denote the intention of the treatment (e.g., darkening, lightening, clarification, reconstruction, dyeing, coating etc.). The text also contains hints on the recognition of the treatments, and in this respect is a practical adjunct to Chapter 6. Each section is fully referenced enabling the reader to check the original article from which the description has been derived. The reviewer found the corundum section of this chapter the most interesting, as it presented together for the first time all the various treatment processes for sapphire (including geuda material), ruby and the synthetic products.

The Appendices contain information on furnaces and furnace construction, temperature measurement and control (including useful details on thermocouple characteristics), on irradiation figures and hardware, on colour and on suppliers of equipment and services (i.e. heating, irradiation and lasering).

Dr Nassau has performed a valuable service in compiling this definitive work on gemstone enhancement, which will rank as an essential companion volume to the 4th edition of 'Gems'. P.G.R.

NIXON (P. H.), ed. *Lesotho kimberlites.* Lesotho National Development Corporation, [Maseru], 1973. pp.xii, 350. Illus. in black-and-white and in colour. Price on application.

The structural setting of kimberlites and their composition are discussed in a series of studies with the aim of determining the composition, structure and thermal gradient of the earth's mantle and crust. Along with this task information on possible locations for diamond is given, this part of the work being financed by the United Nations Development Programme. Chapters are written by invited contributors. The importance of Lesotho for kimberlite research can be seen when it is realized that there are 17 pipes, 21 dyke enlargements or blows and over 200 dykes. Many of the areas are barren from the diamond prospector's viewpoint, but some of the diamonds which are found are of very high quality.

The first pipe to be described is Letsang-la terae which has produced superb quality diamonds; other pipes are described subsequently, and in each case the geology is discussed, together with mineralization and morphology of the diamond crystals where appropriate. The book concludes with a bibliography, maps and abstracts in Russian.

Students of kimberlites are exceptionally fortunate to have this major book covering one discrete area. A good deal of information was obtained from satellite imagery and some of this is shown in colour. Gemmologists will be interested to hear that the diamonds from Letseng-la-terae show virtually no octahedra, though transitional forms between octahedra and dodecahedra were observed. Two stones in a sample showed octahedron and dodecahedron on either side of the same crystal. Commonest morphologies were rounded, irregular dodecahedra and rounded, irregular and flattened octahedra. Macles were frequently observed but no cubes or cubo-octahedra. The general colour varied from medium to light brown, progressing into pale yellow and colourless stones with a faint yellow tint. After this come completely colourless stones. Common inclusions were black flakes lying in (111) planes and were probably graphite. No silicate or oxide inclusions were noted on first examination. Diamonds from the Kao kimberlite progress from flat, smooth-faced straight-edged octahedra through rounded forms to rhombic dodecahedra. There is a higher proportion of white varieties among whole crystals compared with irregular stones in which the grey, yellow and brown varieties are more common.

These examples give some idea of the contents of this exceptional book.

M.O'D.

O'LEARY (B.). *A field guide to Australian opals.* Second edn. Gemcraft Publications Pty Ltd, East Malvern, Victoria, Australia, 1984. pp. 159. Illus. in colour. $12.95.

This book is misdescribed as second edition. Only the publisher has changed and the correct designation should be a re-issue as there is no textual change. (Originally reviewed in *J.Gemm.,* 1978, **XVI**, 3, 215). M.O'D.

POHL (W.), NIEDERMAYR (G.). *Geology of the Mwatate quadrangle and the vanadium grossularite deposits of the area.* Kenya Ministry of Natural Resources, Mines and Geological Department, Nairobi, 1979. pp. 55. Map. Price on application.

This study of degree sheet 195/2 forms Report No. 101 of the Mines and Geological Department of Kenya. The occurrence of the vanadium grossular garnet prompted the establishment of a joint Austrian-Kenya Geological Mapping and Mineral Exploration Project whose findings are reported here. Details of the mineral occurrences are given with details of the individual mines. M.O'D.

PEMBERTON (H. E.). *Minerals of California.* Van Nostrand Reinhold, New York, 1983. pp.vii, 591. Illus. in black-and-white. £29.95.

The first list of Californian minerals was compiled by W. P. Blake in 1866, and a mineralogy has appeared eight times since then; in 1966 a centennial volume was published, and the present work is described by the publishers as an update of it.

The total number of terrestrial species described is now 736, and 5 meteoritic species are also included. Arrangement is by chemical composition, and within each category occurrences are described by alphabetical order of county. Each occurrence is given the best or most up-to-date reference, and map coordinates are provided in many cases. There are a first-class bibliography, an index to maps and a subject index. Gemmologists will turn first to the sections on garnet, tourmaline and benitoite in this excellent book. M.O'D.

Chinese ivories from the Shang to the Qing. (An exhibition catalogue organized by the Oriental Ceramic Society jointly with the British Museum). The Society, London, 1984. pp.200. Illus. in black-and-white and in colour. Price on application.

The book opens with a useful discussion of ivory, its properties and colour, and of the way in which it has been worked by the Chinese. The catalogue proper is arranged by period and type of piece; pre-Ming ivory carving is dealt with first, followed by Ming and Qing figure carvings and useful and ornamental pieces. There are a map and a glossary, a short bibliography and a list of lenders to the exhibition. The standard of reproduction is high, especially with the colour plates. M.O'D.

ASSOCIATION NOTICES

JOHN ALAN FLEMING, F.G.A., A.C.A.N.Z.*
A Tribute

Born in the 1920s Alan (as he was known to his friends) was the youngest son of a wealthy gentleman and was educated and brought up in Auckland, New Zealand.

After leaving college Alan entered into training as an accountant, qualifying at an early age as an Associate Chartered Accountant of New Zealand. When war came he served as a sergeant, but never left New Zealand. After the unexpected death of his father in 1948, Alan formed several companies but finally settled in the stamp business, which is still in existence today.

His first experience of London was in 1954, when he and his wife Joy came on holiday. He travelled widely, and it was on a visit to Sri Lanka that he developed a keen interest in gemstones. In 1959 he decided to return to London and shortly after his arrival he enrolled in the gemmology classes and qualified as an F.G.A. in 1962.

From this point onward he specialized in rare and unusual gemstones and mineral specimens. Alan handled a wide range of goods, including some of the first examples of new materials available in this country. He had some of the first 'trillings' of alexandrite from Fort Victoria in Zimbabwe (then Rhodesia), and carried for some time the finest range of blue zoisite (tanzanite) in the country. He was one of the first dealers to obtain the chrome grossular garnet, later to be named tsavolite.

Alan had a keen eye for unusual and interesting items, revelling in their discovery and delighting in teasing the unsuspecting gemmologist with them. Many items were not only made available to the Gem Testing Laboratory and the Geological Museum, but a number were actually donated to their reference collections. During the years a number of these have been published in the *Journal of Gemmology*. Material was also made available to virtually any interested party, who was fortunate enough to think to ask. He gave talks and lectures and never missed an opportunity to spread the message and interest in gemmology.

*Whose death on 3rd May, 1984, was reported above on p.283. -Ed.

Alan remained a one-man business until early 1977, when he together with Peter Hurrell and Christopher Cavey, F.G.A., joined forces to market the first diamonds in kimberlite from Siberia; this was achieved by the acquisition of a company called Rough Gems Ltd. It was one year later that charoite became available, and Alan with his world travels carried news of new materials far and wide. With the decline of the collector market in 1980, Alan expressed a yearning to return to his native New Zealand, finally departing last year, leaving his London business affairs in the hands of Tony French, F.G.A. Unfortunately shortly before leaving London he developed liver trouble and upon his arrival in New Zealand underwent surgery. He never regained his full strength, and, only a few weeks before he died, he was informed that he had terminal cancer.

Alan was a rare man with a wonderful sense of humour; he had a habit of always looking at the best side of people, and was one of the finest intuitive gemmologists I have ever had the pleasure of meeting. He will be sadly missed not only by those who knew him but by the entire gemmological world which has without doubt lost one of its greatest friends.

NEWS OF FELLOWS

On 26th June, 1984, Mr M. J. O'Donoghue, M.A., F.G.S., F.G.A., gave a lecture on 'Recent developments in synthetic gemstones' to the Amateur Geological Society in London.

MEMBERS' MEETINGS

London

On 24th April at Kensington Town Hall, Hornton Street, W.8., a talk was given to members of the Association by Mr Ken Scarratt, F.G.A.

The subjects dealt with during the talk included the jades, amber, pearl, ruby, sapphire, diamond, iolite, haematite and emerald (all of which were illustrated by slides), the common factor amongst them being that the Laboratory had been asked to examine interesting examples of them in the recent past.

On the subject of pearls, a large baroque pearl set as a cigarette holder was described in which the centre had been drilled out to accommodate the tube along which the smoke travelled; also described was a very large orange conch pearl. Mention was also made of naturally coloured natural and cultured pearls as well as the problems associated with differenciating between the modern non-nucleated cultured pearl and the natural pearl.

A collection of amber and related products was then described, which was followed by a report upon the present situation with regard to both the Lennix synthetic emerald, and the Biron synthetic emerald.

Amongst the next items discussed were a necklace of faceted iolite, a nephrite and ivory knife, a blue jadeite vase, diffusion treated corundum and heat altered inclusions in blue sapphire.

The talk then passed on to the problems associated with the natural and the modern synthetic rubies and the way in which, if care is not taken, natural ruby may be mistaken for synthetic. The new Ramaura synthetic ruby and new Seiko synthetic gems were then described.

In conclusion a current problem concerning a new magnetic haematite was related.

Most of the subjects spoken on will, if they have not already, be included in future 'Notes from the Laboratory'.

K.S.

North West Branch

On 19th July, 1984, at Church House, Hanover Street, Liverpool 1, Mrs Val Duke gave a talk on Brazilian gems.

South Yorkshire and District Branch

On 17th May, 1984, at Sheffield City Polytechnic, two films were presented, one on diamonds and one on Orapa, mining in Botswana.

On 21st June, 1984, at Sheffield City Polytechnic, a film evening was held. The first film was on the History of Jewellery. This was followed by two films on the production of gold. The films replaced a talk on valuation by Mr Hugh Ransom, which had to be cancelled because of illness.

On 5th August, 1984, an evening treasure hunt was held in the Peak District.

ASIAN INSTITUTE OF GEMOLOGICAL SCIENCES

The A.I.G.S. is hosting a diamond and emerald seminar in Bangkok from 15th to 17th November, 1984. Participants include Mr Peter G. Read, C.Eng., F.G.A., Mr Roy V. Huddlestone and Dr Peter C. Keller. The attendance fee for the three days is U.S.$100.00. Further details may be obtained from the Registrar, Asian Institute of Gemological Sciences, 987 Silom Road, Rama Jewelry Building (4th Floor), Bangkok 10500, Thailand.

SUBSCRIPTIONS 1985

At the Meeting of the Council held on Tuesday, 24th April, 1984, the business transacted (in addition to the elections to membership recorded on p.286 above) included increases in the subscription rates for 1985 as follows.

Fellows £16: Ordinary Members and Associate £19.

LETTERS TO THE EDITOR

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

Dear Sir,

Mrs Barbara Anderson has very kindly drawn my attention to an omission in my obituary notice for her husband.

Among his many honours, Basil Anderson took particular pleasure in having been made a Member of the Indian Academy of Sciences. I should add also that he had been elected to honorary membership of many foreign gemmological organisations and had held office in the Mineralogical Society, served on C.I.B.J.O. committees and so on. A man of many parts, his influence in the world of gemmology was almost universal.

I trust that you will be kind enough to print this letter in the next issue of the Journal.

Yours etc.,
R. Keith Mitchell.

31st July, 1984.
Orpington, Kent.

From Mr Richard W. Hughes, A.G., F.G.A.
Asian Institute of Gemological Sciences.

Dear Sir,

Please include this A.I.G.S. Gem Lab Report in the next issue of The Journal of Gemmology.

Surface Repaired Rubies—A New Gem Treatment

Gemologists in the Gem Lab of the Asian Institute of Gemological Sciences in Bangkok, Thailand, have uncovered what appears to be the latest form of corundum treatment to emerge from the ovens of Thailand's skilled gem chefs—the Surface Repaired ruby.

Surface pits and cavities are a common feature on faceted rubies, especially expensive stones. To grind them away completely sacrifices weight. In the ruby business a few extra points may be the difference between profit and loss, and so the pits remain; at least they did until recently. Then a parcel of nine one-carat rubies was brought in for examination. Every stone in the lot was found to have had the surface pits repaired by filling them with a transparent colourless material. These repaired areas stood out in high relief when the stone was immersed in methylene iodide and examined under magnification. Gas bubbles of various sizes were also seen in some of the filled areas. Additional tests proved the filling material to be singly refractive with a 1.52 refractive index, thus suggesting its identity to be some type of glass.

Because the filling material seems to have been fused into the surface pits and cavities, it appears that some type of high temperature heat treatment is involved. Gem cookers have been known to add a wide variety of substances to the crucible,

FIG. 1. Large repaired area (with shaded appearance) in Thai ruby visible under oblique illumination. Note suspended gas bubble. 23 ×.

FIG. 2. Repaired areas (dark contrast at edges) visible in Thai ruby immersed in methylene iodide. Note the gas bubble.

FIG 3. Repaired areas (with shaded appearance) in Thai ruby visible under oblique illumination. Note suspended gas bubble inside repaired area. 38 ×.

and this could be the accidental by-product of the ordinary burning. However, since the initial discovery, other rubies have been found displaying similar repaired features. Thus it seems more likely that the process is being done with the aim of improving the appearance of stones by lessening the visibility of surface flaws.

Regardless of the motives behind this new treatment, the fact remains that in certain cases the surface repairing of rubies could substantially raise the price of a stone, if it were to go undetected. Thus it is of great importance that buyers be presented with full details regarding the absence or presence of surface repair (and its extent) before deciding to purchase a particular stone.

Detection of Surface Repaired Rubies

Detection of the surface repair of rubies should not present too much of a problem to the well-equipped gemmologist. The stone in question should be immersed in pure methylene iodide and examined under magnification with diffused lightfield illumination. Any repaired cavities will be visible as high relief (highly reflective) areas breaking the surface of the stone, especly when viewed at an angle to the surface. Gas bubbles within the filling material are often seen as well. However, care should be taken not to confuse a repaired pit or cavity with a naturally occurring included crystal, which may also break the surface.

A.I.G.S. feels that the sooner the trade becomes aware of this treatment, the better, and we expect to see more of these altered gems in the near future.

Yours etc.,
R. W. Hughes
Laboratory Director.

19th June, 1984.
Bangkok 5, Thailand.

[*Although an article on the same subject, received some time before Mr Hughes's letter, appears on pages 293-297 above, his letter also is published in view of the obvious importance to the trade of awareness of this new treatment and to show that it is causing concern in Bangkok as well as in London. The three colour-photographs (Figures 1, 2 and 3) were sent by Mr Hughes at the end of August in the hope that they might accompany his letter. It should be borne in mind that not all infillings contain bubbles.—Ed.*]

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 and the Gemmological Association of South Africa.

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 Editor is 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 Editor.

Articles published are paid for, and a minimum of 25 prints of individual articles may be supplied to authors provided application is made on or before approval of proofs. Applications for prints should be made to the Secretary of the Association—not to the Editor—and current rates of payment for articles and terms for the supply of prints may be obtained also from the Secretary.

Although not a mandatory requirement, it is most helpful if articles are typed (together with a carbon copy) in double spacing on one side of the paper, with good margins at sides, top and foot of each page. Articles may be of any length, but it should be borne in mind that long articles are more difficult to fit in than short ones: in practice, an article of much more than 10 000 words (unless capable of division into parts or of exceptional importance) is unlikely to be acceptable, while a short note of 400 or 500 words may achieve early publication.

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No. 4
October, 1984

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