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Cover Picture

An orange coloured pearl showing a 'flame structure' comparable with that displayed by pink pearls from the Giant Conch, *Strombus gigas*. This pearl was fished off the Mergui archipelago, Myanmar (Burma) around 1960 and is 20mm in diameter; others have been found in the Baler shell, *Melo amphora* in Australian and Malaysian waters.

Photograph taken in sunlight by E. A. Jobbins

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Notes from the Laboratory – 15

Kenneth Scarratt

Gemmological Association and Gem Testing Laboratory of Great Britain, London EC1N 8SU

Damaged fire opal

Gems with a water content, such as opal and pearl, need special care when being displayed for sale. These gems when kept for extended periods in an enclosed atmosphere and under strong heat-generating lighting are prone to dehydration which may result in cracking or other forms of damage. To reduce the risk of damage many traders keep a small container of water in a show case where pearls or opals are on display, and also regularly wipe them with a damp cloth.

A client sold a 2.31ct pear-shaped fire opal set in a cluster ring, seen in Figure 1, to a retailer approximately three years ago. Recently the retailer returned the ring stating that a large opaque cone had appeared stretching from the rear facets into the centre of the stone. The new 'inclusion' was easily visible to the unaided eye and therefore the stone was no longer saleable.

Our client unset the stone and sent it to the Laboratory for examination and any recommendations that could be made to bring the stone back to its former beauty. The opaque cone (see Figure 2) was indeed quite large and had a dramatic effect on the appearance of the stone.

The solution was both simple and effective. The stone was placed in a container of water for a period of three weeks, after which the opacity had virtually disappeared. After a further week in the water the opacity had disappeared altogether leaving only a small turbid area (Figure 3).

Fig. 1. Pear-shaped fire opal set in a cluster ring. Note the opaque cone at the top right and under the table facet.

Fig. 2. The pear-shaped fire opal in Fig. 1, unset and displaying a side view of the opaque cone.

Fig. 3. The pear-shaped fire opal in Figs. 1 and 2 after soaking in water for four weeks. The opaque cone has disappeared leaving only a small turbid area.

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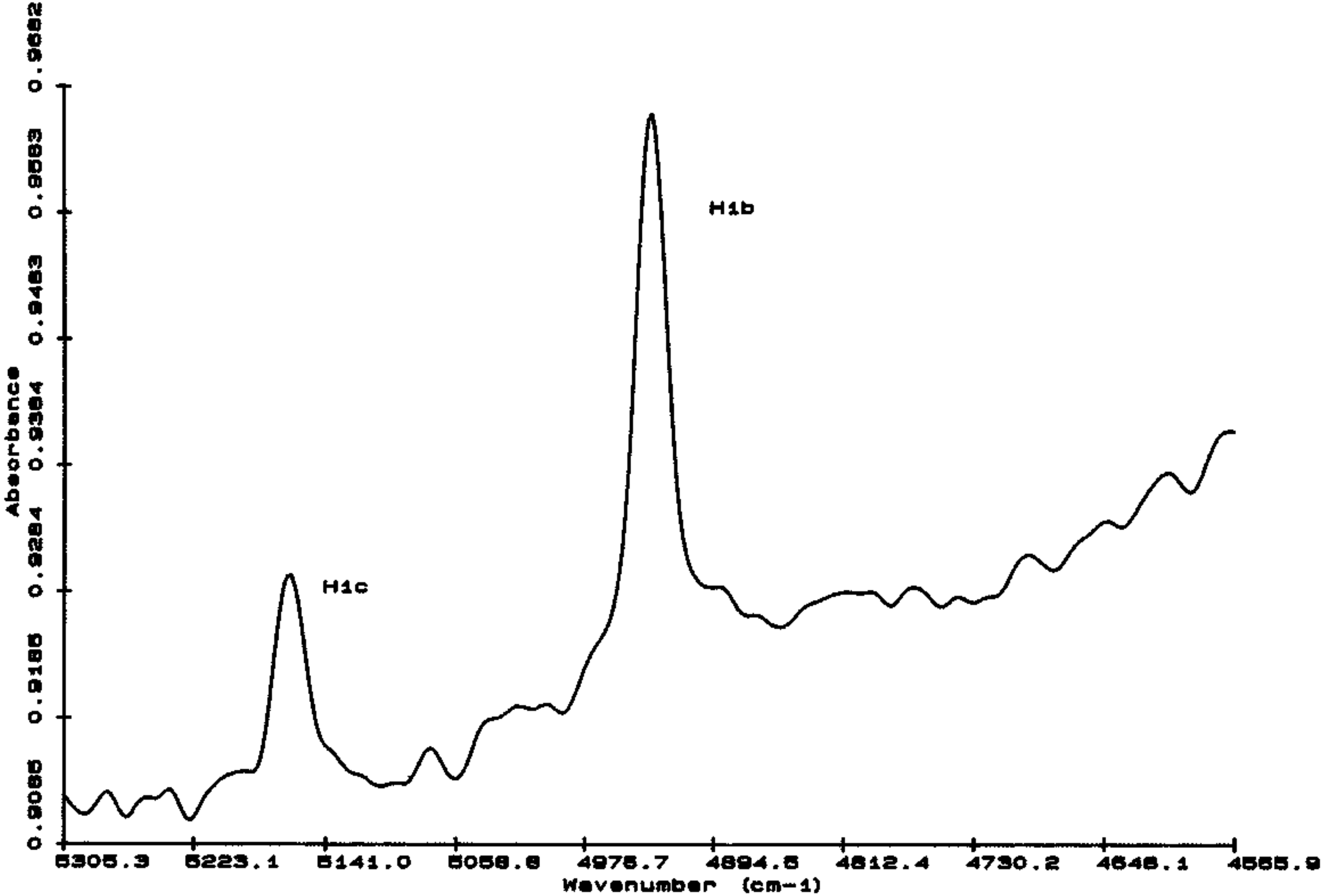


Fig. 5. Partial infrared spectrum of the 33ct treated yellow diamond in Fig. 4, displaying the H1b and H1c peaks at 4935 and 5165cm^{-1}.

Large treated yellow diamond

It is sometimes difficult to understand why certain stones are artificially treated. Obviously, colour or clarity enhancement can make a stone more saleable. However, when one has a 33ct diamond irradiated and annealed to produce a 'treated yellow' one has to question whether it is more saleable before or after treatment.

Figure 4 shows a 33ct round brilliant-cut 'intense yellow' diamond recently submitted to the Laboratory for a report on the origin of its colour. Examination of the stone's visible spectrum using a hand-held spectroscope revealed an intense line at 503nm but there were no indications of the 595nm line usually seen in treated yellow diamonds. Low temperature spectroscopy, down to 120K, using a Pye Unicam Pu 8800 UV/vis spectrophotometer confirmed that the stone had a strong Cape spectrum along with peaks at 503 and 496nm, and also the absence of the 595nm peak.

Fig. 4. A 33ct treated yellow diamond.

The peak at 595nm normally seen in treated yellow diamonds is destroyed if the annealing temperature, during treatment, rises to the 1000°C region. Fortunately, whilst this treatment indicator is destroyed, two further peaks in the infrared are formed i.e., the H1b and H1c (at 4935 and 5165cm^{-1}). An examination of the infrared spectrum of this 33ct stone revealed the presence of both the H1b and H1c peaks (Figure 5) proving the stone to be treated.

An unusual imitation pearl

An unusual green imitation pearl was submitted recently for X-ray examination. The 'pearl' (Figure 6) weighed 9.27ct and measured 13.13 x 9.80 x 9.30mm. A visual examination determined that it was a composite with a junction between the two parts occurring approximately two-thirds of the distance down from the 'top', (see Figure 6). Overall the imitation fluoresced a dull blue/white under short-wave ultraviolet radiation and a stronger version of a similar colour under long-wave ultraviolet, whilst the area of the junction fluoresced a stronger blue. As the imitation had an unusual translucent appearance, and peculiar colour, it was also examined with the hand-held spectroscope. The spectrum revealed a strong band in the region of 650nm and a further but much weaker absorbence in the area of the orange/yellow border.

Fig. 6. An unusual composite imitation 'pearl'.

Two radiographs were taken in directions at 90° to each other and the results may be seen in Figure 7. The 'pearl' exterior was found to be quite transparent to X-rays and therefore could only be seen in low relief. However, the interior was found to be quite opaque to X-rays, and stood out in very high relief.

Fig. 7. Two radiographs of the composite imitation 'pearl' in Fig. 6. Left: side view. Right: plan view. Note the high transparency of the exterior and the opacity of the interior to X-rays.

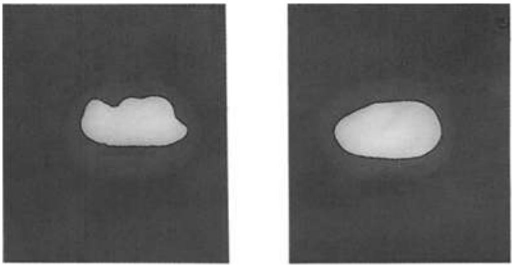


Fig. 8 Highly porous Brazilian opal before (rough) and after being dyed and plastic impregnated.

Dyed and plastic-impregnated opal

During my recent visit to the USA, John Koivula gave me a piece each of a new 'blue enhanced opal' and the material before treatment (see Figure 8).

Highly porous Brazilian opal of a chalky-white colour is soaked in solutions of potassium ferrocyanide and ferric sulfate and this produces a material of a distinct blue colour. The treaters, Gerard and Joyce Raney, of Redwood City, California, then allow the material to dry. The material is then placed in a slightly warmed plasticizing liquid of methyl methacrylate with a small amount of benzoyl peroxide. This last stage has two effects upon the finished product, firstly it seals the pores reducing the porosity, and secondly it clarifies the stones to the point where they are almost transparent. Once fashioned into cabochons this material provides an excellent 'imitation' of the much valued black opal, although its distinctive blue colour in transmitted light should provide the gemmologist with the first indication of its unnatural nature. The stones also feel quite light in the hand and have a 'plastic' feel to them.

Proof of the treatment may be obtained by infrared spectroscopy. Figure 9 compares the infrared spectrum of the treated with that of the untreated material. A number of extra features are seen in the treated material, principally at 5953, 4735 and 4680cm^{-1}.

Fig. 10. Kyocera synthetic alexandrite in the light produced by a 'fibre optic' source.

Synthetic alexandrite

Despite the very apparent dangers presented by the modern synthetic gemstone, i.e. those produced by processes other than the Verneuil method, the Laboratory is asked only rarely to identify stones which are eventually discovered to have been produced in this way. Recently the twelve-sided faceted stone featured in Figure 10 was submitted for examination. The stone weighed 1.75ct and measured 7.18 x 7.61 x 4.69mm, and had a distinct colour-change from green in daylight to that seen in Figure 10 when illuminated by the light produced from a fibre optic source. The least and greatest biaxial refractive indices recorded for the stone are 1.740 and 1.748, and the spectrum was also typical of alexandrite. The stone was seen to be a bright red when viewed through the Chelsea Colour Filter and fluoresced a bright red under both long-wave and short-wave ultraviolet light.

When viewed microscopically the stone was found to be relatively free from inclusions but fine structural growth lines which appeared to be slightly curved were observed. These growth features were similar to those previously observed in specimens of Kyocera synthetic alexandrite. However, as can be seen from Figure 11 one should remember that in other examples of this type of synthetic the growth features may appear to be angular rather than curved. Infrared spectroscopy (Figure 12) confirmed the stone to be a Kyocera type synthetic alexandrite.

Fig. 11. Kyocera synthetic alexandrite showing angular appearing growth features.

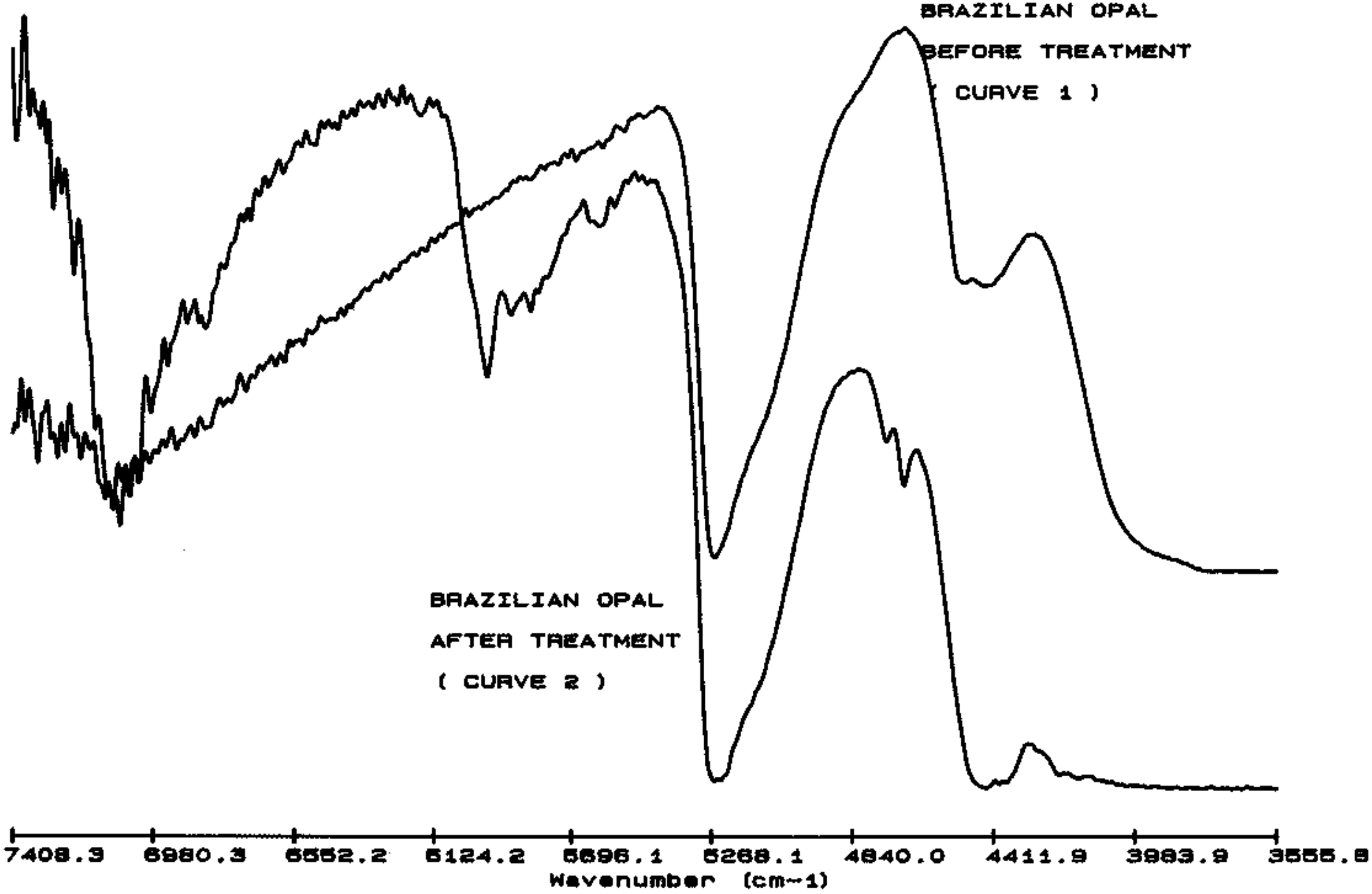


Fig. 9. The infrared transmittance spectra of the Brazilian opal in Fig. 8 – curve 1, before treatment and curve 2, after treatment.

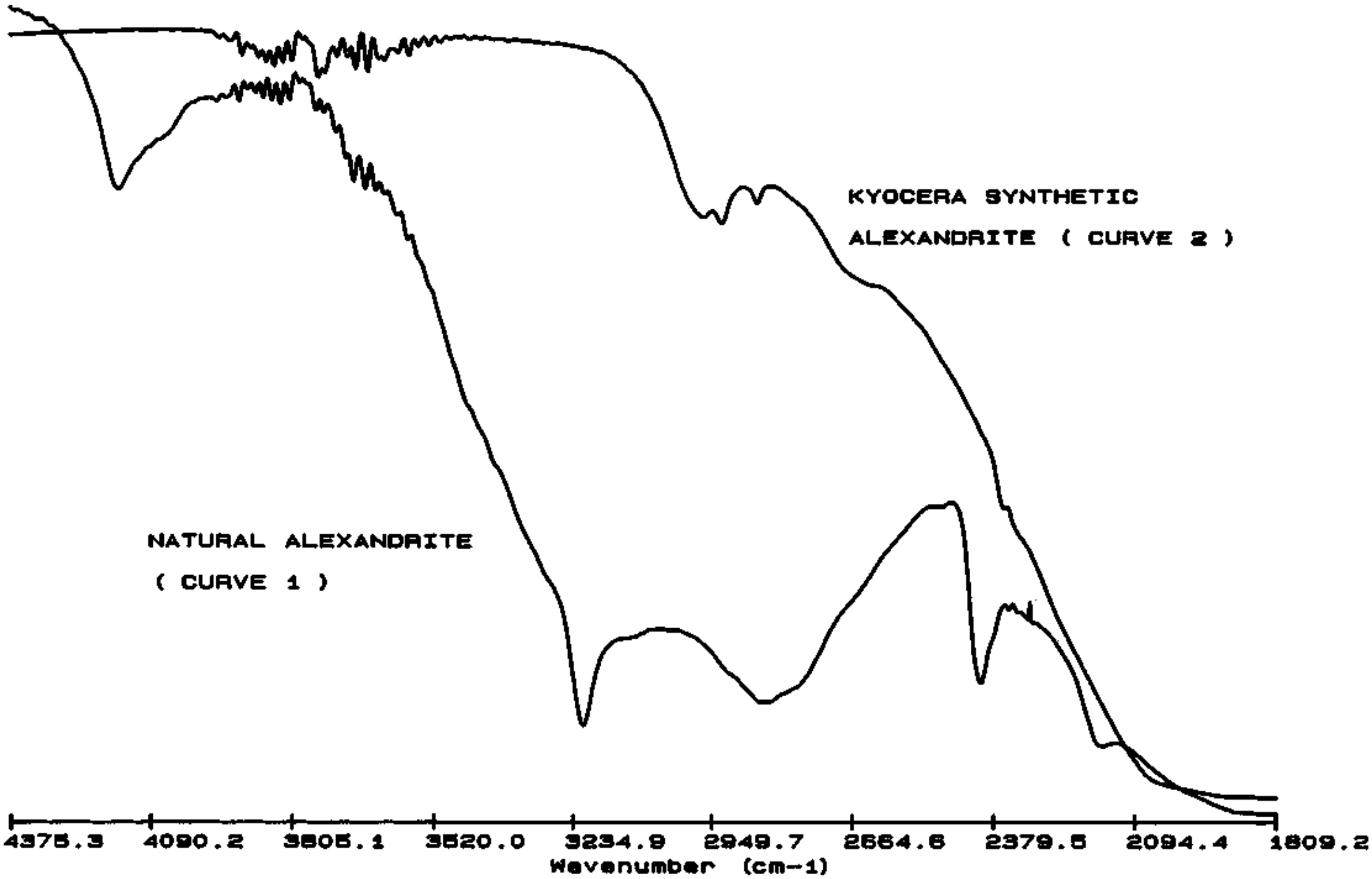


Fig. 12. Infrared transmittance spectra of a natural alexandrite (curve 1) and the Kyocera synthetic alexandrite in Fig. 10 (curve 2).

Fig. 13. A Mabe type composite cultured pearl.

Mabe pearl – coloured with nail varnish

The Mabe type composite cultured pearl is a very popular product often used in earrings and brooches (Figure 13). Following the inauguration of our 'Nacre Thickness Reports' for whole cultured pearls (see Gem and Jewellery News, January 1992), we were approached by one merchant who wondered why his Mabe products could not be assessed in a similar manner and given a Nacre Thickness Grade. He stated that the same problems were occurring with his product as had instigated the introduction of nacre thickness reporting with whole cultured pearls, i.e. the introduction on to the UK market of 'cultured pearls' with extremely thin coatings of nacre.

In further conversations, the merchant stated that not only was the nacre thickness extremely thin in some cases, but in addition these same Mabe type composites tended to have been painted on the inside with 'nail varnish' in order to give them a pinkish 'bloom'.

Fig. 14. A radiograph of two Mabe type composite cultured pearls, showing clearly the mother-of-pearl base, the bead in the centre and the nacreous exterior. Note also the bright line on the inside edge of the nacreous exterior which is indicative of that surface being coated with 'nail varnish' to give the 'pearl' a slight pinkish colour.

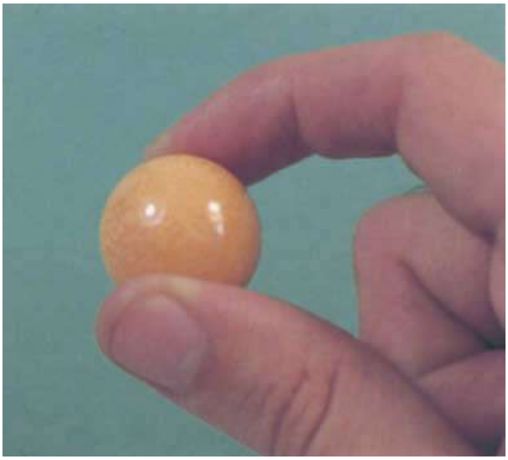


Fig. 15. A 110.48ct orange pearl, possibly from the Baler shell, examined in 1983.

In attempting to assess the nacre thickness problem a number of radiographs were taken and in doing this it was discovered that the 'nail varnish' used to give the product its colour, was clearly revealed on the radiograph as a bright white line running along the inside edge of the nacre (Figure 14).

Three interesting orange pearls

In 1983 we examined a perfectly round orange pearl (Figure 15) with a surface structure similar in appearance to that normally seen on pink pearls from the conch (*Strombus gigas*), i.e. the characteristic 'flame structure'. At the time it was assumed that the pearl was of the 'conch variety' and indeed at 110.48ct was the largest we had recorded.

Recently three orange pearls similar in appearance to the 1983 example were submitted for examination (Figure 16). The first was of a normal size and shape for a 'conch pearl' (ovoid measuring 13.7 x 12.6 x 11.00mm and weighing 14.04ct), and displayed the characteristic 'flame structure'. The

Fig. 16. Three orange pearls, possibly from the Baler shell, submitted for examination recently – the largest weighing 139.71ct.

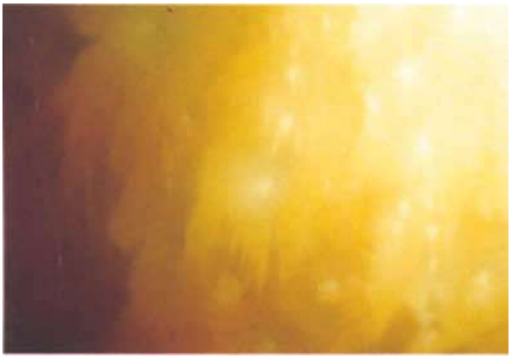


Fig. 17. The unusual not entirely 'flame-like' structure seen on the round pearl in Fig. 15.

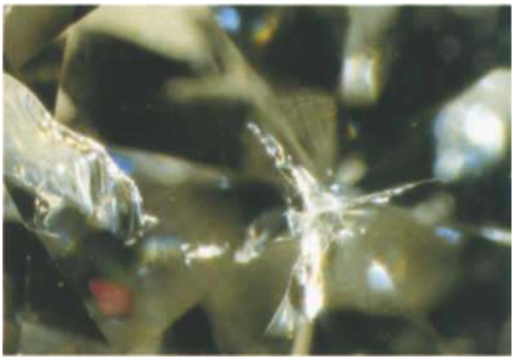


Fig. 19. The same surface reaching fractures in Fig. 18 after being treated by the 'oscillating technique'.

second pearl was almost perfectly round, measured 19.0mm in diameter, and weighed 54.93ct. The interesting feature of this pearl was the unusual surface structure which was not entirely 'flame-like' (Figure 17). The structure, which was over the entire surface, was in fact closer to the structure one normally observes in one direction only for other such pearls. The third and largest pearl displayed a good 'flame structure', measured 31.0 x 26.4 x 22.7mm, weighed 139.71ct, but had a shape more akin to a peach stone rather than a pearl. However, this is undoubtedly the largest of this 'type' of pearl that we have recorded.

A pearl with a similar colour and appearance that was recovered from a species of the Baler shell, the *Melo amphora*, was described in a report in the *Australian Gemmologist* (Brown and Kelly, November 1990). It is possible that the 1983 pearl and the others described here have a similar origin.

Clarity enhancement – 'The Oscillating Technique'

Alan Hodgkinson recently sent two diamonds to a London company in order that their clarity might be enhanced by the 'laser drilling' technique. When the stones were returned, one had indeed been enhanced by the requested method, but the other had been treated by a process which the company termed 'oscillating'.

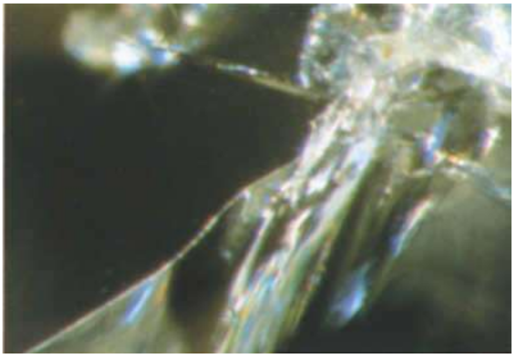
The stone treated by this technique originally contained a number of black lined surface-reaching fractures and a central inclusion (Figure 18). Following the treatment the 'blackness' in fractures disappeared (Figure 19). When questioned about the treatment, beyond stating that they now treated all surface reaching fractures by this method, the company refused to discuss the process beyond giving its title.

Upon examination the treated fractures have a peculiar appearance. They appear to be 'clinically clean', very bright, and the internal surfaces are similar in appearance to that seen on a freshly broken surface of colourless glass (Figure 20). Where the fracture meets the surface a yellowish material could be seen within the fracture boundaries.

An examination by X-ray fluorescence (XRF) determined that no heavy metals were present and that therefore the treatment was not a glass filling process such as that of Yehuda or Koss. The filler

Fig. 18. Black-lined surface reaching fractures in a diamond (as seen from the pavilion) before being treated by the 'oscillating technique'.

Fig. 20. A closer view of the treated fractures seen in Fig. 19 showing their almost glassy appearance.



sealing the fractures at the surface was determined to be organic in nature with a possible chlorine content. At this stage it is not possible to determine the details of the treatment process, without further information from the company. However, bearing the descriptive title in mind, it is possible that the fractures are 'cleaned' with a non-viscous acid that is assisted on its journey into the fracture by a technique that involves the stone and/or the acid vibrating. Once treated the fracture is sealed at the surface with an organic substance presumably to prevent foreign material from entering. The sealant by its very nature will not be permanent.

An interesting ewer

The ewer in Figure 21 was submitted recently in order that the material of its body could be determined. The ewer, which measured 30cm in height, had four engraved colourless sections that were joined by white metal collars. The beautifully balanced handle was mounted with three enamelled representations of an eagle eating a serpent, a bust of a turbaned gentleman, and what is possibly a figure of Pan. Of the four engraved colourless sections, the base, lower main body, and spout were found to be quartz, whilst the upper main body was found to be glass. The quartz sections had refractive indices in the region of 1.55 (distant vision technique) and observable double refraction. Included crystals and feathers were also present in these sections. The glass section had a moulded appearance, internal 'swirl' structures, bubbles, and a refractive index in the region of 1.57.

Fig. 21. A 30cm high quartz ewer in which the upper part of the main body was found to be glass.

Acknowledgements

It is with great pleasure that the author acknowledges the input of his two colleagues Nick Sturman and Ana Castro, on a number of the topics discussed. He is also grateful to Alan Jobbins for producing Figures 20 and 21, to Nick Sturman for producing Figure 16, and to Alan Hodgkinson for producing Figure 17.

[*Manuscript received 26 May 1992.*]

Emeralds from Madagascar

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Introduction

The island of Madagascar is known for its wealth of precious stones. In his survey on the occurrences of precious stones in Madagascar, Chikayama (1989) has mentioned 50 different precious stones found and mined on this island situated off the east coast of Africa. Among these precious stones, the mineral beryl plays an important part. When the island was occupied by the French in 1883, news about important occurrences of aquamarines and other beryls of various colours became known in Europe.

In his 'Mineralogie de Madagascar', Lacroix (1922) gave a detailed survey on the Madagascar occurrences of beryls of cuttable quality. He mentioned a large number of primary and secondary (i.e. alluvial) occurrences, where colourless, yellow, pink (morganite) and blue (aquamarine) beryls were found. Especially the blue beryls possess an extraordinary wide colour variation – from light blue to deep blue, and from greenish-blue to bluish-green.

Until that time, emerald occurrences had not been known in Madagascar. Although Levat (1912) had mentioned an occurrence of emerald of medium quality in Madagascar, but no detailed information had been published.

According to Lacroix (1922), certain beryl crystals were found together with large amounts of rose quartz in a kaolinized pegmatite at Tongafeno, near Tsaramanga, about 3 kilometres north of Mont Itongafeno, and south west of Antsirabe. The beryl crystals possessed a blue external zone and an 'emerald green' nucleus, which did not consist of emerald, however, but rather of iron-coloured green beryl.

Sinkankas (1981) has mentioned an emerald occurrence located in the Mananjary-Ifanadiana region at the east coast of the island. This alluvial occurrence consists of small, rounded emerald fragments together with kyanite. The occurrence is situated about 50 kilometres west-south-west of Mananjary, and about 250 kilometres south-east of Tananarive.

In 1982, Hänni & Klein described a primary emerald occurrence at the south-east coast of Madagascar. Near Kianjavato, in the so-called Ankadilalana mine, blue-green emeralds of faceting quality are found in mica-schists. The characteristics of this material are comparable with those of emeralds from Zambia.

Chikayama (1989) has also mentioned emerald occurrences near Mananjary, near the east coast of Madagascar.

The occurrences of emeralds in the Mananjary region have been known for 20 years and now and again various interested parties have successfully prospected emeralds in this region. For about 5 years occurrences situated about 30 kilometres south of Mananjary have been exploited commercially. The occurrences are very extensive, and hopes for an important emerald production seem to be justified. The source rocks of these emeralds are mica-schists. For this paper, thorough investigations have been carried out with material originating from the Morafeno region, near Mananjary. The mine extends over an area of about one square kilometre. It yields partly transparent emerald crystals of some centimetres in size, embedded in dark mica.

Physical properties

The values of refractive indices, birefringence and densities are shown in Table 1 together with other data for emeralds from Madagascar and Zambia, hitherto published in gemmological literature.

The refractive indices, birefringence and densities measured by the authors of this work are in the same range as the data determined by Hänni & Klein (1982) on Madagascar emeralds. The values are compared with those of Zambian emeralds, because of the similar colour. The emeralds from Madagascar possess data, which are comparable with features of Zambian material located in the lower variation range. The higher values of Zambian emeralds have been determined on material

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with relatively high iron contents (Bank, 1981; Schmetzer & Bank, 1981).

Chemical properties

Table 2 gives the chemical data of six emeralds from the Morafeno mining region in Madagascar. Columns 1-6 show the single analyses, column 7 gives the amounts of variation of the analysed oxides and column 8 the mean concentrations observed in the six analysed samples. Table 3 shows the chemical data of some emeralds from other African mining regions for comparison.

The element correlation diagrams of Figures 2-4 show the representative points for the Morafeno emeralds, together with those for emeralds coming from occurrences in Brazil, Australia, Norway and some African mining areas (for details see legends of Figures 2-4).

The element correlation Al_2O_3/MgO shows a clearly developed diagonal trend (with negative ascent): the increase of the MgO concentration is accompanied by decreasing Al_2O_3 contents. This behaviour is controlled by the substitution reaction: $Al^{3+,VI} = Mg^{2+,VI}$.

The representative points for the Morafeno emeralds are situated in the lower third of the population area and also show a distinct diagonal distribution pattern. The mean concentrations of MgO in the examined samples (1.71-3.00%) are medium to high.*

The population area for the representative points of emeralds from different localities in the Na_2O/MgO correlation diagram shows also a well pronounced diagonal trend (with positive ascent): the increase of the magnesium concentration parallels the rising sodium contents. The crystallochemical model which defines this behaviour is given by the reaction:

$Al^{3+,VI} = Mg^{2+,VI} + Na^{1+}$ (channel)

ie, the sodium necessary for electric charge compensation (substitution of trivalent Al ions by bivalent metal ions, principally Mg^{2+}) occupies positions in the channels of the beryl structure. The

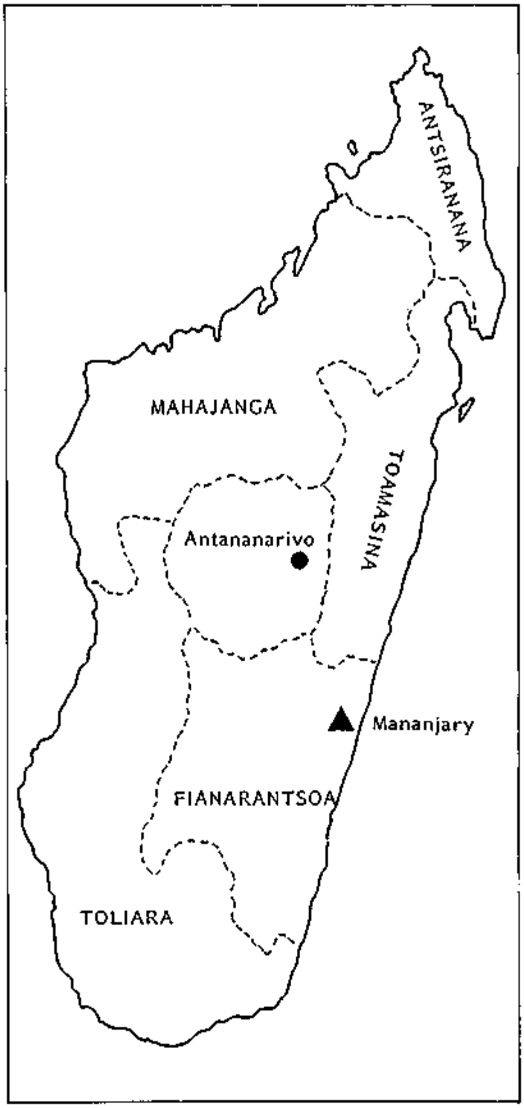

Fig. 1. Geographical location of the Mananjary emerald occurrences.

Table 1: Physical properties of emeralds from Madagascar and Zambia

	Madagascar*	Madagascar**	Zambia***
n_e	1.580-1.582	1.581-1.585	1.580-1.592
n_o	1.588-1.591	1.589-1.591	1.583-1.602
Δn	−0.008 to −0.009	−0.006 to −0.008	−0.007 to −0.010
D [g/cm^3]	2.68-2.71	2.727	2.74-2.77

* present work
** Hänni & Klein, 1982
***Campbell, 1973; Bank, 1974, 1980

Table 2: Chemical data of emeralds from the Morafeno mining region, Madagascar

	1	2	3	4a	4b	5	6
SiO_2	65.04	64.01	64.67	64.41	64.23	63.48	63.78
Al_2O_3	14.54	13.40	13.96	14.60	13.93	12.91	12.78
Cr_2O_3	0.19	0.12	0.08	0.24	0.12	0.21	0.34
V_2O_3	<	0.03	0.01	0.02	<	0.02	0.02
FeO	1.00	1.30	1.10	0.91	1.06	1.11	1.05
MnO	–	–	–	–	–	–	–
MgO	2.20	3.00	2.64	1.71	2.40	2.83	2.81
Na_2O	1.49	2.16	1.81	1.28	1.54	2.09	1.93
CaO	0.05	0.05	0.05	0.03	0.10	0.04	0.06
K_2O	0.12	0.09	0.14	0.05	0.21	0.12	0.15
TiO_2	<	<	<	<	<	0.01	0.01

	7	8		7	8
SiO_2	63.48-65.04	64.23	MgO	1.71-3.00	2.51
Al_2O_3	12.78-14.60	13.73	Na_2O	1.28-2.16	1.76
Cr_2O_3	0.08- 0.34	0.19	CaO	0.03-0.10	0.05
V_2O_3	< - 0.03	0.01	K_2O	0.05-0.21	0.13
FeO	0.91- 1.30	1.08	TiO_2	< - 0.01	–
MnO	-	–			

Observations:
1-6 = single analyses
4a, 4b = crystal showing color zoning:
a – border zone
b – core zone
7 = amounts of variation
8 = mean concentrations of 6 analysed samples
< = element concentration below detection limit of applied analytical method (Electron microprobe)
– = no data for this element

Morafeno emeralds are situated in the upper part of the population area and also show a strong diagonal distribution pattern. The mean sodium contents (1.28-2.16% Na_2O) are medium to high.*

The element correlation diagram FeO_{tot}/MgO does not show a broadly simple diagonal distribution trend: besides the diagonal 'distribution corridor' in which most of the representative points (also those for the Morafeno emeralds) are situated, we can observe a separate population area somewhat below the diagonal distribution corridor which contains the representative points for the Brazilian emeralds from Pirenópolis/GO, Salininha/BA, and Itaberaí/GO and also those for the African emeralds

Table 3: Chemical data for emeralds from different African mining regions

	a	b	c	d	e
SiO_2	63.81	64.91	63.8	67.27	63.5
Al_2O_3	15.07	16.98	14.6	13.21	14.2
Cr_2O_3	0.31	0.23	0.4	0.42	0.6
V_2O_3	0.02	–	0.0	0.02	0.0
FeO	1.03	0.40	0.9	0.81	0.5
MnO	<	–	0.0	–	0.0
MgO	2.04	1.49	2.3	2.83	2.9
Na_2O	1.86	1.12	1.9	2.25	2.2
CaO	0.03	–	–	0.05	–
K_2O	0.04	0.06	–	0.04	–
TiO_2	<	–	0.0	<0.01	0.0

Observations:
a = mean concentrations of 11 analysed samples from Kamakanga/Zambia (Schwarz, 1991b)
b = mean concentrations of 5 analysed samples from Cobra Mine/Transvaal (Fillmann, 1987)
c = mean concentrations of 2 analysed samples from Zambia (Hänni, 1982)
d = mean concentrations of 2 analysed samples from Machingwe/Zambia (Kanis *et al.*, 1991)
e = mean concentrations of 2 analysed samples from Zimbabwe (Hänni, 1982)
< = element concentration below detection limit of the applied analytical method
– = no data for this element

*The concentration bands for the elements chromium, vanadium, iron, and magnesium were delimited empirically by the following values (in wt% Cr_2O_3, V_2O_3, FeO, Na_2O and MgO; data for chromium, iron, magnesium and sodium from Schwarz, 1988:

	low	medium	high
chromium	<0.2	0.2-0.4	>0.4
vanadium	<0.2	0.2-0.4	>0.4
iron	<0.5	0.5-1.0	>1.0
sodium	<1.0	1.0-2.0	>2.0
magnesium	<1.5	1.5-2.5	>2.5

from Machingwe/Zimbabwe (Kanis *et al.*, 1991) and 'Zimbabwe' (Hänni, 1982). The pegmatite beryls from the regions of Aracuai-Salinas and Governador Valadares, Minas Gerais, Brazil, examined by Correia Neves (1984) are located outside the emerald population areas. Their representative points are displaced distinctly upwards.

Absorption spectra

Absorption spectra have been carried out with a Perkin Elmer Lamda 9 Spectrophotometer in the UV/VIS/NIR-spectral region.

Figure 5 shows the absorption spectrum of an emerald from the Morafeno occurrence in the 1000-300 nm range (10,000-33,333cm^{-1}). The

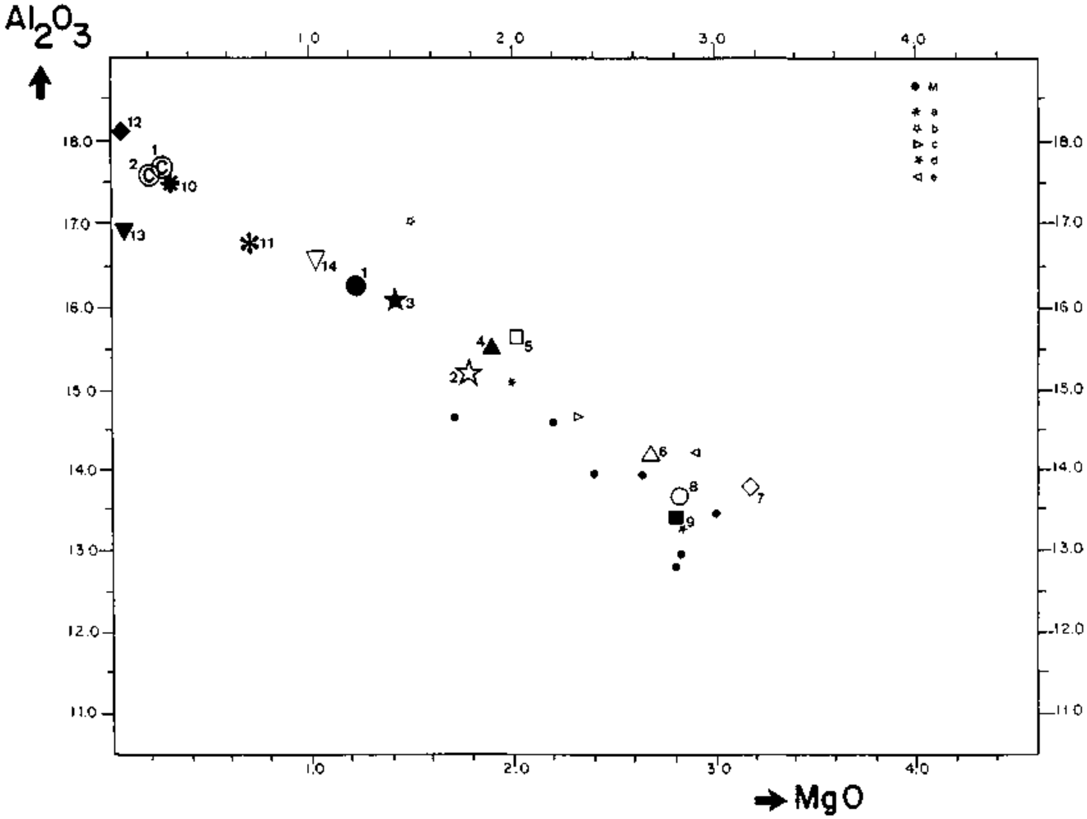

Fig. 2. Correlation diagram Al_2O_3/MgO for emeralds from Brazil, Australia, Norway and Africa

M = Morafeno/Madagascar (06)*
a = Kamakanga/Zambia (Schwarz, 1991) (11)*
b = Cobra Mine/Transvaal (Fillmann, 1987) (05)*
c = Zambia (Hänni, 1982) (02)*
d = Machingwe/Zimbabwe (02)*
e = Zimbabwe (Hänni, 1982) (02)*
1 = Carnaíba/BA (38)*
2 = Capoeirana/MG (16)*
3 = Belmont Mine/MG (48)*
4 = Socotó/BA (63)*
5 = Tauá/CE (11)*
6 = Pirenópolis/GO (07)*
7 = Salininha/BA (05)*
8 = Itaberaí/GO (13)*
9 = Santa Terezinha/GO (29)*
10 = Poona/Western Australia (12)*
11 = Menzies/Western Australia (08)*
12 = Emmaville/New South Wales (05)*
13 = Eidsvoll/Norway (04)*
C1 = Pegmatite beryls from the Aracuai-Salinas region (Correia Neves *et al.*, 1984) (09)*
C2 = Pegmatite beryls from the Governador Valadares region (Correia Neves *et al.*, 1984) (05)*
* = number of analysed samples

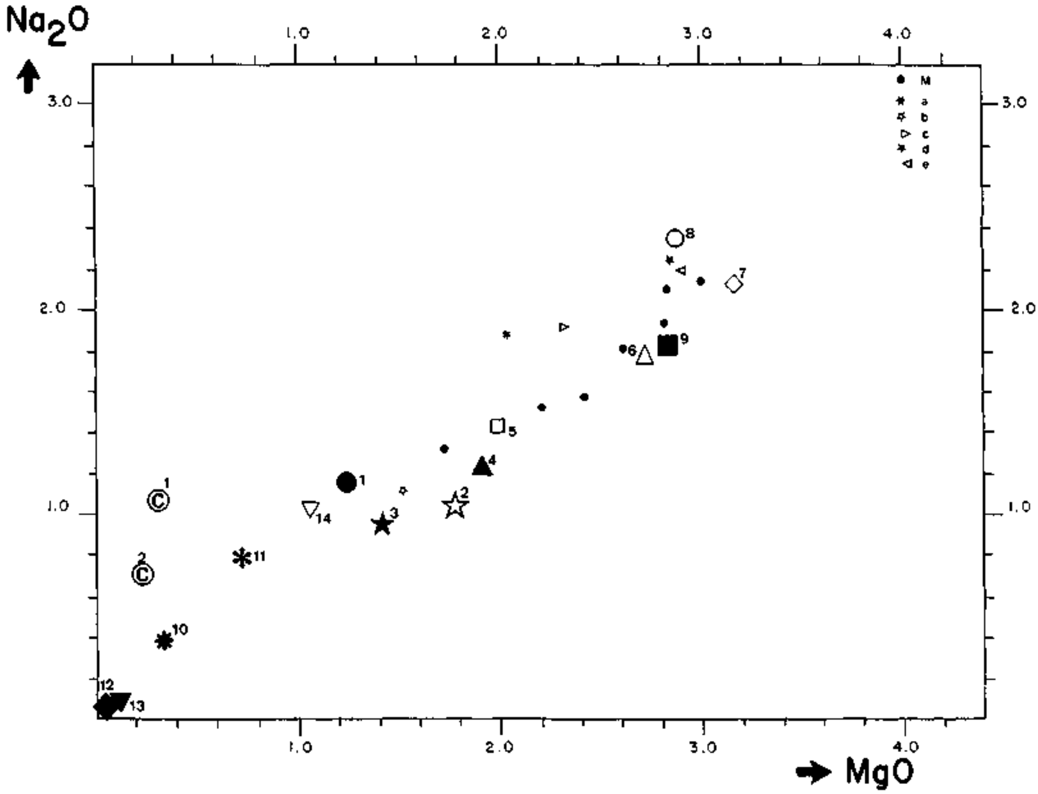

Fig. 3. Correlation diagram Na_2O/MgO for emeralds from Brazil, Australia, Norway and Africa

M = Morafeno/Madagascar (06)*
a = Kamakanga/Zambia (11)*
(Schwarz, 1991)
b = Cobra Mine/Transvaal (05)*
(Fillmann, 1987)
c = Zambia (02)*
(Hänni, 1982)
d = Machingwe/Zimbabwe (02)*
e = Zimbabwe (02)*
(Hänni, 1982)
1 = Carnaíba/BA (38)*
2 = Capoeirana/MG (16)*
3 = Belmont Mine/MG (48)*
4 = Socotó/BA (63)*
5 = Tauá/CE (11)*
6 = Pirenópolis/GO (07)*
7 = Salininha/BA (05)*
8 = Itaberaí/GO (13)*
9 = Santa Terezinha/GO (29)*
10 = Poona/Western Australia (12)*
11 = Menzies/Western Australia (08)*
12 = Emmaville/New South Wales (05)*
13 = Eidsvoll/Norway (04)*
C1 = Pegmatite beryls from the Aracuai-Salinas region (Correia Neves *et al.*, 1984) (09)*
C2 = Pegmatite beryls from the Governador Valadares region (Correia Neves *et al.*, 1984) (05)*
* = number of analysed samples

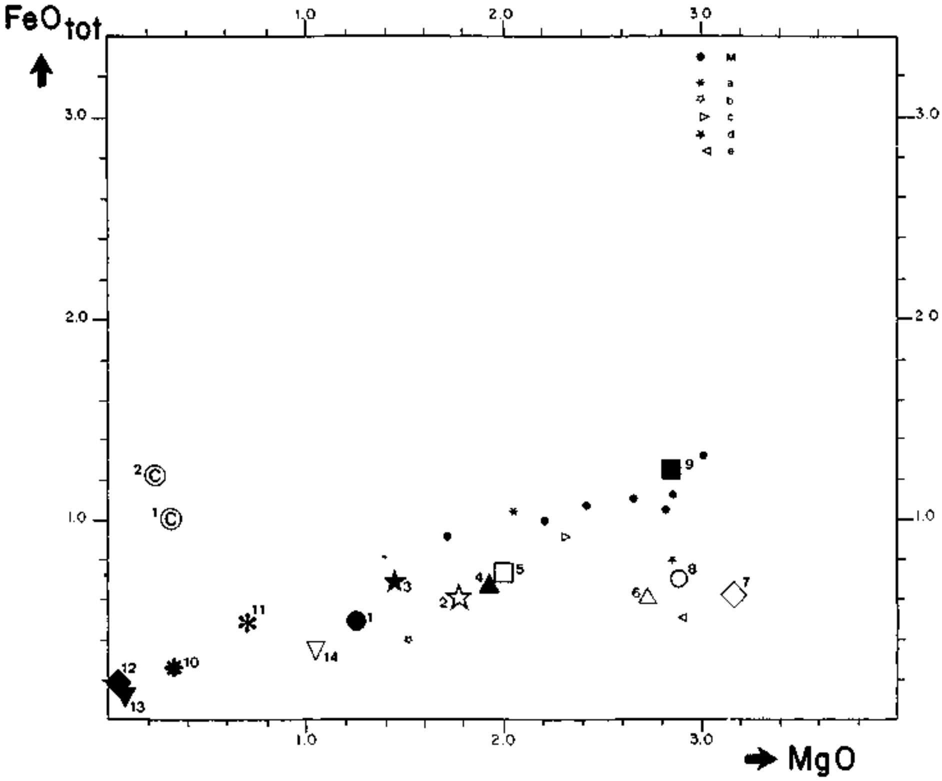

Fig. 4. Correlation diagram FeO_{total}/MgO for emeralds from Brazil, Australia, Norway and Africa

M = Morafeno/Madagascar (06)*
a = Kamakanga/Zambia (11)*
(Schwarz, 1991)
b = Cobra Mine/Transvaal (05)*
(Fillmann, 1987)
c = Zambia (02)*
(Hänni, 1982)
d = Machingwe/Zimbabwe (02)*
e = Zimbabwe (02)*
(Hänni, 1982)
1 = Carnaíba/BA (38)*
2 = Capoeirana/MG (16)*
3 = Belmont Mine/MG (48)*
4 = Socotó/BA (63)*
5 = Tauá/CE (11)*
6 = Pirenópolis/GO (07)*
7 = Salininha/BA (05)*
8 = Itaberaí/GO (13)*
9 = Santa Terezinha/GO (29)*
10 = Poona/Western Australia (12)*
11 = Menzies/Western Australia (08)*
12 = Emmaville/New South Wales (05)*
13 = Eidsvoll/Norway (04)*
C1 = Pegmatite beryls from the Aracuai-Salinas region (Correia Neves *et al.*, 1984) (09)*
C2 = Pegmatite beryls from the Governador Valadares region (Correia Neves *et al.*, 1984) (05)*
* = number of analysed samples

Table 4: Absorption maxima in the 1000-300 nm range of emerald from Morafeno area, Mananjary, Madagascar

wavelength [nm]	wavenumber [cm^{-1}]	assignment
835	11,980	Fe^{2+}oct
685	14,600	Cr^{3+}oct
662	15,100	Cr^{3+}oct
648	15,430	Cr^{3+}oct
638	15,670	Cr^{3+}oct
611	16,370	Cr^{3+}oct
427	23,420	Cr^{3+}oct
371	26,950	Fe^{3+}oct

absorption maxima and their assignments are given in Table 4. The *o*-spectrum is characterized by a broad absorption band in the near infrared, which is split by Jahn-Teller effect. This absorption is caused by spin-allowed d-d-transitions of Fe^{2+} in octahedral coordination (Platonov *et al.*, 1978). The maximum of the band is situated at 835 nm (11,980cm^{-1}) but is less well developed in the *e*-spectrum. Absorption bands of Cr^{3+} in octahedral coordination are located in the orange-red and in the violet spectral region. The Cr^{3+} absorption line in the red is at 685 nm (14,600cm^{-1}) with $e > o$. Weak absorption bands of Cr^{3+} are located at 662 nm (15,100cm^{-1}) for *e* and at 638 nm (15,670cm^{-1}) for *o*. The main pleochroic Cr^{3+}-absorption band has its maximum at 648 nm (15,430cm^{-1}) for *e* and 611 nm (16,370cm^{-1}) for *o*. The second Cr^{3+}-absorption has its maximum at 427 nm (23,420cm^{-1}).

These absorption bands correspond with those described in the literature for natural and synthetic emeralds (Wood & Nassau, 1968; Schmetzer *et al.*, 1974). In the UV range a sharp absorption band is detectable at 371 nm (26,950cm^{-1}) in both *o* and *e* direction. This absorption is caused by octahedral coordinated Fe^{3+}

The absorption minimum is located at 507 nm for *o* and 498 nm for *e*. The pleochroism is yellowish-green for *o* and greenish-blue to blue for *e*.

The absorption spectrum of the Morafeno emerald represents a typical mixed spectrum, containing both an emerald component with Cr^{3+}-absorption bands and an aquamarine component with Fe^{2+} and Fe^{3+} bands. The main Cr^{3+} absorption bands in the orange-red and violet spectral region are both overlapped by iron absorption resulting in more or less asymetrical shapes to the bands. Similar absorption spectra have been described by Schmetzer & Bank (1981) for Zambian emeralds and by Hänni & Klein (1982) for Madagascar emeralds.

Figure 6 shows the absorption spectrum of a Morafeno emerald in the near infrared region in the range of 2500-1000 nm (4,000-10,000cm^{-1}). The observed absorption bands completely refer to vibrations of H_2O molecules in the channel sites of the beryl structure. The maxima of these vibration bands and their assignments are given in Table 5.

Table 5: H_2O-vibration bands in the 2500-1000 nm range of emerald from Morafeno area, Mananjary, Madagascar

wavelength [nm]	wavenumber [cm^{-1}]	type H_2O
1897	5271	II
1789	5590	I
1465	6826	I
1413	7077	II
1401	7138	I
1376	7267	I
1151	8688	II
1132	8834	I

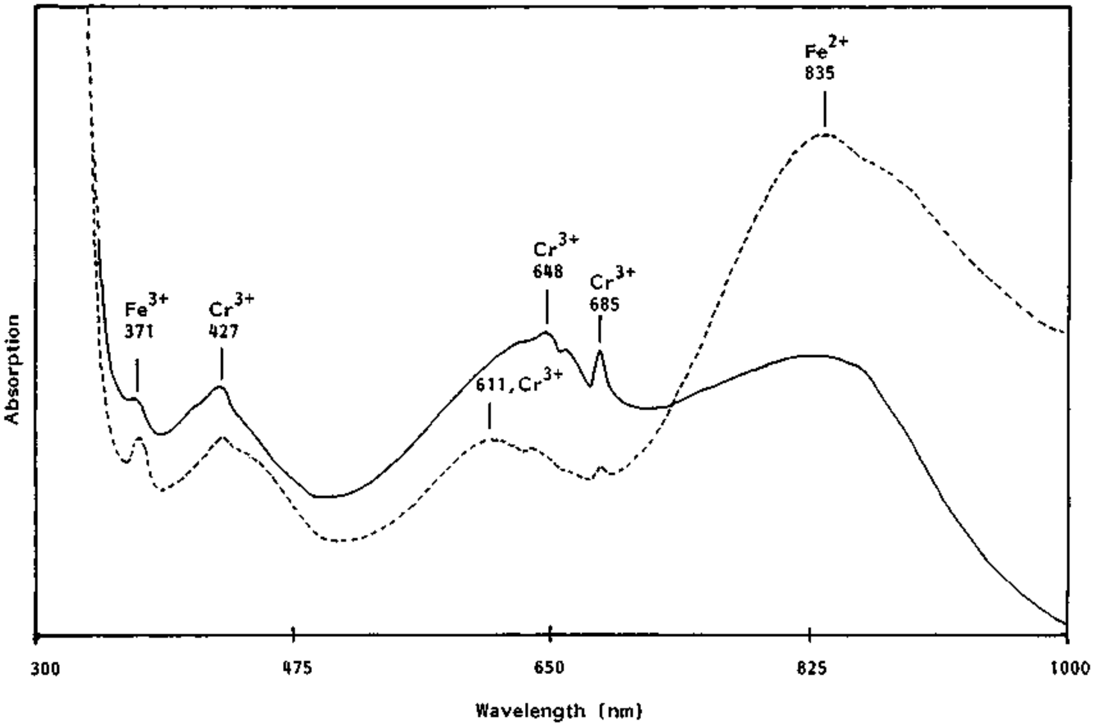

Fig. 5. Polarized absorption spectrum in the 1000-300 nm range of a Morafeno emerald (———— *o*, ———— *e*).

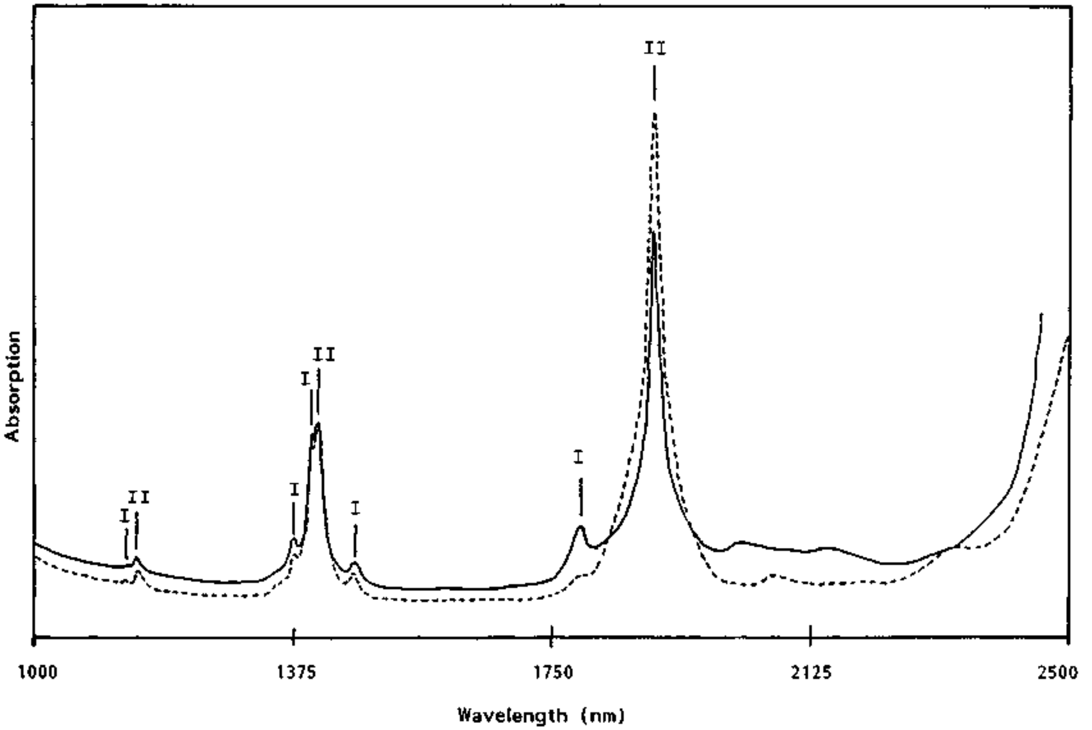

Fig. 6. Absorption spectrum of a Morafeno emerald in the near infrared region (-------- E||c; ———— E⊥c).

Internal features of Madagascar emeralds

The mineral inclusions in Madagascar emeralds from the Morafeno region are very interesting. Apart from brown mica crystals, many of the examined stones exhibit a large number of greenish-brown tremolite/actinolite rods and needles which are not oriented and show an uneven distribution in the host emerald. Frequently the tremolite/actinolite rods present the well-known 'bamboo' appearance. Other mineral inclusions are colourless and transparent prismatic crystals that are oriented in the direction of the emerald's *c*-axis. These are generally associated with fluid inclusions (enclosed in negative crystals or growth tubes). This inclusion type is practically identical to the internal features observed in many Brazilian emeralds from the Belmont mine and the Capoeirana/Nova Era mining field (Hänni *et al.*, 1987; Schwarz *et al.*, 1988). The Madagascar emeralds do not display, however, the enormous variation of different types of fluid inclusions that can be observed in their Brazilian counterparts. A second type of colourless and transparent crystal inclusion is well-rounded and sometimes shows almost ideal spherical or egg-like forms. Other mineral inclusions are opaque grains or opaque pseudo-hexagonal plates and colourless to brownish crystals with a strong relief.

Besides the mineral inclusions, the Madagascar emeralds present the well-known healed fractures (feathers, veils) with small fluid inclusions and also larger fluid inclusions (partly developed as negative crystals) with different types of filling. Most common are two-phase inclusions of the 'lg'-type (liquid and gas), but three-phase inclusions ('slg'-type) and multi-phase inclusions occur also.

Other internal features observed in Madagascar emeralds are colour zoning (almost colourless central area with a green rim); systems of almost parallel-running fractures that are only partly healed; concentrations (agglomerations) of different inclusions (minerals, fluid inclusions) in certain domains of the emerald host crystal.

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Surface features on natural rubies and sapphires derived from volcanic provinces

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Abstract

The majority of surface features observed on natural rubies and sapphires associated with volcanic provinces reflect their trigonal crystal structure and are the result of layer dissolution or etching that occurred while the crystals were exposed to a hostile melt environment en route to the surface. Such features generated by magmatic resorption include trigonal prismatic hillocks, trigonal pyramids, inverted trigonal pyramids, flat floored trigonal and hexagonal depressions (often with a central rhombohedral or pyramidal termination), and 'brick-like' stacks of trigonal prisms. The style of features observed on a given surface is dependent both on the angle of the surface to the *c*-axis of the corundum crystal and the degree of subsequent etching. More irregular sculpture-like features appear to arise from continued dissolution, and the growth and merging of the above-mentioned features. Many of the crystal surfaces also show a superimposed surface texture consisting of fine corrosion pits.

Fluvial transport and residence in the alluvial environment are responsible for the remainder of the surface features observed. These include conchoidal fracture surfaces radiating from points of impact (particularly along exposed edges on some stones), clean fracture surfaces where pyramidal and prismatic protrusions have been broken, and exposed healed-fracture surfaces.

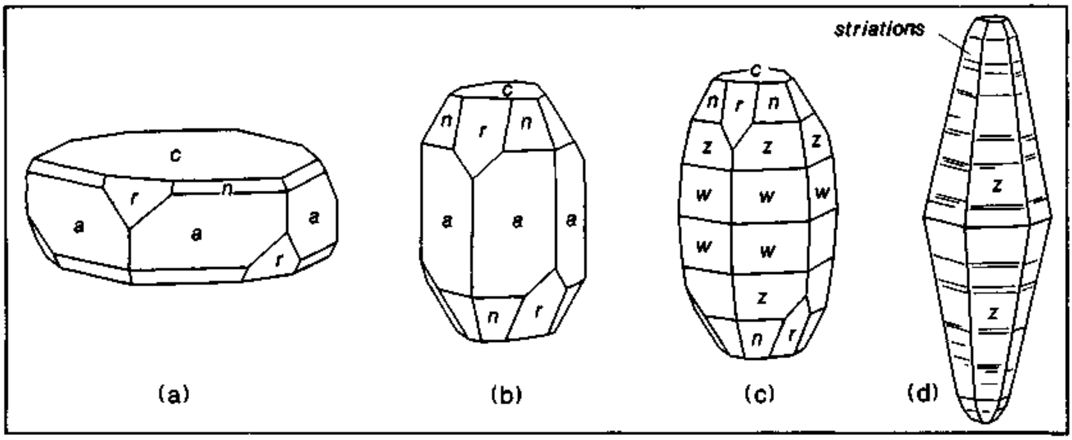
The grain surface features indicate minimal amount of damage due to fluvial transport. This, together with the spatial variability in the physical characteristics of corundum in a given placer deposit, indicates a minimal degree of downstream reworking and mixing. Such observations suggest that the corundum sources are local to the placer deposits.

Introduction

Ruby and sapphire are members of the corundum family. They are aluminium oxide (Al_2O_3), which is colourless when pure, and owe their striking colours to the presence of minor amounts of other elements. In ruby, chromium is responsible for the red colour whereas in sapphire, titanium and divalent iron are responsible for the blues and greens.

Corundum crystallizes in the trigonal system with ruby and sapphire often displaying quite distinct forms. Crystals of ruby typically display short six-sided prisms and large basal pinacoids, with only minor rhombohedral and bipyramidal development between the pinacoid and prism faces.

Fig. 1. Ruby and sapphire crystal forms belonging to the rhombohedral division of the trigonal system. Ruby crystals typically display short six-sided prisms and large basal pinacoids, with only minor rhombohedral and bipyramidal development between the pinacoid and prism faces (part a) whereas sapphire crystals show a more pronounced development of the bipyramidal faces with only minor prismatic and pinacoid development (c and d).



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The result is a flat to tabular prismatic habit shown in Figure 1a. Crystals of sapphire show a more pronounced development of the bipyramidal faces with only minor prismatic and pinacoid development, such as shown in Figure 1b. Oscillation between the different bipyramid forms gives the crystals a stepped tapering appearance with fine striations on the bipyramid faces at right angles to the *c*-axis. These features are masked in sapphires of volcanic origin due to dissolution of the crystal surfaces.

Origin of volcanic ruby and sapphire

Rubies and sapphires are mined from heavy mineral concentrates in alluvial gravels which have been derived from either volcanic or metamorphic terrains. Gem fields associated with basaltic volcanism include New England and Anakie in Australia (MacNevin, 1972; Broughton, 1979; Coenraads, 1990); Pailin in Cambodia (Jobbins and Berrange, 1981); Chanthaburi-Trat, Denchai, Bo Ploi and Khorat Plateau in Thailand (Vichit *et al*, 1979; Barr and MacDonald, 1981; Keller, 1982; Gunawardene and Chawla, 1984; Vichit, 1987); Bokeo Plateau, Xuan Loc Plateau, Cardamones Massif, Solovens Plateau and Kassens Plateau in Kampuchea (Lacombe, 1969-70); Haut Chalong Plateau, Pleiku Plateau, Darlac Plateau and Djiring Plateau in South Vietnam; Kouang Tcheoci Wan, Fujian Province and Hainan Island in Southern China (Keller and Wang, 1986; Keller and Keller, 1986); Mercaderes Rio Mayo area in Colombia (Keller *et al*, 1985); Gimi Valley near Jemaa and Kaduna Province in Nigeria (Kiefert and Schmetzer, 1987). These gem fields are associated with predominantly alkaline basaltic lava fields, cones or eroded remnants.

The corundum appears to be of the same age as the associated alkaline volcanic rocks, as shown by (Coenraads *et al*, 1990) for the New England gem fields. Mineral inclusion compositions and the present study suggest that the corundum formed as part of a coarse-grained, pegmatite-like assemblage that crystallized from strongly evolved, silica-poor magmas rich in volatiles and incompatible elements. Alkali basaltic magmas served as carriers, firstly disaggregating and partially resorbing the corundum assemblage, and then bringing the material rapidly to the surface.

Surface features of Ruby and Sapphire

The surface features of a large number of stones from placer deposits associated with volcanic provinces in both eastern Australia and Thailand were examined.

Australian sapphires were collected from Reddestone Creek No 1 plant (29°41'30"S, 151°38'50"E), No 2 plant (29°43'00"S, 151°38'20"E), and Kings Plain Creek (29°41'00"S, 151°27'50"E) near Glen Innes, New South Wales; and Braemar (29°47'20"S, 151°17'30"E), near Inverell, New South Wales. Thai sapphires were collected from the SAP Mining Co, near Bo Ploi, Kanchanaburi region (14°20'30"N, 99°29'30"E); and the Elem Mine near Ban Khlang, Chanthaburi-Trat region (12°36'10"N, 102°18'10"E). Thai rubies were collected from the Elem Mine and the Ruby Well Mine, near Noen Chali, Chanthaburi-Trat region, (12°32'0"N, 102°30'10"E).

Samples were examined with a binocular microscope, then selected specimens were cleaned for 5 to 10 minutes in an ultrasonic bath of water or hydrogen peroxide, mounted on scanning electron microscope stubs and gold coated. Photographs

Fig. 2. 1. Negative crystal socket in blue sapphire, X18. 2. Negative crystal in blue-purple sapphire, X14. 3. Negative crystal socket in purple ruby, X14, all from the Ruby Well mine, Chanthaburi-Trat. 4. Sapphire from Reddestone Creek, No.2 plant, New England, X25; a) detail showing flat topped triangular hillocks, X66; b) detail showing relief of hillocks and their irregular, eroded appearance, X330; c) detail of one hillock showing gradual rise from the floor into the hillock wall, X935; d) detail of one hillock showing pock marked, etched surface, note damage to top edge of the hillock due to fluvial transport, X1210.

Fig. 3. (p.154) 1. Blue sapphire from Reddestone Creek, No.1 plant, New England, surface perpendicular to the *c*-axis; a) oriented flat, shallow hexagonal etch depressions with central hillocks, X358; b) detail of several hexagonal depressions, X2200; c) stages of formation of etch features, right-early stage of originally flat surface breaking down into etch depressions with central hillock, bottom centre-edges of depressions removed leaving only sub-triangular to rounded hillocks, left-more extensive etching gives surface a spongy appearance, X237. 2. Blue sapphire from SAP mine, Bo Ploi, hexagonal etch depressions with a central hillock, X1100. 3. Pink-purple ruby, Ruby Well mine, Chanthaburi-Trat, showing early stages of formation of triangular and hexagonal hillocks; a) X330; b) X660. 4. Deep prominent etch sculpturing on a pink-purple ruby, Ruby Well mine, Chanthaburi-Trat; a) complete specimen, X28; b) detail of etch channels, X138.

Fig. 4. (p.155) Blue sapphires from New England; a) complete specimen, X7; b) detail of 'shark skin like' etch channels,,X66. 2. SAP mine, Bo Ploi; a) 'intaglio-like surface due to extensive etching, X61; b) detail of a) showing structural control of 'intaglio' pattern and microlamination due to successive layer dissolution, X440. 3. Braemar, New England; a) etch pattern resembling trigonal prismatic 'stacked bricks' on a surface oriented at a low angle to the *c*-axis, X825; b) detail of surface, X2200. 4. Braemar, New England; a) triangular pyramidal depressions resulting from etching of a surface at an intermediate angle to the *c*-axis, X825; b) detail of pyramidal depressions, X2200.

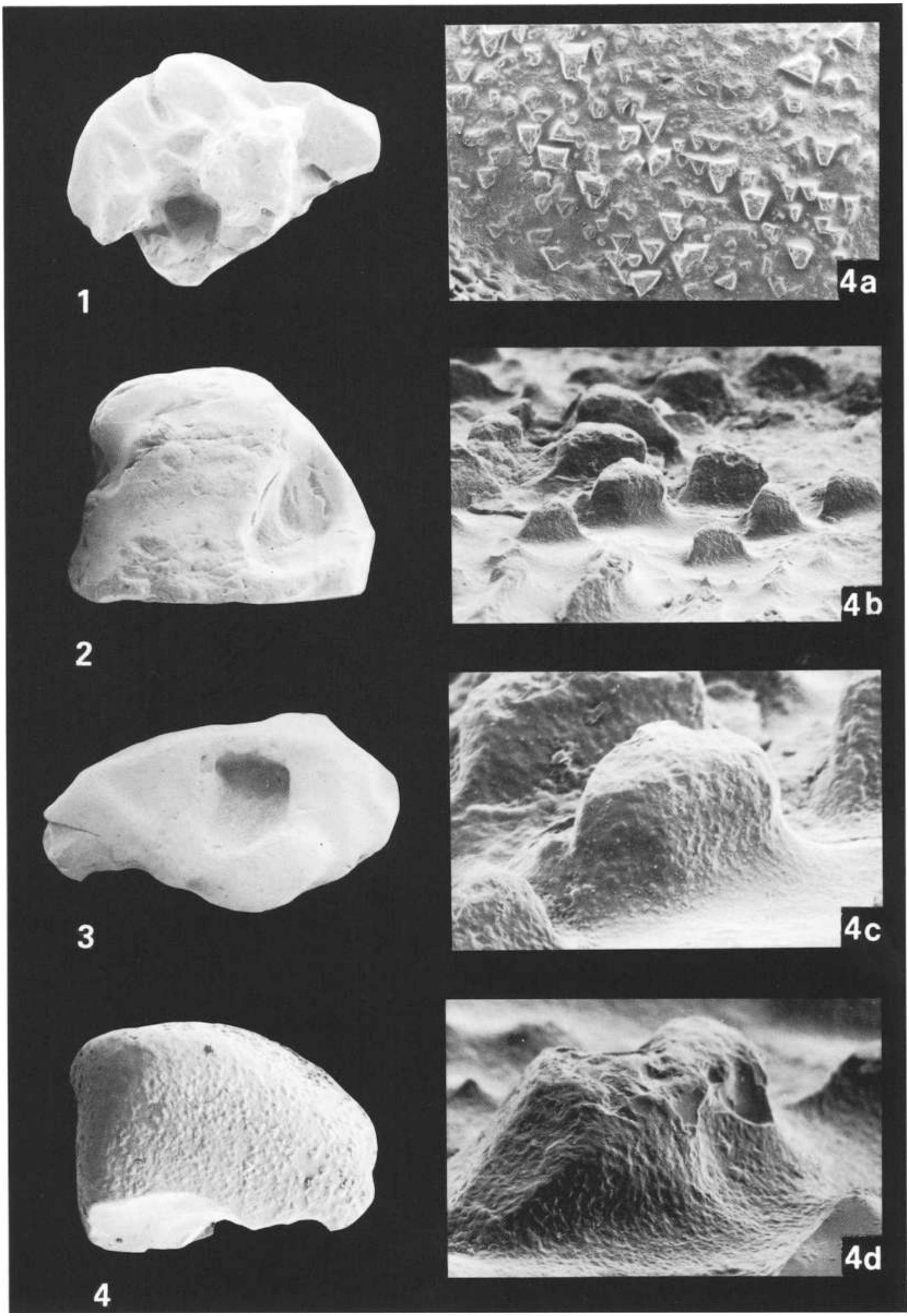

Fig. 2.

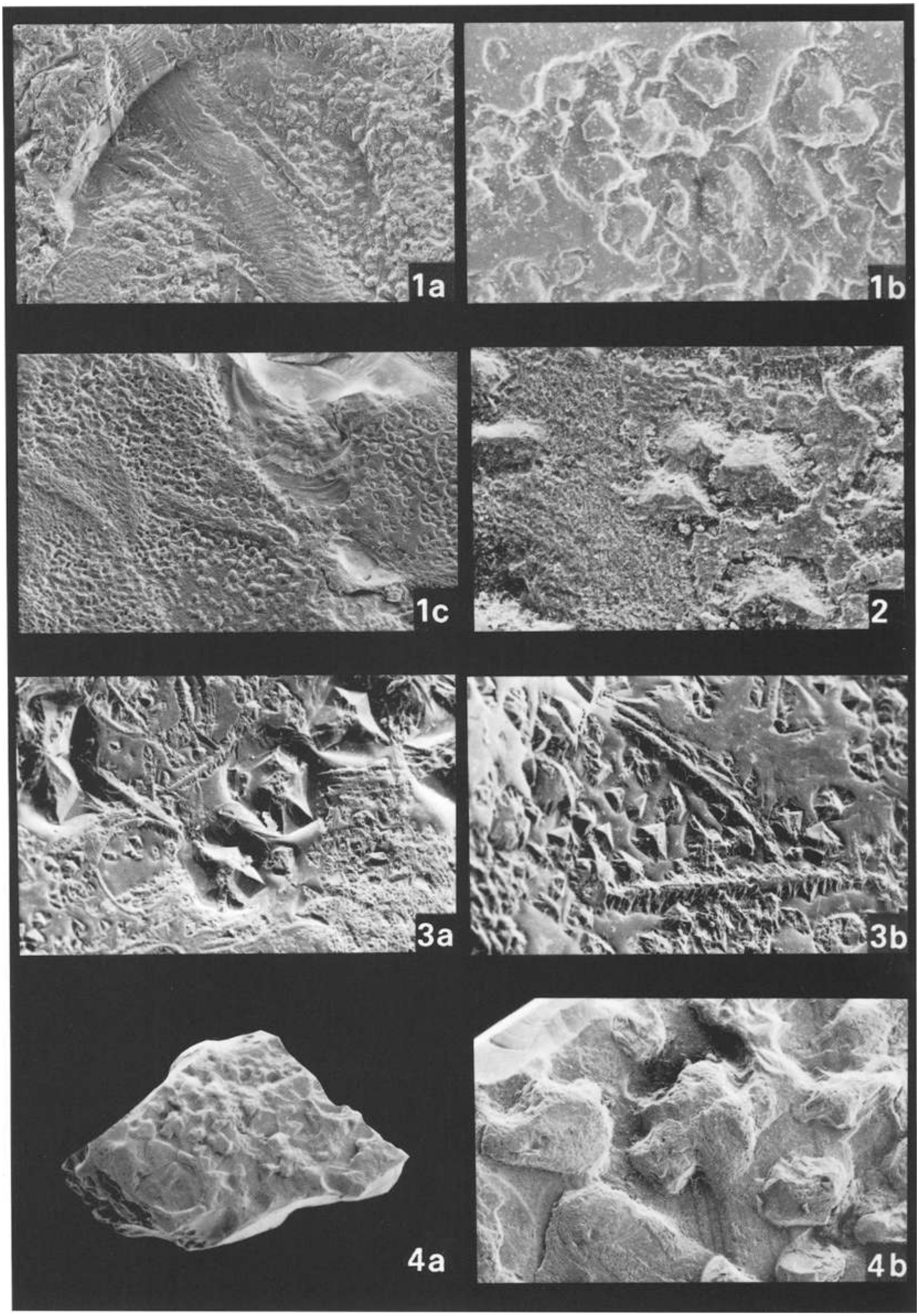

Fig. 3.

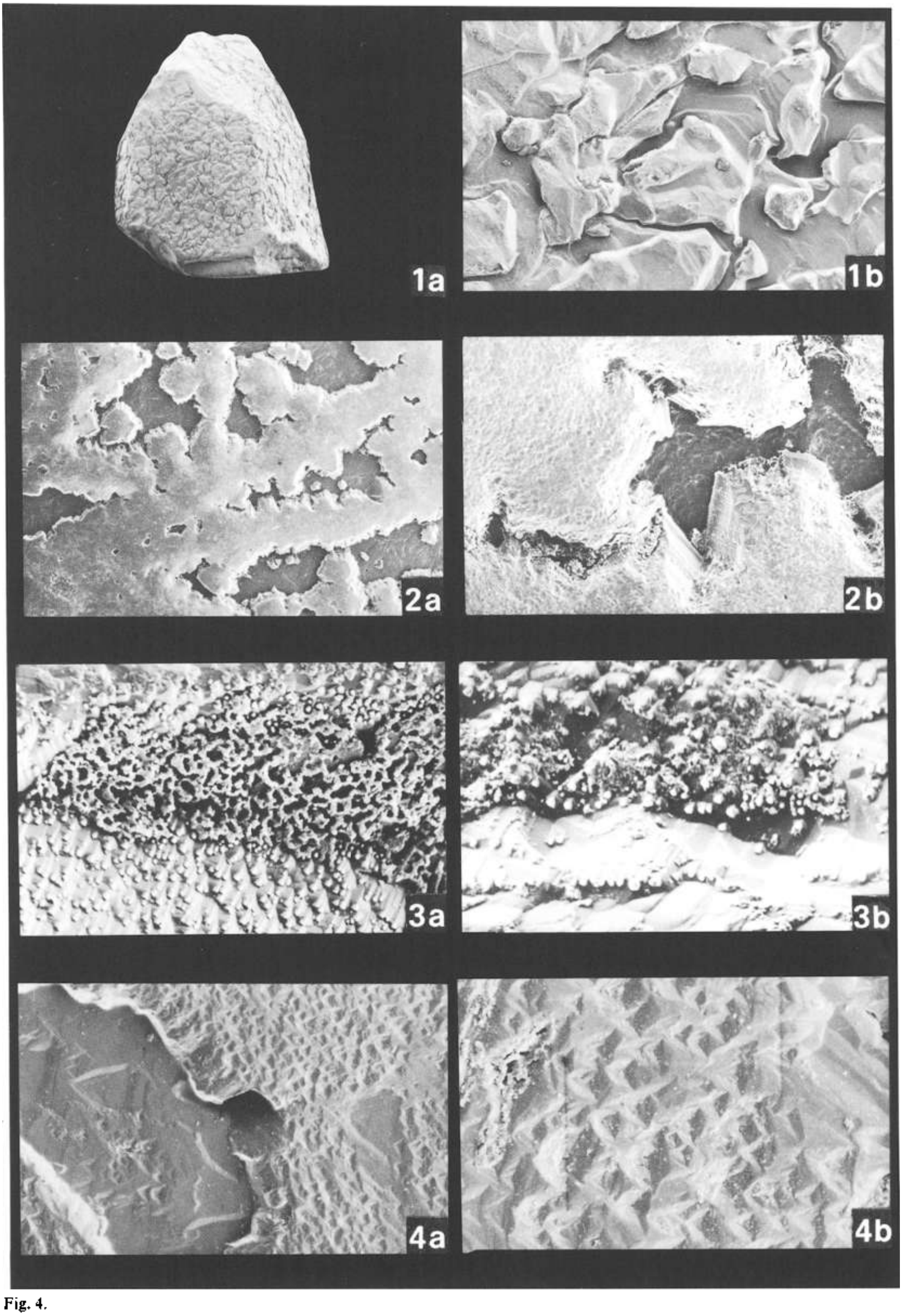

Fig. 4.

were taken with a JEOL JSM 840 scanning electron microscope.

The observed features may be broadly grouped as negative crystal impressions, surface resorption or etch features, including chatter marks, and surface damage consistent with transport in the alluvial environment.

1. Negative Crystal Impressions

Figures 2-1, 2-2 and 2-3 show sharp edged, deep, geometric shaped holes, or crystal impressions of the order of 0.5-1.0mm across on sapphire and ruby crystal faces. The angles between the impression faces in Figures 2-1 and 2-2 are 120°. The negative crystal shape in Figure 2-3 is particularly interesting in that it appears to show tetragonal symmetry, thus precluding the possibility of it having been a fluid filled negative crystal cavity. These impressions developed as the corundum grew as part of a coarsely crystallized aggregate with minerals such as anorthoclase and zircon (Coenraads *et al*, 1990) and spinel (Vichit, 1987).

2. Surface Etch Features

The above figures, as well as Figures 2-4, 3-4a, 4-1a, 5-3a, 6-1a and 6-2a show the corundum to be sub-rounded to rounded in appearance. This rounding, although once attributed to alluvial wear, is clearly the result of resorption by magmas responsible for carrying the corundum to the surface. The grains in Figures 2-4 and 6-1a show the surface to be covered with flat topped triangular hillocks of the order of 15-20 μm which reflect the internal trigonal crystal symmetry. The only exception is where the bottom of the grain in Figure 2-4 has broken away along a conchoidal fracture surface. A further enlarged view of the sapphires' surface in Figure 2-4b shows the relief of the triangular hillocks and their irregularity in detail. They stand like sculptured 'monoliths' on the surface of the sapphire, roughly equidimensional and have a relief of about 20 μm. Figures 2-4c and 2-4d show the gradual rise of the surface from the floor in between the hillocks into their walls, and the surface in detail, which is covered with sub-geometrically regular to rounded pock marks or shallow dishes about 1 μm in diameter. These features give the hillocks a distinctly eroded appearance.

The hillocks are most likely of similar origin to the pyramidal or drop shaped hillocks on rounded surfaces of diamonds (Orlov, 1977, p.93) and also reproduced in etching experiments (Patel and Agarwal, 1966).

Figures 3-1a and 3-1b show relief on a face perpendicular to the *c*-axis {0001} of a sapphire crystal. The etching is variable in distinct bands. Figure 3-1b shows detail of the etching as oriented flat shallow hexagonal depressions of the order of 5-10 μm in diameter with a hexagonal shaped remnant hillock centrally positioned in each. The probable sequence of formation of the etch features is illustrated in Figure 3-1c where all stages are present on the one crystal, and where each form merges into another across the surface. In the bottom centre of the photograph, below the large chip displaying conchoidal fracture, the surface is covered by sub-triangular to rounded hillocks described earlier. In the right of the photograph can be seen what may be the early stages of formation of such a surface. Here an originally flat surface has been etched to produce a number of hexagonal depressions, each with a centrally placed hillock. In the left of the photograph the surface has a spongy or porous appearance, probably as a result of extensive etching.

Figures 3-3a and 3-3b show detail of the early stages of formation of hexagonal and triangular hillocks on a Thai ruby. Peaked hillocks bounded by crystal faces, ranging up to 50 μm, are surrounded by a moat into which the outer wall gradually slopes. In some cases preferential alignment of etching has led to the formation of ridges as seen in Figure 3-3b. The hillocks are similar in appearance to the hexagonal etch marks (of the order of 10-20 μm) seen on a Thai sapphire (Figure 3-2 and also Figure 3-1b, described above), only in this case, the outer walls of the moats are roughly sculptured as opposed to being smoothly sloping. The reason for the development of a peaked hillock remnant bounded by crystal faces situated centrally within an etch pit is not clear, although it could be a response by the crystal to minimize its surface free energy when it was in contact with the hostile carrier magma.

As the dissolution process proceeds, etch features appear to grow and interfere with one another producing deep and prominent sculpturing ('shark skin' appearance) such as seen on the surface of the Thai ruby (Figures 3-4a and 3-4b) and Australian

Fig. 5. Blue sapphires from Braemar, New England. 1. Detail of etch surface at a low angle to the *c*-axis resembling trigonal prismatic 'bricks', X3300. 2. Chatter marks or sub-parallel curved grooves attributed to mechanical stress; a) X358; b) detail of chatter marks X1375; c) further detail, finely striated faces within chatter marks indicate that they have been enhanced by dissolution, X2365. 3. Sapphire traversed by numerous fractures; a) complete specimen, X18; b) detail of fractures, X193; c) detail of b), X495. 4. Fracture radiating from an inclusion in sapphire, X110.

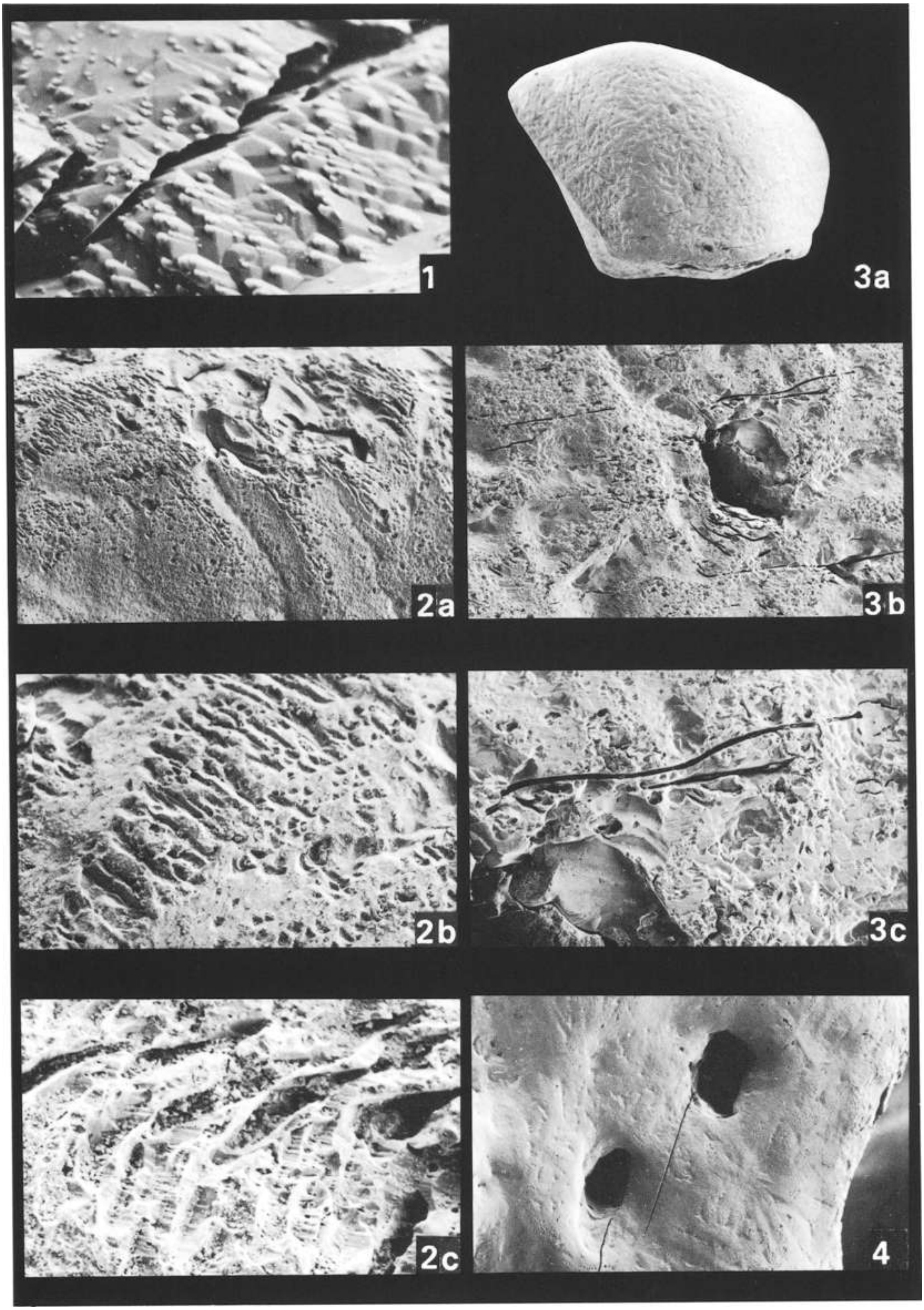

Fig. 5.

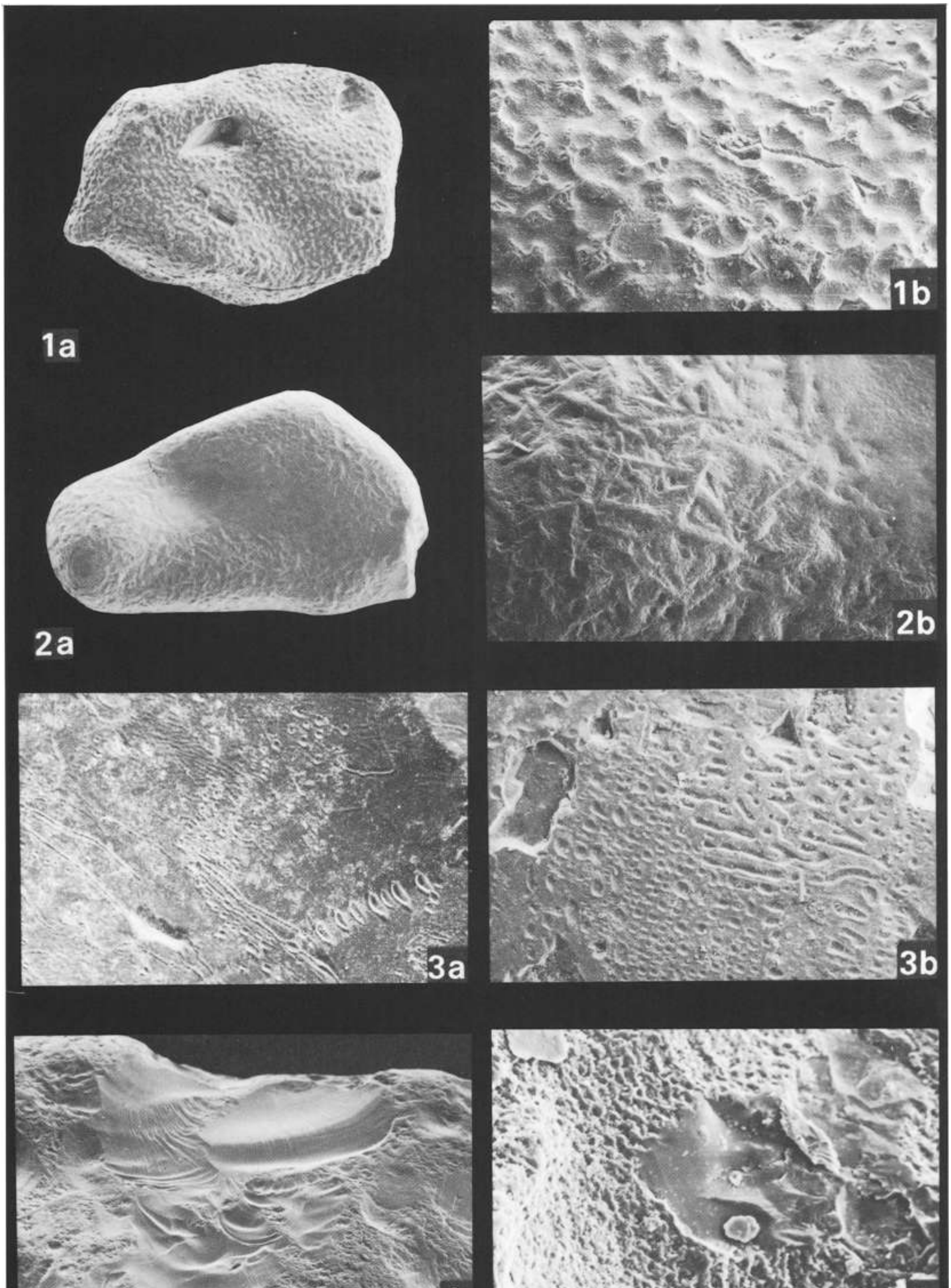

Fig. 6.

sapphire (Figures 4-1a and 4-1b). Orlov (1977, p.98) found similar features on the octahedral faces of diamond resulting from continued dissolution which caused the etch trigons to grow larger and crowd in on one another. Such extensive dissolution also seems to have been responsible for the 'intaglio-like' surface produced on the sapphire in Figure 4-2a. The outer surface has been removed in places to a depth of about 15 μm, to a lower level which appears to be more resistant and only lightly etched. Detail in Figure 4-2b reveals a fine micro-lamination which has been emphasized by the dissolution as a series of steps of the order of 1 μm in size. Such micro-lamination is also observed in diamond (Orlov, 1977, p.87) and has been attributed to successive layer dissolution.

On surfaces which appear to be at a lower angle to the *c*-axis of the corundum crystal (see Figures 4-3a, 4-3b and 5-1), the etch patterns are quite different, and resemble inclined stacks of elongated, triangular shaped bricks. These structures clearly reflect the internal crystal structure of the corundum. Figure 4-3a shows two surfaces; in the lower part of the photograph, a surface roughly parallel to the *c*-axis displays triangular prisms whilst in the upper part of the photograph a surface perpendicular to the *c*-axis, partially covered by lichen, shows typical triangular hillocks described earlier.

Figure 4-4a and the detail in Figure 4-4b, show triangular depressions of the order of 1-2 μm across, with the depression walls forming a negative triangular pyramid. Such features appear to be the result of etching on a surface at an intermediate angle to the *c*-axis.

The surface features of most grains studied, even those with an apparently random 'blade-like' texture such as seen in Figure 6-2a, could be ultimately explained in terms of surface etching. Under magnification (Figure 6-2b), a crystallographic control of the features is revealed. In Figure 6-2b the raised 'blades' are seen to form the sides of triangular shaped pits.

Chatter marks are occasionally present and are shown in Figures 5-2a, 5-2b and 5-2c. These features are attributed to some form of mechanical stress leading to the formation of a series of parallel or curved marks on the surface of the grain. Detail in Figure 5-2c shows that the marks may be of 1-2 μm in width and as deep or deeper. The finely striated faces within the curved chatter mark grooves show a pattern, not unlike that described in Figures 4-3a, 4-3b and 5-1. This suggests that the grooves have been enhanced by dissolution and implies that the corundum displaying chatter marks has been subject to stresses prior to, or possibly during transport to the surface.

3. Healed fracture surfaces and damage resulting from transport in an alluvial environment

Figures 5-3a, 5-3b and 5-3c show narrow (1-2 μm) but deep fractures which traverse the stone irregularly or in a semi-oriented manner. These start and end abruptly and probably represent healed or partially healed stress fractures. They are described by Orlov (1977, p.53) as planar dislocation growth defects originating from a defect centre such as an impurity or inclusion in the interior of the crystal and radiating to the faces. Such may be the case in Figure 5-4. It is logical that such planes of weakness would be likely sites for breakage in the alluvial environment. Figures 6-3a and 6-3b show such rebroken healed fracture surfaces revealing a 'fingerprint-like' pattern of tubes of about 1-2 μm in size. Such fingerprints are commonly photographed within gem rubies and sapphires using light microscopes (Gübelin and Koivula, 1986, p.340).

Damage in the alluvial environment results from impacts during transport. This is seen as conchoidal fracturing particularly around the more exposed edges of crystals as shown in Figure 6-4, or as chipping on protruding hillocks (Figures 2-4d and 6-1b). In Figure 6-5, an impact has completely broken off a protruding hillock leaving a smooth fracture surface.

Conclusion

Surface features on rubies and sapphires from volcanic provinces may give an insight into the history of such crystals from the time of their growth to their eventual recovery by mining.

1. Negative crystal impressions suggest that the corundum grew as part of coarsely crystallized aggregates together with minerals such as anorthoclase, zircon and spinel.
2. Surface resorption or etching and layer dissolu-

Fig. 6. Blue sapphires 1. Ruby Well mine, Chanthaburi-Trat showing surface covered with triangular hillocks; a) complete specimen, X30; b) detail of triangular hillocks, some chipped due to fluvial damage, X165. 2. Reddestone Creek No. I plant; a) complete specimen showing a 'bladed' surface texture, X24; b) detail shows crystallographic control as the raised 'blades' form two sides of triangular pyramidal shaped pits, X110. 3. SAP mine, Bo Ploi. Rebroken healed fracture surfaces reveal a 'fingerprint-like' pattern of exposed fluid remnants; a) X440; b) X550. 4. Reddestone Creek, No.1 plant, New England. Conchoidal fracturing on the edge of this sapphire is evidence of damage in the fluvial environment, X138. 5. Ruby Well mine, Chanthaburi-Trat. Protruding hillock broken off at its base leaving a clean fracture surface is evidence of damage in the fluvial environment, X2200.

tion features clearly result from reaction with the magmas responsible for carrying the corundum to the surface. These features include, triangular and hexagonal hillocks and depressions on faces perpendicular to the *c*-axis, and stacks of triangular prisms on surfaces parallel to the *c*-axis of the corundum crystal. Chatter marks imply that the corundum has been subject to stresses prior to, or possibly during transport to the surface.

3. Surface damage including impact marks displaying conchoidal fracture, broken off protrusions and exposed healed fracture surfaces indicate the degree of reworking in the alluvial environment. The grain surface features generally indicate minimal damage due to fluvial transport. This observation, when considered in conjunction with the spatial variability in the physical characteristics of corundum in a given placer deposits (Coenraads, 1990), indicates minimal degree of downstream reworking and mixing, and suggests that the corundum sources are local to the placer deposits.

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H_2O and all that!

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It is generally accepted that quartz in its many varieties is the most abundant and ubiquitous mineral, although if all the different feldspars were to be considered as one mineral there could be some argument as to which of these two predominates in the terrestrial crust. The feldspars are the more important in the classification of rocks.

But there is a very familiar third contender for predominance which is scarcely thought of as a mineral by the layman. I refer to H_2O, – water – which at the sub-zero temperatures of the Poles obviously forms a massive mono-mineralic rock which we know as *ice*. Once that fact is accepted, then the liquid hydrosphere has to be included correctly under the heading of mineral.

The oceans cover about 71% of the Earth's surface, and their mean depth is estimated at about 12,000 feet (3650 metres) which gives us 317,000,000 cubic miles (1,320,000,000km^3) of water, give or take a river-full. Fresh water in ice caps (2½%), lakes and rivers, plus ground-water amounts to no more than 3½%. Atmospheric water forming rain evaporates from just the surface of oceans or land and deep water in both zones can wait for thousands of years before taking its turn to form rain clouds. Once in the upper regions of the atmosphere water vapour can remain air-borne for more than a year before coming down again as rain.

In its crystalline form as ice, water is trigonal in symmetry, although this is generally observable only in the ephemeral microscopic beauty of a single crystal of snow (Figure 1). Its SG as a solid is 0.917, the mean RI is 1.31 and the birefringence is 0.004. (Liquid water is both denser and has a slightly higher RI of 1.33; while ice under great pressure assumes other crystalline forms some of which are denser than liquid water.) Hardness evaluation is complicated by the fact that pressure causes ice to melt, but it can be considered to be a soft mineral since ice skates obviously scratch it, and it is also cleavable and very easily frangible in most circumstances. (I have had personal experiences, however, of the remarkable tenacity of thin films of ice when backed by iron plates, while the iced superstructure of a steel ship can be almost impossible to clear of the dangerously top-heavy mass that can accumulate.)

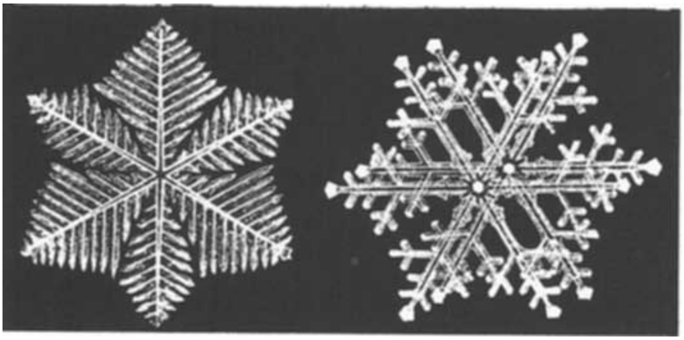

Fig. 1. Diagrams of two snow crystals showing the characteristic trigonal form. After A.E.H. Tutton, 1911.

The estimated relative amounts of quartz, feldspar and water are, of course, largely hypothetical, for no one knows with certainty what quantities of each might exist deeper in the crustal layers, and liquid water certainly penetrates strata many kilometres deep, a great deal of it at pressures and temperatures which enable it to behave as a gas,

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with additional properties which will be described below. As vapour it forms part of the atmosphere to very considerable heights, and can constitute up to 7% of the total air in exceptional circumstances. There is a great deal of water about! [None of which information appears to concern us much in gemmology, apart from the occasional trade references to 'ice' when describing a particularly fine diamond, or an item of diamond jewellery of outstanding merit.]

However, gemmologists normally use water for hydrostatic weighing and this practice brings us to one of the most peculiar properties of this ubiquitous liquid mineral.

We are taught that the specific gravity of a gem is its weight compared with that of an equal volume of pure water at 4°C. (A more exact figure is 3.8°C.) At that temperature water is at its densest. At higher temperatures it is less dense, e.g. at a room temperature of (20°C) its density is 0.99823. As the temperature gets lower the density increases, as it would in any liquid, until at 3.8°C it reaches a value which is regarded as unity (1.00). However, as further heat is lost, water behaves quite abnormally and starts to expand and become less dense until at 0°C it reaches 0.99987. At this temperature it freezes, turning to ice, and a truly dramatic increase in volume occurs, the density going down suddenly to 0.917.

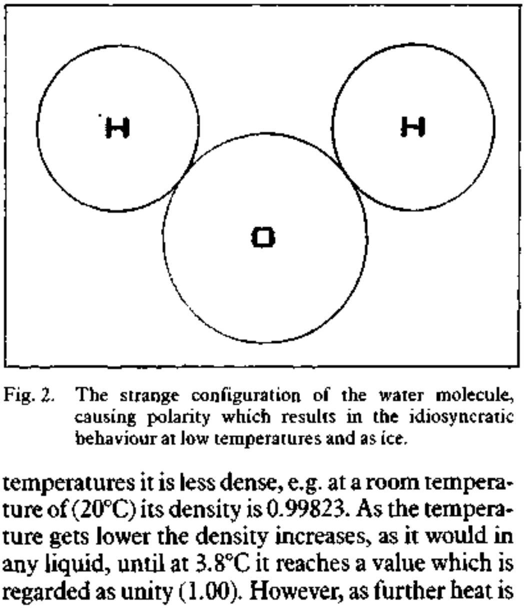

Fig. 2. The strange configuration of the water molecule, causing polarity which results in the idiosyncratic behaviour at low temperatures and as ice.

The reason for this anomaly has been understood only comparatively recently. For many years it was thought that the water molecule had a linear configuration, like the word OXO, i.e. H-O-H. then it was shown that the two hydrogen atoms attach themselves to the negative oxygen at an angle of 105° (Figure 2). Ideally they would be at right angles, but the hydrogens are positively charged and repel each other, so that the angle between them widens. This fact also gives the molecules polarity, so that even in the liquid state they tend to join up to form larger but constantly changing complex structures of molecules, a tendency which increases as the temperature gets lower.

The thermal vibration of molecules in liquids and in solids keeps them apart, but this movement decreases as temperature falls, so that almost all substances become progressively denser as they cool, and vice versa; and the solid, or close-packed version of a liquid, is usually denser still and therefore sinks in the liquid. This applies to almost all other liquids, including molten metals when cooling and solidifying.

But in the case of water the unusual bent configuration of the single molecule prevents such close-packing, or any further reduction in volume beyond that achieved at 3.8°C and as more and more molecules join up to form large multiples the density reduces from 1.00 to 0.99987. Then ice forms and the molecular configuration takes over completely, forcing an irresistible expansion which lowers the density suddenly to 0.917. So ice is about one-tenth less dense than liquid water. In other words it occupies one-tenth more space than it did before freezing and does so inexorably regardless of pressure. This, I think, makes it clear why water at 3.8°C is used as a standard when determining the specific gravity of solids.

It will be seen that ice floats, a fact with which we are so familiar as to accept it without further thought. Also cold water can continue to sink only until it cools to a density of 1.00, after which it starts to ascend again as it gets colder still. If it then goes on to freeze, the much less dense ice can only form at the surface, where it provides a thermal barrier which effectively prevents freezing from going far below the surface layers. The lower regions of deep water are almost always in a state which makes freezing unlikely and really thick ice can achieve permanence only on land. In water the frozen under-surface is continually thawing and reforming, or being replaced from the top by compacted snow. Icebergs slowly melt both above and below the surface of the water in which they float. If that water is appreciably warmer they are reputed to turn turtle as they melt more rapidly there than in the air and become top-heavy, but a little thought will show that as the base reduces in size so the whole mass will settle in the water and such acrobatic somersaults seem rather unlikely to occur other than in shallow water.

Back to gemmology. Water of crystallization becomes part of the mineral structure and temperatures below zero probably do not affect it. But where, as in the case of opal, the water is held entrapped by the silica structure I feel that there is some possibility that freezing may contribute to the tendency for that gem to crack.

Another gemmological point can be made here in the fact that we are told to use water at room temperature for hydrostatic weighing and to multiply the result by the density of water at that temperature, a calculation which is scarcely necessary since a specific gravity of 2.65 becomes 2.645 when multiplied by 0.99823 (the density at 20°C), which is well within the margin of experimental error in normal hydrostatic weighing of small stones. For most practical gemmology the temperature gradient can be ignored.

Another important property of water lies in its behaviour when it is heated to the critical temperature of (374°C), which can be done by heating in a sealed autoclave, or 'bomb', so that it is under pressure of its own super-heated vapour. (This is not a unique condition since all liquids have their critical temperature at which they can no longer remain as liquids even under pressure.) In these conditions water becomes highly compressed very hot steam, and will take minerals such as quartz, beryl, corundum and others into solution quite readily. This gives us yet another connection with gemmology, since it is the basis for hydrothermal manufacture of synthetics, where mineral substances are taken into solution at or above the critical temperature in an autoclave, the lower end of which is allowed to cool, so that the gas condenses to its liquid form again and deposits the dissolved mineral as crystals, either spontaneously or onto a seed crystal. By careful regulation of temperatures and of colouring impurities superb synthetic crystals are obtained for cutting as gems (or for laser use).

Another gemmological tip arising from our earlier discussion of hydrostatic weighing is the fact that it is by no means a waste of time to do a hydrostatic on a stone in a mount. How often are we called upon to estimate the weight of a set stone for insurance purposes or with a view to buying it in over the counter? Various methods have been advocated from plain guesswork, to gauges of greater or lesser efficiency, to comparison with stones of a known weight, to weighing another mount to get somewhere near the weight of the one in question, or even to measuring the stone in all its dimensions and working out a weight using complicated mathematical formulae to obtain an approximation. Some of these might work, but there is a risk of getting hopelessly wrong answers to what should be a simple enough question even when we cannot get permission to unset and weigh the stone separately.

In the past I have been offered a peridot ring with the remark that it 'Must weigh over 12 carats' and have found myself in possession of a nice stone of over 26 carats. A star sapphire offered at 'about 15 carats' estimated weight, turned out to be around 35 carats when I took it out of its setting. Such inexact guesses are quite unnecessary and are very dangerous to the jeweller if he is valuing the stone. The answer lies in doing an ordinary hydrostatic weighing, a matter of a few minutes only.

Simply weigh the whole item in air and then weigh it again in water. Subtract the second weight from the first to find the total loss of weight.

Then, if we already know what the stone is (from its RI) and the nature and quality of the metal (hallmark), it is very easy to arrive at a weight for either the stone or for the mount by simple calculation. First assume that the whole ring is composed of stone and multiply the stone's SG by the loss of weight. Deduct this figure from the total weight of the piece and that will give us the extra weight due to the greater density of the metal used. Divide this figure by the known SG of the metal *less* the SG of the stone.

SGs of PRECIOUS METALS:–

YELLOW GOLD		WHITE GOLD	
9ct	11.2	9ct	12.0
14ct	14.1	14ct	12.9
18ct	15.5	18ct	16.1

PLATINUM 21.4

SILVER 10.3

VICTORIAN GOLD MOUNTS with silver settings are usually 15ct gold, so an SG figure of 12 would be a fair approximation, but the method is a little less accurate with such mounts.

This gives us the loss of weight due to the mount alone. Subtract this from the total loss of weight to find the loss due to the stone only, and multiply the result by the SG of the stone. This sounds complicated, but it is nothing of the kind. Try it and see. The longest part is the weighing and even that should not take more than a few minutes.

To give an actual example:

An aquamarine (SG 2.70) and 18ct gold (SG 15.5) ring weighs 35.32cts.
In water it weighs 28.75 carats.
Loss of weight = 6.57 carats.
If all aquamarine then weight would be 6.57 x 2.70 = 17.74.
Extra weight due to gold = 35.52 − 17.74 = 17.58.
So loss of weight of mount is 17.58 divided by 15.5 − 2.7 = 1.37.
So loss of weight due to the stone is 6.57 − 1.37 = 5.20.
Weight of stone is then 5.20 x 2.70 = 14.04 carats.

There are very minor differences in the SG of a gem species from stone to stone, and rather greater differences in the SG of gold of a given caratage [bullion dealers for this reason usually quote only to one place of decimals]. But this method can usually be relied upon to give an answer well within 10% of the true weight of a stone. Where there are a few small diamonds included in the design one obviously needs to take these into account at the end of the main calculation by deducting say half a carat from the estimated weight of the main stone. Most jewellers are expert at estimating the weight of small diamonds by sight and should have little difficulty in making a reasonable correction for this situation. The method only really comes to grief when a mass of large stones of mixed species are found in one mount, and even then some guidance can be obtained from the exercise if it is used intelligently.

Reverting to the extraordinarily anomalous behaviour of water at low temperatures it may be seen with a little thought that if this did not happen life could never have developed on this planet, for an ocean in which ice sank to the bottom could not remain liquid very far below the surface layers. Even in equatorial latitudes currents could not descend to carry oxygen down to maintain life; and life is known to have started in the oceans many millions of years before it moved out onto the land.

Again the sudden and irresistible expansion when ice forms is probably one of the most important natural forces of all, in that it is this which cracks hard rocks and gradually reduces them to smaller and smaller sizes until a fine soil is produced in which plant life can flourish.

Without these extraordinary responses to temperature, life as we know it could not exist.

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Application of geochemistry to exploration for gem deposits, Sri Lanka

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Abstract

Geochemical analysis of stream sediments, when integrated with heavy mineral surveys, can be used as an effective tool in the exploration for sedimentary gem deposits. Recent research studies carried out by the authors have shown that certain rarer minerals associated with the gem minerals leave a special geochemical signature which could be identified and used in the delineation of areas suitable for further detailed exploration for gem minerals. In the placer gem-bearing terrains located within a high-grade metamorphic terrain in Sri Lanka, it has been found that Sr/Rb ratios, thorium and uranium, fluorine, tantalum, niobium, yttrium and the rare-earth elements can be used as pathfinders in the search for new gem deposits.

Introduction

Exploration for gem deposits in an alluvial environment very often consists of panning stream sediments for heavy minerals. Geochemical drainage surveys had been developed from this practice of tracing heavy minerals in stream gravels. Most of the world's major gold and tin camps had been discovered by the identification of gold and cassiterite in panned concentrates (Hawkes and Webb, 1965). Chemical analysis of the stream sediments integrated with mineralogical investigation of the heavy concentrates forms a powerful tool in the exploration for economically important heavy mineral deposits.

Anomalous concentrations of metals in stream sediments occur in primary ore minerals, resistant secondary minerals and in precipitates of various kinds. The heavy mineral fraction of the stream sediments contains the resistant primary ore minerals commonly having a high specific gravity. Beryl however, on account of its lower specific gravity, is generally found in the lighter fraction associated with quartz.

Chemical analysis of the heavy mineral fraction often highlights the anomalous concentrations of geochemically immobile elements such as Au, Sn, W, Hg, Ta and Nb. Under exceptional circumstances however, some of the more mobile elements are known to occur in the heavy fraction (Hawkes and Webb, 1965).

As a special group of minerals, gems occur in the heavy fraction of the stream sediments. Figure 1 illustrates the mean density values of the more important sediment forming minerals inclusive of gem minerals. The chemistry of this heavy mineral fraction of the stream sediments is not often fully utilized in the geochemical exploration for gem deposits. This paper describes the successful application of geochemistry in the search for new gem deposits in Sri Lanka.

Chemistry of rare minerals

Even though many of the more common gem minerals are found in nature as oxides (or silicates) they tend to be associated with rarer minerals which have a unique geochemical signature. Many of these rarer minerals have anomalous concentrations of rare-earth elements (REE) Ta, Nb, Zr, Th, U, Ti, Be, and F. Table 1 shows the chemistry of the rarer minerals associated with the gem minerals in the stream sediments. Some elements such as Zr, Be, and F will naturally be found in gem minerals such as zircon, beryl and topaz respectively and their abundances will lead to the discovery of these minerals and hence other associated gem minerals such as corundum, spinel, garnet and tourmaline.

Rare earths and rare elements, when found in anomalous concentrations lead to the discovery of occurrences of minerals such as zirkelite, monazite, gadolinite, chevkinite, samarskite, aeschynite, anatase etc. These rare-earth bearing minerals are commonly associated with the gem minerals, as in the case of the sedimentary gem deposits of Sri Lanka, and can therefore be used as excellent indicator minerals in the search for gem-bearing terrains. It must be emphasized however, that the use of rare-earth elements and rarer minerals in the search for gem occurrences depends largely on the geology of the terrain and possibly on a genetic link between the mineral suites concerned. In their study on the corundum, Cr-muscovite rocks at O'Briens, Zimbabwe, Kerrich *et al.* (1987) com-

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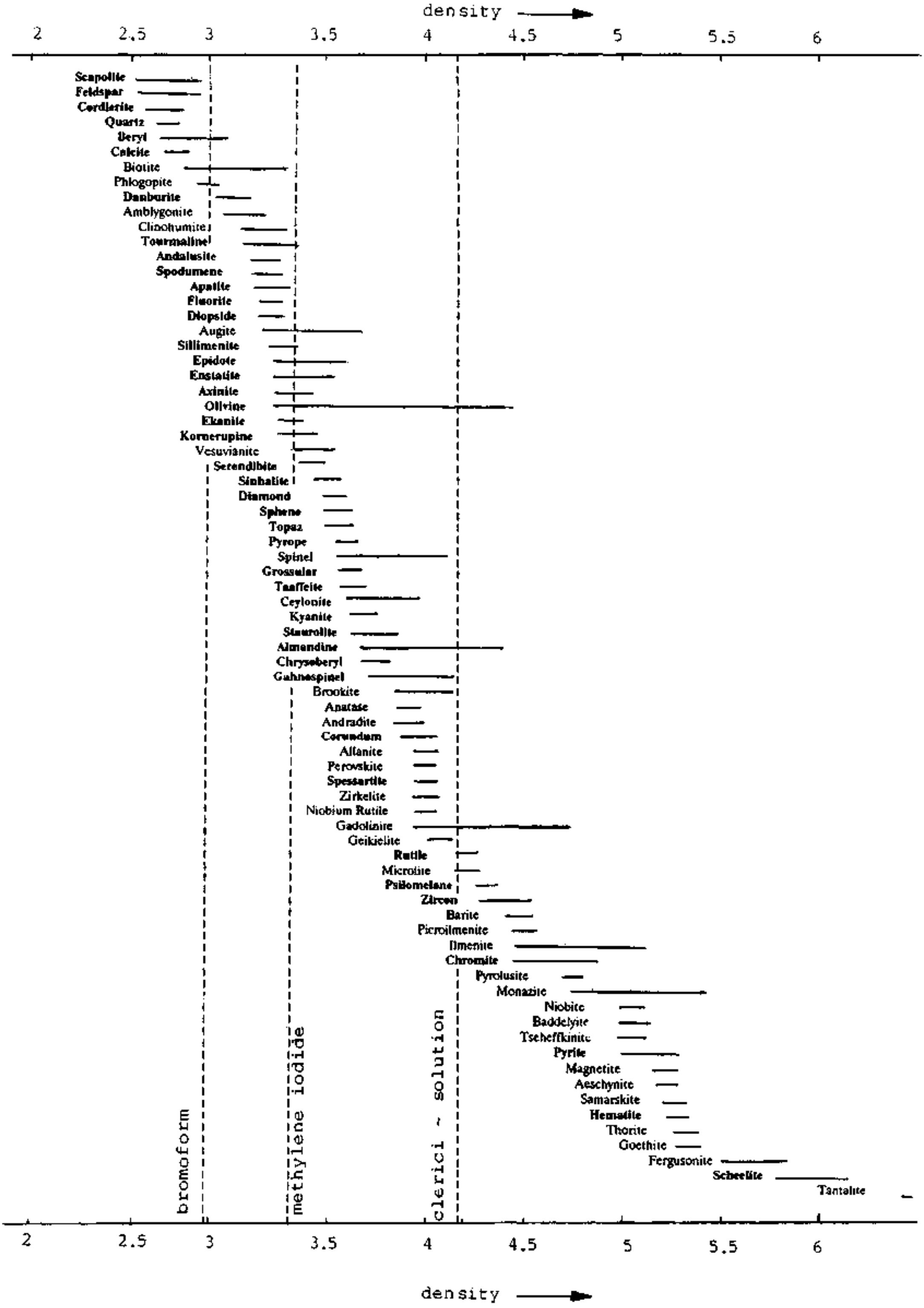

Fig. 1. Mean density values of the more important sediment-forming minerals inclusive of gem minerals.

Table 1: Some rare minerals associated with gems in Sri Lanka

Mineral	SG	Chemical formula	Other elements found
Ekanite	3.28	$K(Ca,Na)_2Th(Si_8O_{20})$ $CaTi(O/SiO_4)$	
Serendibite	3.4	$(Ca,Mg)_5(AlO)_5[BO_3/(SiO_4)_3]$	
Anatase	3.9	TiO_2	Nb,Ta,REE
Allanite	4	$(Ca,Ce)(Fe^{3+},Fe^{2+})Al_2O(SiO_4)(Si_2O_7)(OH)$	
Perovskite	4	$CaTiO_3$	Nb,Ta,REE
Zirkelite	4	$(Ca,Ce,Y,Fe)(Ti,Zr,Th)_3O_7$	1-14%U_2O_8,REE
Rutile	4	TiO_2	Nb,Ta,Fe
Gadolinite	4-4.7	$Y_2Fe^{2+}Be_2[O/SiO_4]_2$	
Geikielite	4.05	$MgTiO_3$	
Microlite	4.2	$(Ca,Na)_2(Ta,Nb,Ti)_2O_6(OH,O,F)$	
Zircon	4.3-4.5	$ZrSiO_4$	U,Th,Hf,REE
Chromite	4.5-4.8	$(Fe,Mg)Cr_2O_4$	
Monazite	4.8-5	$CePO_4$	U,Th,REE
Columbite	5	$(Fe,Mn)(Ta,Nb)_2O_6$	
Baddeleyite	5	ZrO_2	
Tantalite	5-8	$(Fe,Mg)(Ta,Nb)_2O_6$	
Samarskite	5.24	$(Y,U,Ca)_2(Nb,Fe^{++})_2(O,OH)_6$	Ta,REE
Thorite	5.3	$ThSiO_4$	U
Fergusonite	5.6-5.8	$Y(Nb,Ta)O_4$	4%U_3O_8, REE
Scheelite	5.9-6.1	$CaWO_4$	
Cassiterite	6.8-7.1	SnO_2	Nb,Ta,Ti, Mn,Zr,W,Fe
Thorianite	9.7	$(Th,U)O_2$	

mented, for instance, on the inter-element relationships for certain major and trace elements. The variations of V, Sc and Y relative to Zr and Hf during genesis of the rocks were attributed to hydrothermal alteration rather than to intrinsic variations diagnostic of different precursors. These authors used the rare-earth elements patterns effectively to make significant observations on the origin of the corundum rocks.

Tantalum and niobium are two elements of great importance in geochemical investigations for granite-associated heavy minerals. The features of the magmatic and postmagmatic evolution for granite related tantalum and niobium mineralization is reflected in the geochemistry. These mineralizations are often associated with geochemically specialized granites and are characterized by their enrichment in fluorine. Alkali granites containing alkali pyroxenes and/or amphiboles are noted for their high Fe, F, Nb, Rb, Zr, Sn and REE and for their low Ca, Ba, Sr and Ta/Nb. Sediments derived from such granite precursors therefore yield valuable geochemical clues as to the possible source rocks of gem mineralizations and their locations. Pollard (1989a, 1989b) and Cerny (1989) have discussed in detail the geochemistry of Ta and Nb mineralizations and their geochemical exploration strategies.

Use of fluorine geochemistry in gem exploration

Pathfinder elements and mineralizers are factors that are of great importance in the formation of mineral deposits. Among these are B, CO_2, F, Cl, Br, I, S and Sc. It has been known that the two elements B and F are universal indicators of nearly all types of epigenetic deposits; where one is not present, the other is, and in many deposits both occur (Boyle, 1984).

Table 2: Fluorine-bearing minerals around Rattota and Matale area

MINERAL	CHEMICAL FORMULA	F^-%
Fluorite	CaF_2	48%
Topaz	$Al_2SiO_4(OH,F)_2$	13-20%
Amblygonite	$Li,Al[(F,OH)PO_4]$	0.57-11.71%
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$	1.35-3.77%
Biotite	$K(Mg,Fe)_3[(OH,F)_2AlSi_3O_{10}]$	
Hambergite	$Be_2[(OH,F)BO_3]$	
Sphene	$CaTiSiO_5$	.07-1.27%

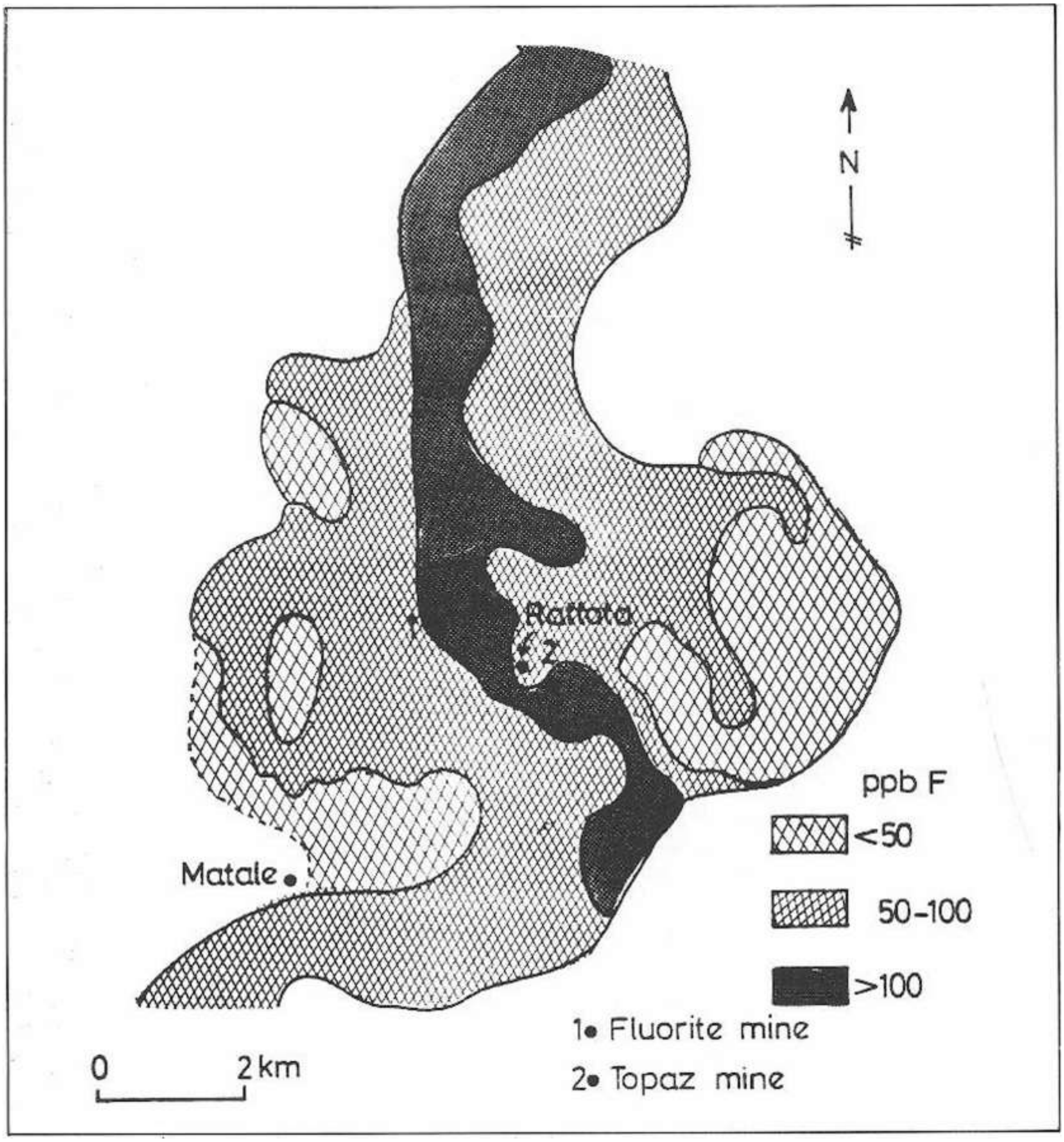

Fig. 2. Hydrogeochemical map of fluorine in ground water in the study area (values in ppb).

Table 3: Rare-earth element abundances in Ratnapura* and Elahera gem-bearing sediments. (ppm)

Sample no.	7*	15*	16*	19*	21*	29*	30*	31	35	37	38
La	79.00	136.82	105.69	145.70	99.85	79.24	53.01	55.10	66.86	52.02	49.53
Ce	215.00	246.18	198.74	392.00	178.11	158.00	251.95	127.00	164.60	124.00	113.00
Pr	19.40	28.05	21.95	39.00	18.42	–	14.33	14.00	–	13.06	13.25
Nd	67.80	107.68	93.05	119.00	61.20	66.45	42.91	48.40	59.21	44.71	41.00
Sm	13.00	17.29	16.71	21.76	9.57	11.80	7.83	9.00	9.43	8.59	6.55
Eu	2.21	2.55	3.23	2.76	0.96	2.29	1.34	1.70	1.39	1.24	1.47
Gd	13.00	18.45	21.40	21.00	7.52	–	–	9.00	7.40	–	–
Tb	1.60	2.00	2.54	2.61	1.07	1.33	1.00	1.30	1.11	1.18	1.04
Dy	8.94	11.55	13.80	15.50	5.66	7.94	–	7.50	5.13	5.43	6.60
Ho	2.11	2.40	3.55	3.00	1.09	–	1.00	1.50	1.08	1.24	1.34
Er	–	–	8.66	10.40	2.71	–	–	4.20	–	3.35	3.97
Tm	–	–	–	–	–	–	–	–	–	–	–
Yb	5.80	6.70	7.75	8.22	2.55	4.33	2.30	4.40	2.70	3.48	3.78
Lu	0.87	1.03	1.15	1.25	0.40	0.66	0.38	0.64	0.42	0.58	0.48

Fluorine is an element widely distributed in ore deposits and in the accessory minerals in igneous rocks. It is also known as an excellent mineralizer that accompanies a large number of metals, and it is this property of fluorine that makes it useful as an indicator in mineral exploration. As pointed out by Lalonde (1976), the mobilization of metal ions as metal-halide complexes in mineralizing solutions is an important aspect of most metallogenic theories and is supported by numerous analyses of fluid inclusions, connate brines and thermal waters. It is therefore logical for one to expect dispersion haloes of halogens around ore deposits, bearing in mind that fluorine is the most promising geochemical indicator of mineralization.

Recent geochemical surveys by the authors in the areas around Rattota and Matale in Sri Lanka known to be a mineralized zone indicated a clear potential for the use of fluorine geochemistry in gem exploration. Table 2 shows the fluoride-bearing minerals that were found in the area.

Nearly 200 groundwater samples were collected from the area concerned and analyzed for their fluoride concentrations. The data obtained were plotted on maps and the regions of anomalous fluoride concentrations highlighted (Figure 2). The dispersion haloes were clearly associated with the topaz and fluorite-bearing regions of the mineralized zone. It should however be emphasized that to obtain the best results one needs to integrate the geochemical survey with a heavy mineral survey of the stream sediments.

Rare-earth elements in gem-bearing sediments

The sedimentary gem deposits of Sri Lanka are well known for their wide variety of gemstones dominated by varieties of corundum, chrysoberyl, spinel, garnet, tourmaline, topaz, zircon etc. These gem-bearing sediments have been the subject of several studies (Katz, 1972; Silva, 1976; Dahanayake *et al*, 1980; Munasinghe and Dissanayake, 1981; Dissanayake and Nawaratne, 1981; Rupasinghe *et al* 1984). Overstreet (1967) had earlier commented on the abundance of monazite in placer deposits of Sri Lanka and emphasized their high Th and REE concentrations.

Rupasinghe and Dissanayake (1984a) made a detailed study of the rare-earth element abundance in the sedimentary gem deposits of Sri Lanka and observed their relatively high concentrations (Table 3). In general the Ratnapura type gem deposits are enriched in REE when compared to the REE of average shale (ZGI-TB – Flanagen, 1973). Table 4 shows the degree to which the gem sediments of Sri Lanka are enriched in REE as compared to shales. The averages for these sediments far exceed those determined for the post – Archean upper crust and the Archean exposed crust, the greatest enrichments being for La-Sm. Figure 3 illustrates the differences in the REE distributions in the two main gem fields of Sri Lanka.

In general, it could be concluded that the gem-bearing sediments of Sri Lanka are highly enriched in REE, particularly LREE, a negative Eu-anomaly being prominent. Rupasinghe and Dissanayake (1984b) assumed that the REE concentrations of the gem-bearing sediments are intimately associated with a charnockite-granite progenitor.

Geochemical mapping of rare-earth element anomalies in stream sediments could yield useful

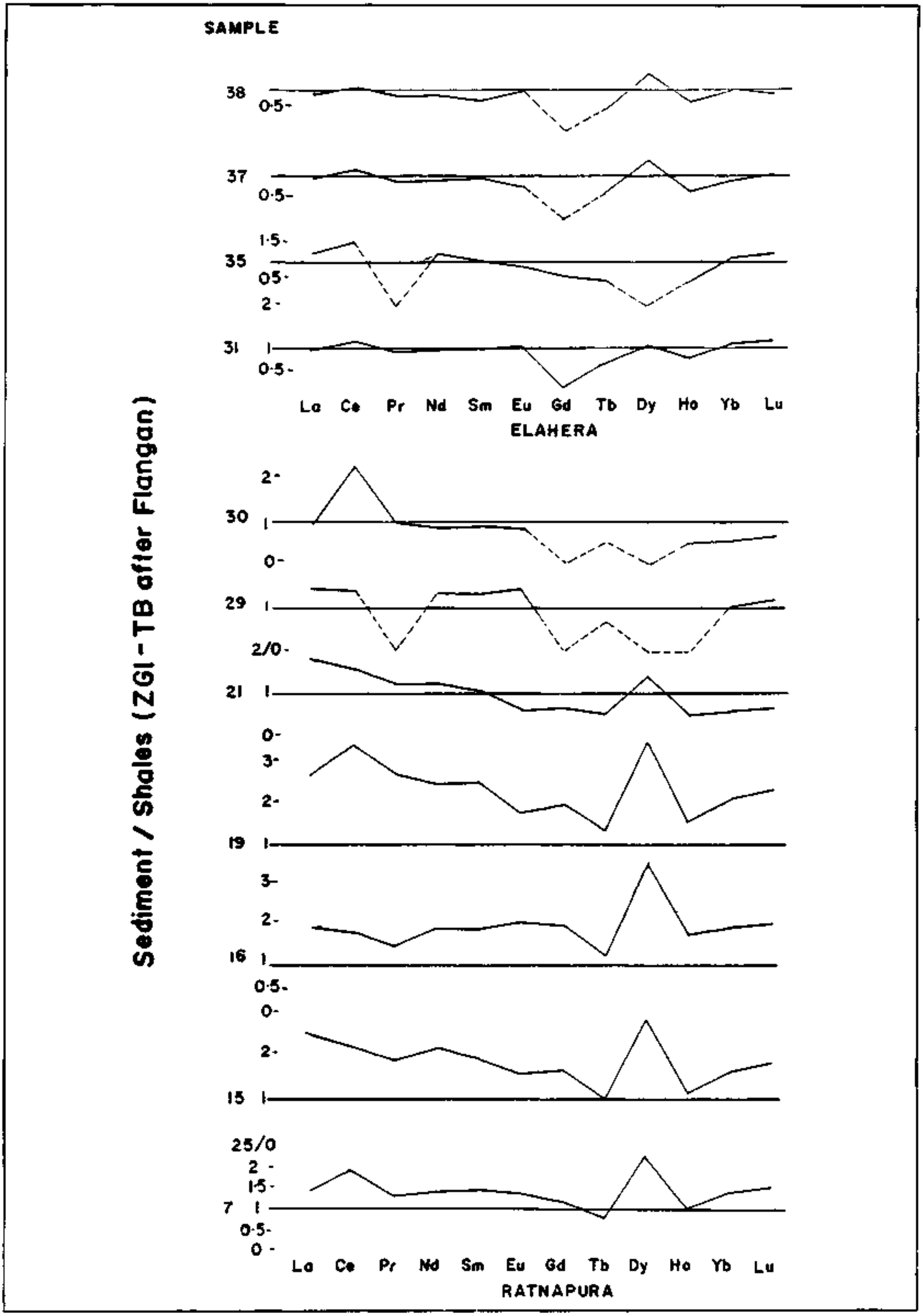

Fig. 3. The rare-earth element distributions in the two main gem fields of Sri Lanka.

Table 4: The REE contents of the gem-bearing sediments of Sri Lanka and of shales, chondrites and crustal averages ppm

	PAAS	ES	NASC	AAS	Chondrites	Post-Archean upper crust	Archean exposed crust	Gem sediments of Sri Lanka	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Ratnapura (8)	Elahera (9)
La	38.0	41.1	32.0	12.6	0.367	30.0	12.6	99.90	55.87
Ce	80.0	81.3	73.0	26.8	0.957	64.0	26.8	234.28	132.15
Pr	8.9	10.4	7.9	3.1	0.137	7.1	3.1	20.16	9.85
Nd	32.0	40.1	33.0	13.0	0.711	26.0	13.0	79.73	48.33
Sm	5.6	7.3	5.7	2.8	0.231	4.5	2.8	13.99	8.39
Eu	1.1	1.5	1.2	0.9	0.087	0.9	0.9	2.19	1.45
Gd	4.7	6.0	5.2	2.9	0.306	3.8	2.8	11.24	4.10
Tb	0.8	1.0	0.9	0.5	0.058	0.6	0.5	1.74	1.16
Dy	4.4	–	5.8	2.9	0.381	3.5	2.9	9.06	6.17
Ho	1.0	1.2	1.0	0.6	0.085	0.8	0.6	1.89	1.29
Er	2.9	3.6	3.4	1.8	0.249	2.3	1.8	3.11	2.88
Tm	0.4	0.6	0.5	0.3	0.036	0.3	0.3	–	–
Yb	2.8	3.3	3.1	1.8	0.248	2.2	1.8	5.39	3.59
Lu	0.4	0.6	0.5	0.3	0.038	0.3	0.3	0.86	0.53
ΣREE	183.0	198.0	173.2	70.3	3.89	143.3	70.3	483.54	275.76
LaN/YbN	9.2	8.4	7.0	4.8	–	9.2	4.8	18.53	15.56

(1) = Post-Archean average Australian Shale (Nance and Taylor, 1976); (2) = European Paleozoic Shale composition (Haskin and Haskin, 1966); (3) = North American Shale Composite (post-Archean) (Haskin and Paster, 1979); (4) = Archean average Sedimentary rocks (Australia) (Taylor and McLennan, 1981a); (5) = chondrite-normalizing factors derived from abundances in Type 1 carbonaceous chondrite (Evensen et al., 1978; Mason, 1979); multiplied by 1.5 to allow for removal of volatiles; (6) = taken to be 20% lower than PAAS to account for low REE-bearing rocks such as carbonates and evaporites (after Taylor and McLennan, 1981b, 1982); (7) = Same as AAS; (8) = Ratnapura gem sediments; (9) = Elahera gem sediments.

indications leading to the discovery of associated gem mineralization.

Abundances of Y and Nb

The presence of minerals such as niobian rutile, perovskite, fergusonite etc in the gem-bearing sediments has resulted in the choice of the elements Y and Nb as pathfinders, particularly in view of the availability of more sensitive and accurate methods of chemical analysis. Dissanayake and Rupasinghe (1986) in their study of the abundances of Nb and Y in some gem-bearing sediments of Sri Lanka showed that Nb and Y are found at maximum concentrations of 229 ppm and 318 ppm respectively. The source rocks of Nb and Y were presumably rocks of the charnockite – granite association and related pegmatites found in the Highland Group of Sri Lanka. During weathering and sedimentation, Nb and Y enter the hydrolysates and get concentrated in the sediments. Apart from the gem minerals themselves, the sediments found in the gem fields of Ratnapura and Elahera contain abundant Nb and Y.

Goldschmidt (1958) noted that during the processes of weathering and sediment evolution, a small fraction of Nb remains in resistant minerals like cassiterite, columbite and rutile, and as such is arrested in residual sediments such as sands and sandstones. Most of the Nb, however, is fixed in hydrolysate sediments such as clays and bauxites along with Ti and Sr. The REE, Nb and Ta and economically useful elements such as Th and U are found in the hydrolysate group (Figure 4) and it is of interest to note that these elements are abundant in the gem-bearing sediments of the Highland and Southwest Groups of Sri Lanka. The fact that the

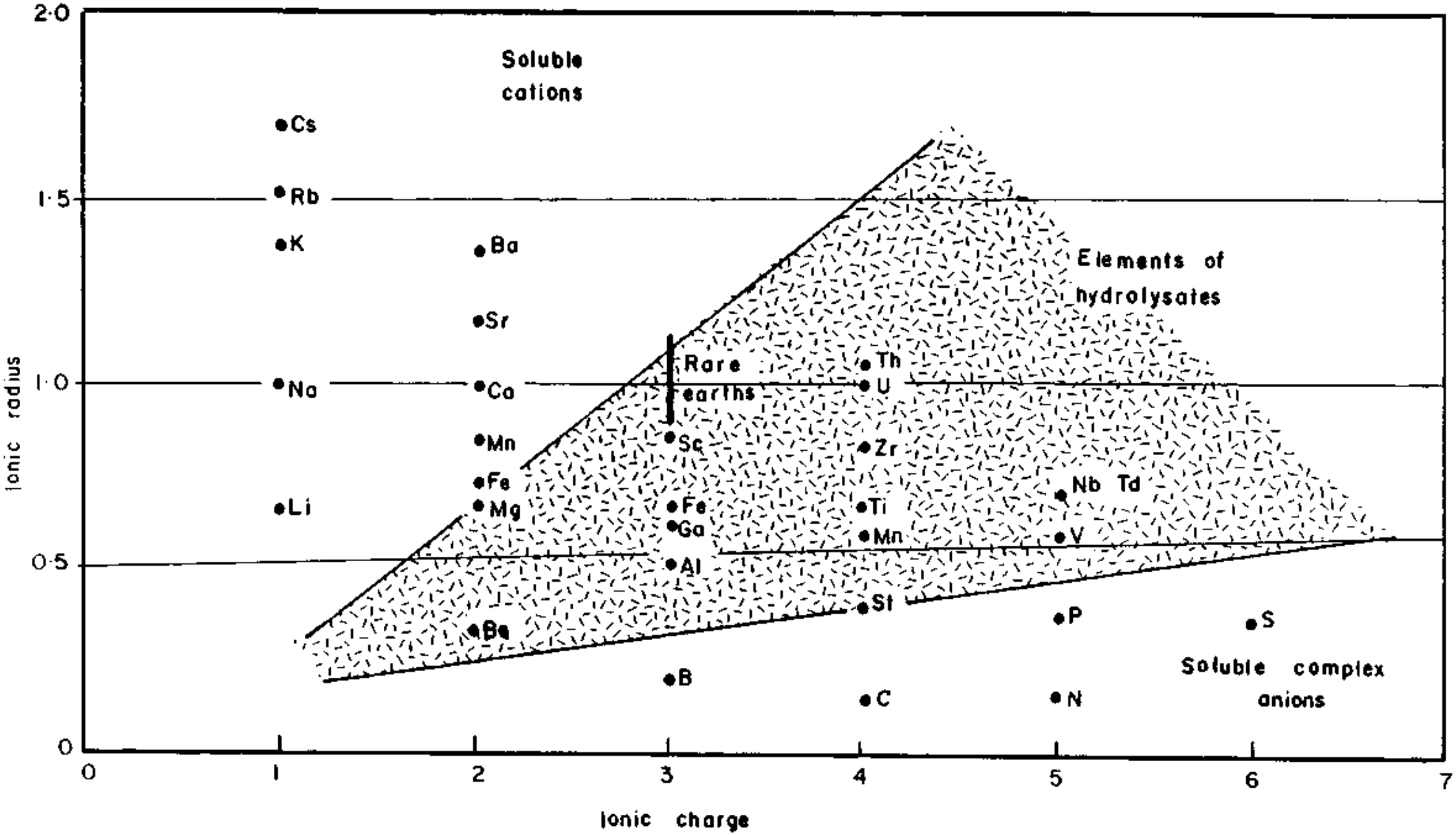

Fig. 4. Geochemical separation of some elements on the basis of their ionic potential (after Mason 1966).

Table 5: Strontium – rubidium ratios of the stream sediments in areas of varying gem potential

Areas	Number of samples analyzed	Nature of sediments	Ratio of Sr/Rb
Prominent gem bearing areas			
Opanayake (west)	05	gem pit sediments	
Opanayake (west)	10	stream sediments	0.2-1.0
Hattota Amuna	30	gem pit sediments &	0.4-1.75
Hattota Amuna	30	stream sediments	0.75-1.5
Areas of moderate potential for gemstones			
Bogawantalawa	60	–do–	0.75-2.5
Pubbiliya	04	gem pit sediments	2.0-3.0
Pubbiliya	42	stream sediments	3.0-5.0
Areas of low potential for gemstones			
Nilambe	55	–do–	0.75-2.0
Opanayake (north and east part)	80	–do–	3.0-7.0
Areas of very low potential for gemstones			
Ridigama (north to south east)	50	–do–	3.0-7.0
Ridigama (south west)	40	–do–	4.0-8.0
Area of no potential for gemstones			
Wariyapola	55	–do–	6.0-12.0

elements concerned are found in the hydrolysates makes them highly amenable to geochemical exploration of gem-bearing sediments. The element Y which has geochemical properties similar to those of rare-earth elements follows them in its geochemical transport mechanisms and hence is another useful pathfinder element. Niobium in particular is indicative of minerals such as titanomagnetite, ilmenite, sphene, zircon etc.

Thorium and uranium

In Kaikawala, a locality in the Southern Province of Sri Lanka, there is a moderately significant deposit of monazite. A clear density separation has resulted in the association of monazite with ilmenite and garnet. Sri Lanka's monazite is known to contain anomalously high concentrations of ThO_2 (approximately 10%) and this is one of the highest percentages found in monazite anywhere in the world. Associated with thorium is the element U which is also found in high concentrations (viz ~ 4000 ppm). La, Ce, Sm are also found in very high amounts (12.4%, 26%, 1.4% respectively). Geochemical analysis of these pathfinder elements will lead to such mineralogical associations indicating the existence of gem minerals such as garnets. The tracing of these heavy mineral concentrates leads to the source regions of the gem-bearing formations.

Use of the Sr/Rb ratio

Ratios of chemical elements are often useful in the delineation of geochemically distinct regions. In a recent study by the authors, it was observed that the Sr/Rb ratio in the stream sediments is a very useful guide in the demarcation of gem-bearing regions from those of non gem-bearing ones.

Stream sediment samples were collected at 200-400m intervals from the following regions:

(a) prominent gem-bearing areas
(b) areas of moderate gem potential
(c) areas of low gem potential
(d) areas of low to no gem potential and
(e) areas totally devoid of gems.

Vertical profile samples and 'illam' (gem-gravel) soil samples from several gem pits were also collected.

A total of 430 stream sediment samples from the above mentioned areas and 35 profile samples from 4 gem pits were collected and analyzed by X-ray fluorescence spectrometry.

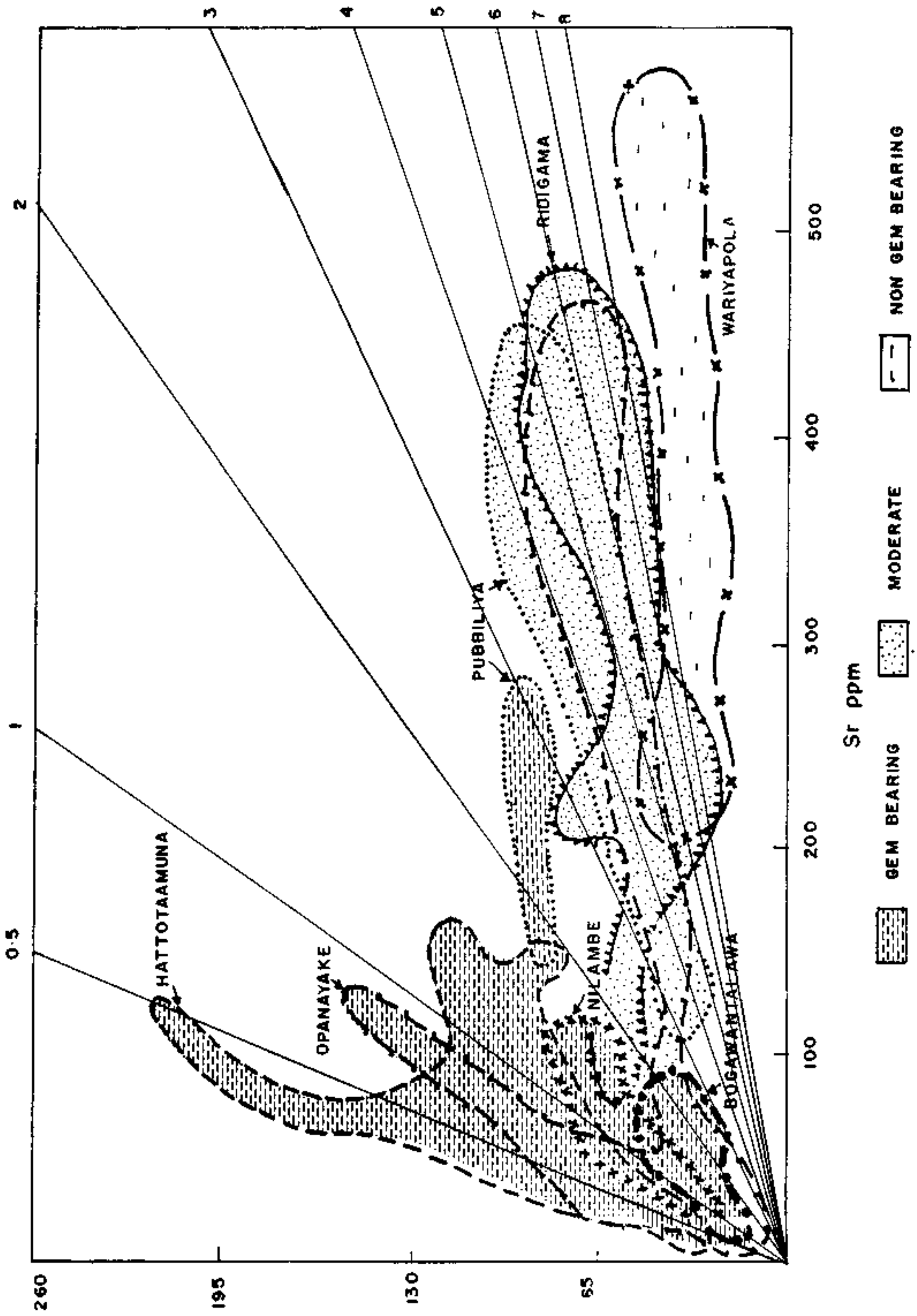

Fig. 5. Delineation of gem-bearing areas on the basis of the Sr/Rb ratios of stream sediments.

The analytical results showed that the concentrations of Sr and Rb in the stream sediments varied significantly between areas while within each subarea the variance was small. The more important observation made however was that the Sr/Rb ratio appeared to be characteristic for a particular area, bearing in mind that the gem deposits of Sri Lanka are located in a metamorphic terrain of granulite facies grade. In general, higher values for this ratio were found in non-gem bearing areas while the areas known for their high gem potential had lower ratios. Table 5 shows the results obtained from the geochemical survey. It is worthy of note that even within a particular gem-bearing region, certain locations, where for certain geological and structural reasons, no gems could be found, differed in their Sr/Rb ratios. In the Opanayake area, well known as a gem field in Sri Lanka, very low Sr/Rb ratios were observed for the gem-bearing part in the Southern and Western regions while higher Sr/Rb ratios were observed for the North-eastern part where no gem pits had been located (Figure 5). Most of the prominent gem-bearing locations had a Sr/Rb ratio of around 1 or less in the stream sediments and this particular value could be used as a rough guide in the delineation of target areas for detailed gem exploration.

Conclusions

Gem minerals concentrated as placer deposits are very often associated with other rarer minerals and which have a special geochemistry. The identification of these unique geochemical anomalies can lead to the delineation of target areas most suitable for gem exploration. Elements such as thorium, uranium, beryllium, fluorine, tantalum, niobium, yttrium and the rare-earth elements are examples of pathfinder elements amenable to geochemical exploration for gem deposits.

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'The most unkindest cut of all'* - recutting the Koh-i-Nûr

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It is the author's hope that this short paper may resolve at least some of Alec Farn's confusion over the recutting of the Koh-i-Nûr diamond (Letter to the Editor, *Journal of Gemmology*, **23**, 2, 120).

The recutting of the stone, by order of Queen Victoria, was instigated by Prince Albert after consultations with, amongst others, Sir David Brewster, Professor Tennant and the Rev. W. Mitchell (the latter two of King's College, London). The intention was to produce a more brilliant stone, with what seems now to be an appalling disregard for the history of this famous diamond.

It was carried out in 1852 on Garrard's Panton Street premises. The work was entrusted to Coster of Amsterdam. Guillaume Coster came to London with his chief cutter Voorzanger and an assistant, Fedder.

The *Illustrated London News* depicted the Duke of Wellington placing the stone on the scaife for the cutting of the first new facet on Friday 16 July. Several authorities, however, credit the Prince Consort with performing this ceremony. It is likely that both gentlemen were present. The recutting was completed on 7 September after 38 twelve hour days of cutting. The reported cost was £8,000.

Emanuel in 1865 (*Diamonds and Precious Stones*) gives the recut weight as $106^{1}/_{16}$ carats. Streeter in 1882 (*Great Diamonds of the World*) repeats this, adding that the stone had been reduced by exactly 80 carats from an original weight of $186^{1}/_{16}$. These figures are repeated by Davenport in 1897 (*The English Regalia*), and by many later authorities.

The pre-metric carat in use in England at the time appears to have equalled 0.205409 grams. $106^{1}/_{16}$ old carats converts to 108.93 metric carats. This, as Alec Farn points out, is stated as the recut weight in numerous books.

However, W. Pole (an associate of Professor Tennant) in 1858 (*Transactions of the London and Middlesex Archaeological Society*, Vol. 1) gives weights of 186 and $102^{1}/_{4}$ carats. Dieulafait in 1871 (*Diamants et Pierres Précieuses*) gives a recut weight of $102^{3}/_{4}$ with which Professor Church in 1882 (*Precious Stones*) agrees. This latter figure converts to 105.53 metric carats. This is only seven points less than the known current weight of 105.60 metric carats.

I would, therefore, suggest that the recut weight may, with reasonable confidence, be stated in old English carats by converting the modern figure. This gives a weight of $102^{11}/_{16}$ old English carats.

The much quoted weight of 108.93 metric carats seems to represent a classic example of spurious information in one book being assiduously repeated by later authors, with no referral to original sources. I have also found numerous other spurious weights mentioned in supposedly authoritative books, ranging from $82^{3}/_{4}$ carats in *A Popular Treatise on Gems by Feuchtwanger* in 1859 (who says that the original weight of $186^{1}/_{2}$ carats was 'rough') to $122^{3}/_{4}$ carats in the 1874 English edition of *Diamonds & Precious Stones* by Dieulafait.

The author would be most grateful if any readers could throw further light onto this subject.

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* Julius Caesar, Act III, Scene II. - Ed.

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Book Reviews

BARIAND, P., POIROT, J.-P., 1992. *The Larousse Encyclopedia of Precious Gems.* Van Nostrand Reinhold, New York. pp. vii, 248, illus. in colour. £37.95.

A translation of Larousse des pierres précieuses, published in 1985, the book is translated by Emmanuel Fritsch and contains work by Michel Duchamp on seals, cylinders, intaglios and cameos. The book is pleasantly and sometimes very well illustrated, almost entirely in colour, and the text on the whole is accurate and balanced. There are many instances, however, of uneven treatment of subject, with some references unexplained. Colour centres are mentioned several times but I could find no section expanding the phrase although there is a short and generally unhelpful glossary which includes amphibole but not pyroxene and notes 'secondary' in a surprisingly recondite sense as an attribute of electrical transformers in a text in which the reader might expect to find an explanation of secondary mineralization!

The glossary is so amateurishly compiled that early reference to it prepares the user for equal disasters in the main text. Here are some of them: the use (in an English translation) of almandite; rubicelle as a main entry not referred to spinel (and it should not be there anyway); subscripts denoting the different rays refracted by a crystal have missed the eye of the translator and are presented with the French initials; chrysolite as a main entry, the text of which wanders over several species - this is confusing and would better have been omitted; choice of species is capricious with perovskite (has no gemmological interest) included. Lame excuses are provided in a brief review of nomenclature for the use of outdated names. It is a great pity that such an undeniably attractive book should introduce problems into a subject at this elementary level; readers will begin their study of gemstones with much information they will later have to abandon. Referral to professional staff at a national or major university museum would have helped raise the standard of the text.

M.O'D.

BENESCH, F., 1991. *Der Turmalin: eine Monographie. 2 durchgesehene und verbesserte Auflage.* Urachhaus, Stuttgart. pp. 380, illus. in black-and-white and in colour. DM296.00.

With a size of 50 x 31cm and a weight (with its slip case) of 4lb this book impresses before the pages are turned. The contents open with a section dealing with references to tourmaline in early books (some of which are reproduced) and continues with a discussion of species nomenclature. The remainder of this preliminary section deals with the different types of crystals and crystal coloration. Then comes a section of 151 pages in all of which (save one) tourmaline crystals are shown in colour photographs. I have seen no mineral and certainly no gemstone book which comes anywhere near the magnificence shown here, an effect enhanced by the superb quality of the colour and by the size of the pages. Though captions on the plates themselves are limited to country names, the following section of text expands on this - wisely, in my opinion, since the effect of the plates would have been diminished by several lines of text.

The second part of the book begins on page 213 with details of geochemistry and paragenesis; this is followed by a section of tourmaline crystallography in which pages from Goldschmidt's *Atlas der Krystallformen* are reproduced and then by a more general discussion of the resemblances between the crystal symmetry of tourmaline compared to that shown by other natural forms, particularly those of plants.

This speculative part of the text is followed by 15 coloured plates of parti-coloured tourmaline crystals from Madagascar; these have been painted by Christiane Lesch with explanations by Bernhard Wihrmann. These are beautifully portrayed.

The text then continues with the place of tourmaline in religious and apocalyptic literature. I am unable to comment on this. There are further reproductions of title pages and sections of text from older scientific books to supplement the points made in this part of the text. There is a useful alphabetical table of names used for tourmaline varieties here and the whole section has its own short bibliography.

Gemmologists will find the section on tourmaline occurrence very useful; it occupies 35 pages and is accompanied by a double-spread map. The book ends with a large general bibliography.

For the size of the book the text, though useful and interesting, is not outstanding, reflecting perhaps the author's preoccupation with non-scientific or anthropological topics. Nonetheless the plates are so magnificent that the book would grace many a museum display or teaching exhibit. Opportunities for this may be limited for non-German gemmologists who may have failed to see the publishers' pre-publication advertisements - almost as spectacular as the book. The first edition was sold out in so short a time that I was offered the second edition as long ago as two months after the exhaustion of the first, in 1990. I am now told that the second edition also has a short print- run and that there is unlikely to be a third. By the time you read this review copies may be unobtainable. M.O'D.

BLAUER, E., 1991. *Contemporary American jewelry design.* Van Nostrand Reinhold, New York. pp. x, 198, illus. in colour. £29.00.

The book introduces American studio goldsmithing with very useful details of the show system and descriptions of the work of a number of major craftsmen and women. Most of the pieces illustrated are made of various precious and other metals, relatively few being gem-set but nonetheless readers will find the book a painless introduction to an aspect of jewellery that may be a little unfamiliar. Appendices list major galleries, craft schools, teachers, organizations and publications. M.O'D.

BULLIS, D., 1990. *Crystals, the science, mysteries and lore.* Crescent Books, New York. pp. 128, illus. in colour. £6.99.

This is an attractively produced book whose text needs to be read with caution! Leaving the mysteries and lore aside (with an open mind) the photographs of crystals are good. M.O'D.

CARSWELL, D.A. (Ed.), 1990. *Eclogite facies rocks.* Glasgow, Blackie. pp. xv, 396, illus. in black-and-white. Approximately £60.00.

As far back as Haüy in 1822 eclogite was assumed to be a rock composed mainly of garnet and clinopyroxene though since that time there has been a wide diversity of interpretations with some emphasis placed upon the characterization of eclogite by the presence more specifically of omphacite or chloromelanite clinopyroxenes with high Al^{VI} and Na contents and by pyrope rich garnets. From the standpoint of the diamond prospector eclogites are well worthy of study since diamond occurs as a primary phase. Eclogitic diamonds are usually sharp-edged octahedra compared with the rounder diamonds found in kimberlite. Other primary phase minerals include graphite, amphibole, rutile and sphene; these, while not of a significant gem importance in this context, are useful indicators of the chemical composition of particular rocks.

Important observations of this kind, of interest to the geologist/gemmologist, occur throughout the book, which is a multi-author compilation of papers, beginning with definitions and continuing with studies of eclogite facies mineral parageneses with experimental studies, surveys of mineral barometry and thermometry, the role of kinetics, isotopic systems and geochronology, occurrence and stability conditions of low- and medium-temperature eclogites from different locations. The points mentioned at the beginning of the review are expanded in the final section of the book, a study of high-temperature and ultra high-pressure eclogites. M.O'D.

CAVEY, C., 1992. *Gems & jewels fact and fable.* Studio Editions Ltd, London. pp. 144, illus. in colour and black-and-white. £14.95.

Christopher Cavey was commissioned to write this work by a firm specializing in art publications rather than scientific ones. His own great interests are in fine mineral specimens, hardstone carvings and antique intaglio seals, as well as the main interest of gemmology. He owns a specialized library of antique and modern books dealing with such things.

The publishers required a book emphasizing the art side of gems and jewels without the scientific bias towards gemmology. Mr Cavey has succeeded admirably in complying with their request in an inexpensive large-format book, and has given us a volume containing 'Over 100 colour illustrations' (I counted 147) and many more in monochrome, the vast majority of which will be new to the reader.

Many gem groups and other pictures are the work of Alan Jobbins, our Editor, and lately Curator of Minerals and Gemstones at the former Geological Survey Museum in London. Some excellent pictures of minerals are from Brian Lloyd of Gregory Bottley & Lloyd. Others are of quite wonderful hardstone carvings by

Gerhard Dreher of Idar Oberstein, Germany, and historic carvings by the late Alfred Pocock of London, who was associated with Faberge's London Manager, H.C. Bainbridge (these printed by courtesy of Mrs W. Bottley); modern jewellery by courtesy of Patrick Aldridge of Gemcut SA, Geneva, and a very considerable number of pictures of intaglios, cameos and other unique items taken by the author himself, together with many black-and-white reproductions from works in his library of associated books.

In a few cases the insistence by the publishers on black backgrounds to some of the colour plates has resulted in needless darkening of detail. But by far the greater part of the illustrations are exceptionally well reproduced and beyond criticism. The text frequently refers the reader to specialist books on various subjects and a reasonably comprehensive bibliography facilitates such reference. The text is also concerned with some of the early history and myth of gem lore, and from time to time refers to gem and crystal healing, apparently one of the many 'alternative medical' procedures of today, but does not attempt to describe this.

This is an exceptionally well illustrated book on the gem aspects which it covers and has been produced at a very reasonable price when compared with other similar volumes recently published. It can be recommended accordingly.

R.K.M.

CODY, A., 1991. *Australian precious opal: a guide book for professionals*. Andrew Cody Pty Ltd, Melbourne. pp. 65, illus. in colour. Price on application.

This is one of the best-produced and attractive opal books I have seen, with a very high standard of colour reproduction. Brief but clear notes on the history, geology and mineralogy of opal precede sections which depict different qualities of cut black and white stones. The plates show enough stones for some idea of grading to be obtained and there are several illustrations of major named stones. There are notes on patterning and on composites and it is good to see a diminution of trade names, the over-use of which has spoilt some earlier opal books. There is a useful glossary and some notes on cutting. A double-page colour spread indicates the main Australian opal fields. This is a good book for the gemmologist and excellent for the customer. M.O'D.

CRAM, L., 1991. *Beautiful Queensland opal*. Robert Brown & Associates, Buranda, Queensland. pp. 28, illus. in colour. Price on application.

This beautiful book gives a stunning introduction to the types of opal characteristic of the Queensland fields. History and anecdotes of the fields take second place to the colour photographs but the text is well worth reading and takes the reader over the whole history of Queensland opal production. As might be expected, considerable attention is paid to boulder opal and to the famous Yowah field. All opal lovers should have this book. M.O'D.

EGGER, G., 1988. *Generations of jewelry from the 15th through the 20th century*. Schiffer Publishing, West Chester, Pennsylvania. pp. 219, illus. in black-and-white and in colour. £49.95.

The book is a translation of *Bürgerlicher Schmuck*, first published in 1984. The English title does not accurately reflect the main argument of the text, which deals in fact with the development of the middle classes in Europe and the parallel development of their jewellery. Thus, major 'royal' pieces are excluded from the survey which extends from the fifteenth century to the Art Deco period. The standard of reproduction is fair; there is a useful bibliography. As with some other books of this type, the text consists, in the main, of captions to photographs. M.O'D.

FARNETI CERA, D. (Ed.), 1992. *Jewels of fantasy: costume jewelry of the 20th century*. Abrams, New York. pp. 408, illus. in colour. Approximately £38.00.

This is a translation of *I gioielli della fantasia* first published in 1991. It is a catalogue of a travelling exhibition of 20th century costume jewellery with accompanying essays by various hands. Sections cover the new century and Art Nouveau (1900-1915): the opulence of the poor look (France and Germany 1900-1950): flights of fancy (France 1920-1939): the luxury of freedom (USA 1935-1968): bijoux de culture (France 1927-1968): from the artisan's workshop to the international style (Italy 1945-1970): the return of the ornament, 1965 to the present. Technical essays deal with the history of the manufacture of glass stones and costume jewellery in Bohemia: the history of the production of ornamental jewels in Tyrol; and the dominance of Providence, Rhode Island and the contribution of electroplating. There is a glossary and a brief technical guide.

This is a splendid book with a very lucid text and excellent quality of illustration. The weight may have daunted those who obtained their copies before visiting the exhibition and who took them round it; I found it better to concentrate on the exhibits and recollect their undoubted beauty in the tranquillity of my office! Do not be put off, however; this is a serious and major study of an aspect of jewellery which has had insufficient treatment hitherto.

M.O'D.

JARGSTORF, S., 1991. *Glass in jewelry.* Schiffer Publishing, West Chester, Pennsylvania. pp. 174, illus. in colour. £29.95.

This is a very useful and attractively produced monograph of the ornamental use of glass, with particular reference to European glass work. Chapters cover bead and gem manufacture in Murano, Bavaria, Thuringia, Bohemia and Silesia; techniques of bead manufacture; faceted glass; glass cameos and incrustations, millefiori and mosaic jewellery and aventurine jewellery. There is a chapter on changing fashions in glass jewellery, a value guide and an index.

The standard of production is quite good and the book is one of the best I have seen in recent years in this field. The subject is a large one and no doubt the book could be doubled in size without covering a great deal more in the area. Interest in glass is increasing as prices rise for natural gemstones and what is cheap today may well be sought after fifty years on. M.O'D.

LIMA-DE-FARIA, J. (Ed.), 1990. *Historical atlas of crystallography.* Kluwer for the International Union of Crystallography, Dordrecht. pp. ix, 158, illus. in black-and-white and in colour. £20.00.

A scheme of time-maps is used to give a continuous comparative chronology of geometrical, physical, chemical and structure determination crystallography. Chapters accompanying the maps fill out the picture and contain very useful bibliographies. An interesting section of the book illustrates the title pages of many seminal works and there is a general bibliography and author and subject indexes. The book will be useful for many and vital for some, since the information will be hard to gather from the multiple sources covered by the production team. M.O'D.

LINTON, T., 1992. *The effective use of gemmological instruments.* 2nd edn. Wellington Point, Queensland. pp. 60, illus. in black-and-white. Price on application.

An excellent survey of currently available and simple gem testing instruments with worked-out examples of how they can best be used. Short lists of references accompany each chapter and there are notes on the commercial exploitation of gem testing practices. M.O'D.

NEWMAN, R., 1991. *The diamond ring buying guide.* 2nd edn. International Jewelry Publications, Los Angeles. pp. 151, illus. in black-and-white. US 12.95.

This is an excellent and sensible guide which disclaims any element of gemmological teaching, concentrating instead on providing hints for the jeweller and customer on the various signs to look for in a diamond if it is to be a reasonable purchase. Nonetheless, a good deal of gemmologically useful information has crept in, particularly cutting and on diamond simulants and composites. As the book covers the whole ring, not just the stone, it includes a discussion on the kind of precious metals used and how to test them.

M.O'D.

POUGH, F.H., 1991. *Peterson first guides-rocks and minerals.* Houghton Mifflin, Boston. pp. 128, illus. in colour. £3.99.

This is an attractive pocket guide which really fits the pocket. After a very brief account of geological processes over 120 examples of the commoner minerals are illustrated with brief though useful descriptions. M.O'D.

READ, PETER, 1992. *Diamond mine* [a novel]. The Book Guild, Lewes. pp. 188. £11.95.

Reviews of works of imagination are rare in these columns but the present book is worth noticing on account of the various aspects of diamond mining and selling which form part of the simple and dramatic plot. The book moves quickly and smoothly and while the principal characters might not be on many dinner party lists they are all very well in a book. I liked the idea of ..., no, I must not give away details of the plot!. M.O'D.

SCHIFFER, N.N., 1988. *Costume jewelry: the fun of collecting.* Schiffer Publishing, West Chester, Pennsylvania. pp. 176, illus. in colour. £26.95.

Interest in costume jewellery has always been considerable but there seems to have been a heightening of the interest in the past few years. No doubt this is due to world-wide recessions and the generally high prices asked for natural stones and precious metals. The present book which consists in the main of captioned photographs gives a useful overview of the type of cheaper jewellery that may attract the collector. For this reason the text is arranged by usage: thus we have bracelets, belts, buckles and buttons, earrings, head ornaments, necklaces, pins, rings, matching sets; the book concludes with a list of marks, a price guide and an index. This is a useful and reasonably-priced book with a good deal of interesting detail. M.O'D.

SMITH, J.R., 1991. *A guide to understanding crystallography.* Crystallography, Box 12, Fairfax, Virginia 22030, USA. pp. 176, text figures. Price on application.

This handy-sized ring-bound book introduces basic crystallography, or rather crystal description in easily understood terms, and forms a useful guide for students and others faced with the need to describe crystals. Many concepts hitherto found essential for inclusion in any book about crystals are omitted and the text seems none the worse; there are a few misprints (the worst I have seen is Bravis for Bravais) but the sense is not affected and the book can be recommended. Publication was under the auspices of the Rochester Mineralogical Symposium. Text figures illustrate all systems and most if not all of the occupied classes; there are introductions to Miller indices and to Herman-Mauguin symbols. At the end is a short glossary and several cut-out crystals whose outlines would need to be transferred to a stouter medium if adequate models are to be made. M.O'D.

WILKS, JOHN, WILKS, EILEEN, 1991. *Properties and Application of Diamond.* Butterworth/Heinemann, Oxford. pp. 525, bibl., index, 417 illustrations comprising tables, diagrams, graphs, photographs, photomicrographs. £90.00.

This is a most useful and comprehensive reference book about today's diamond technology.

After an introduction, the book is divided into three parts, dealing with structure, mechanical properties and application and wear respectively. The introduction deals with the genesis of diamond; some mining methods are briefly mentioned; there is an easily understandable description of various methods of synthesis, the growing of diamond films and the production of PCD (sintered polycrystalline diamonds).

The five chapters on the structure of diamond (impurities, optical absorption and colour, luminescence, morphology and geometric defects in the lattice) and the six chapters on mechanical properties (strength and fracture, plastic deformation, polishing and shaping, mechanical differences between diamonds, friction and PCD) are the most detailed and the most valuable part of the book for the gemmologist. The morphology is particularly well explained; lonsdaleite, however, is not mentioned. All aspects of the manufacturing process are described in detail, perhaps the use of lasers might have been enlarged on. The third part of the book provides information on the various applications of industrial diamond in turning, boring, milling, grinding, sawing and drilling. The authors incorporate recent data on wear and surface characteristics of the diamond and the effect on the workpiece.

The subject is well and clearly presented. Scientific data (such as the growth mode of synthetic diamonds or dislocations in the lattice) are easily understandable and should be of great help to the student. It seems a pity that in so comprehensive a work only just over two pages are devoted to diamond as a gem material. A diagram shows the Tolkowsky cut, no other cut is described, but the existence of other cuts is mentioned.

Each chapter closes with its own full bibliography, a recommendable time-saving device for the researcher. The text itself includes many references to literature.

Drs John and Eileen Wilks have produced an invaluable handbook for anyone interested in any aspect of the diamond industry. E.S.

Chinese jade. Spink & Son Ltd, London, 1991. pp. 84, illus. in colour. £10.00.

164 jade artefacts forming an important private collection are briefly described and well illustrated in a sale catalogue in which prices range up to £10,000. There is a short glossary, introductory matter and a bibliography. Entries include references. M.O'D.

Chinese jewellery, accessories and glass. Spink & Son Ltd, London, 1991. pp. 83, illus. in colour. £10.00.

This well-illustrated sale catalogue includes jade, gold and turquoise jewellery as well as snuff bottles and various artefacts in glass. The descriptions include references where appropriate. M.O'D.

Proceedings of The Gemmological Association and Gem Testing Laboratory of Great Britain and Notices

NEWS OF FELLOWS

On 27 May 1992 at the Crown Hotel, Blandford Forum, Dorset, **Peter Read** gave a talk on researching his novel *Diamond Mine* to the Wessex Branch of the National Association of Goldsmiths. The talk included a series of slides showing mining operations in the Premier, Finsch and CDM mines, as featured in the novel.

Launch of the book included an interview on 28 May with BBC presenter Sally Taylor on Solent Radio, Southampton, in which Peter publicised the courses of the GAGTL, and on 30 May an 'author signing' event at the Athena bookshop, Old Christchurch Road, Bournemouth.

During the period 9 to 11 June 1992 **Michael O'Donoghue** and **Peter Read**, with Roy Huddlestone, conducted a course for students intending to sit the GAGTL examinations in 1992.

MEMBERS' MEETINGS

London

On 13 May 1992 at the City Conference Centre, Mark Lane, London EC3, Dr Roger Harding, Dr J.W. Harris and M. Issacharoff gave illustrated lectures on the gemstone deposits and trade in Australia.

On 9 June 1992 at the City Conference Centre, Alan Hodgkinson and Harry Levy gave an illustrated lecture on the gemstone deposits and trade in South East Asia.

Midlands Branch

On 24 April 1992 at Dr Johnson House, Bull Street, Birmingham, the Annual General Meeting of the Branch was held at which David Larcher, FGA, was re-elected Chairman and Gwyneth Green elected Secretary.

North West Branch

On 20 May 1992 at Church House, Hanover Street, Liverpool 1, Nigel Israel, FGA, gave a talk entitled 'Historical Aspects and valuations'.

On 17 June at Church House an 'Exchange and Mart' evening was held, when members had the chance to buy and sell books, crystals and instruments.

GIFTS TO THE GAGTL

The GAGTL is grateful to the following for their gifts:

Ameena Kaleel, FGA, D Gem G, of Mount Lavinia, Sri Lanka, for 93 crystal specimens, selected for their crystal shapes, spectra or inclusions, donated for teaching purposes;

Dominic Mok, FGA, of the Asian Gemmological Laboratory, Hong Kong, for specimens of bleached and resin-impregnated jadeites;

Hong Kong gemmology lecturer Memory Stather, FGA, for several fancy cut diamond simulants for use in the DGA Practical Workshops.

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held on 15 April 1992 at 27 Greville Street, London EC1N 8SU, the business transacted included the election to membership of the following:

Fellowship

Senaratne, Amal C., Dehiwela, Sri Lanka. D.1986

Ordinary Membership

Grafin Von Zech-Burkersroda, Euphemie, Reutlingen, Germany.
Ku, Sarah J., Tuen Mun (NT), Hong Kong.
Lambert, Jonathan, Margate.

At a meeting of the Council of Management held on 20 May 1992 at Chapel House, Hatton Place, London EC1N 8RX, the business transacted included the election to membership of the following:

FORTHCOMING MEETINGS

TRADE LUNCHEON

This year's Trade Luncheon, to which all members of GAGTL are invited, will be held on Tuesday 22 September 1992 at the Ironmongers' Hall, London EC2. Tickets for this prestigious event will be £35.00 plus VAT (inclusive of wine). For reservations please contact: Miss L. Shreeves, GAGTL, 27 Greville Street, London EC1N 8SU. Telephone: 071-404 3334.

1992 ANNUAL CONFERENCE AND PRESENTATION OF AWARDS

The second GAGTL Annual Conference is to be held on Sunday 8 and Monday 9 November, at the Great Western Royal Hotel, Paddington, London, with a full programme of lectures and displays.

The Conference will be followed on the evening of Monday 9 November by the Presentation of Awards which will take place at Goldsmiths' Hall, Foster Lane, London EC2. This year the awards will be presented by Dr Kurt Nassau.

Full details of the Conference and Presentation of Awards will be circulated to members nearer the time.

MEMBERS' MEETINGS

London

On 24 November 1992 at the City Conference Centre, Mark Lane, London EC3R 7JN, lectures will be given on the gemstone deposits of Africa and the trade associated with them. Admission by ticket only, at a cost of £5.00 for GAGTL members, £10.00 a member and a guest, and £8.00 for non-members. For further details and tickets contact the GAGTL.

Midlands Branch

Meetings will be held at Dr Johnson House, Bull Street, Birmingham. Further details from Gwyn Green on 021-440 1428 or 021-445 5359.

25 September 1992	Bring and Buy evening. Sale of books, specimens and gem testing instruments.
1 November 1992	Annual Practical Gemmology Seminar, to be held at the Cobden Hotel, Birmingham. Tickets £18.00 from David Larcher, Midlands Branch Chairman, c/o GAGTL.
27 November 1992	Nigel Dunn. 'Jewellery through the ages'
27 January 1993	Edgar Taylor. 'Fossicking in Wales'
26 February 1993	Robert Campbell-Legg. 'The art of the engraver'
26 March 1993	Peggy Stock. 'Crystal healing'
30 April 1993	AGM and filmshow

North West Branch

Meetings to be held at Church House, Hanover Street, Liverpool 1. Further details from Irene Knight on 051- 924 3103.

16 September 1992	Adrian Klein. 'Emerald'
21 October 1992	Dr Jamie Nelson. 'Optical attributes of a diamond'
18 November 1992	Annual General Meeting

Members having gained their Diploma in Gemmology or the Gem Diamond Diploma (FGA or DGA) may now apply for use of the Coat of Arms on their stationery or within advertisments.

Laboratory members are also invited to apply for use of the Laboratory Logo.

It is still a requirement of GAGTL, in accordance with the Bye Laws,that written permission be granted by the Council of Management before use.

Members interested in further information please contact:

Linda Shreeves

Gemmological Association and
Gem Testing Laboratory of Great Britain

◆ 27 Greville Street, (Saffron Hill Entrance), London EC1N 8SU ◆

Tel: (071) 404 3334
Fax: (071) 404 8843

Fellowship
Flint, Sara E., Leeds. D.1991

Ordinary Membership
Almudallal, Mohammad, Abu Dhabi, UAE.
Boxsey, Pauline M., Eton.
Dansereau, Eva M., Anola Manitoba, Canada.
Fricker, Rowena, Dulwich, SA, Australia.
Jones, Michael, Bournemouth.
Mifsud, Ivan, Sliema, Malta.
Nilaratanakul, Chiraphong, Bangkok, Thailand.
Pash, A., London.

MEETING OF THE TRADE LIAISON COMMITTEE

At a meeting of the Trade Liaison Committee held on 30 April 1992 at 100 Hatton Garden, London EC1 the business transacted included election to membership of the following:

Ordinary Laboratory Member
Laurick Jewellery Ltd, 17 Station Bridge, Harrogate, Yorks HG1 1SP.

THE CANADIAN GEMMOLOGICAL ASSOCIATION

On 24 and 25 October 1992 the Gem Conference '92 will be presented by the Canadian Gemmological Association at the Park Plaza Hotel in Toronto, Canada. Presentations and workshops covering a wide range of topics relevant to the jewellery and gem trade will be included.

For further information contact the CGA office on (416) 603-0451.

CORRIGENDA

On p.90 *above*, Fig. 2, for '6000 kg' read '600 kg'

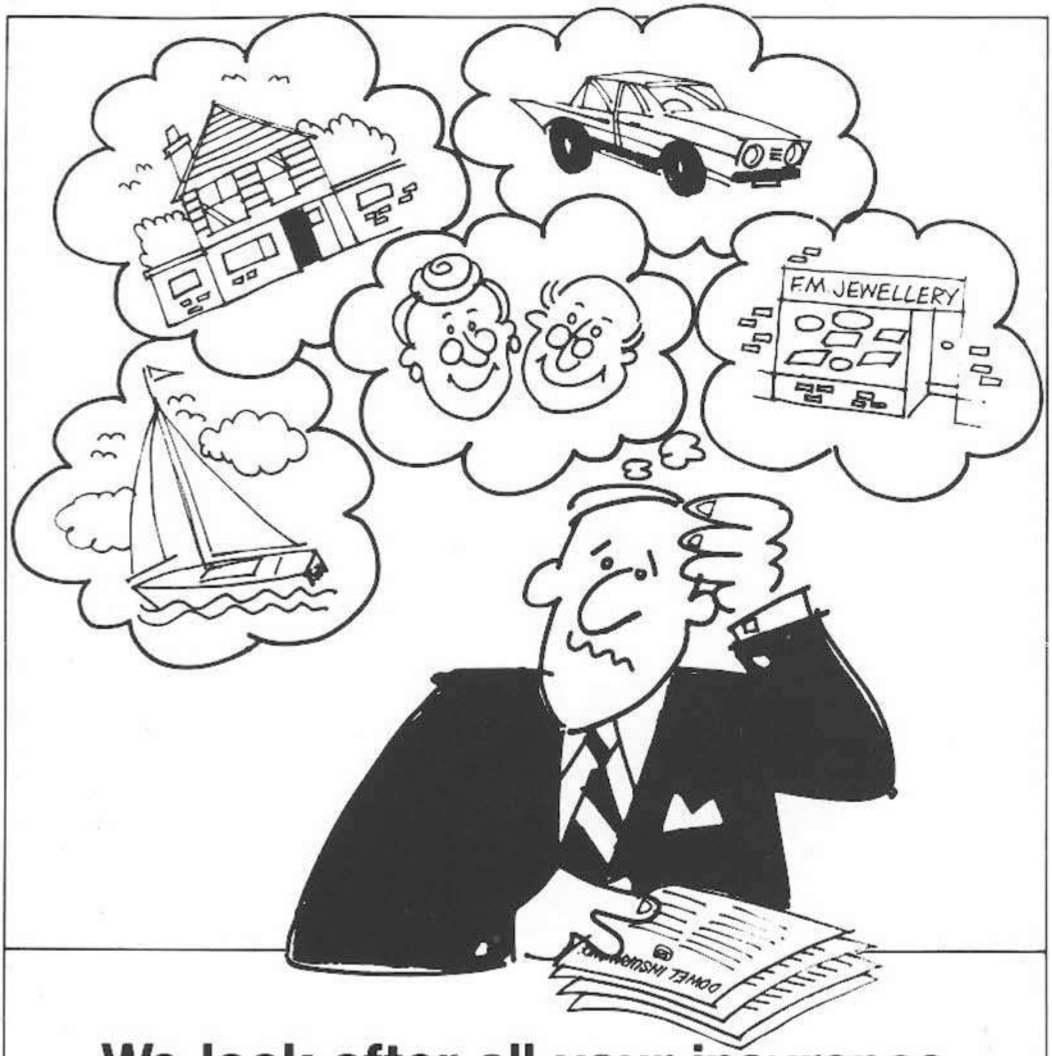
On p.91 *above*, second column, line 12, insert 'and other' after 'iron'

On p.96 *above*, Fig. 1 was omitted; it is included with this issue as a separate sheet so that it may be inserted in the correct place

PEARL CONFERENCE

The Society of Jewellery Historians will be holding a one-day Conference on Saturday 7 November 1992 at the Society of Antiquaries, Burlington House, London W1, on the subject of 'The history and use of pearls'. A variety of aspects will be covered ranging from sources and use in the ancient and medieval world to modern cultured pearls and pearl treatments and testing.

The cost of the day will be £25.00 for SJH members and their guests (limit one guest per member), and £40.00 for non-members. If you would like to attend, please send your name and address (plus stamped, self-addressed envelope if in the UK) to Nigel Israel, 14 Ryfold Road, Wimbledon Park, London SW19 8BZ. Please state whether you are a member of the Society of Jewellery Historians.



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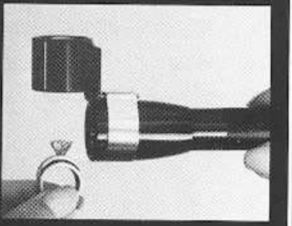

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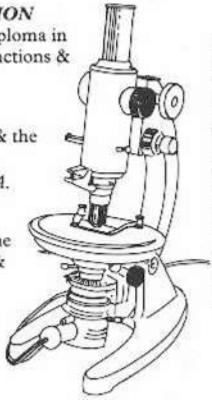

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