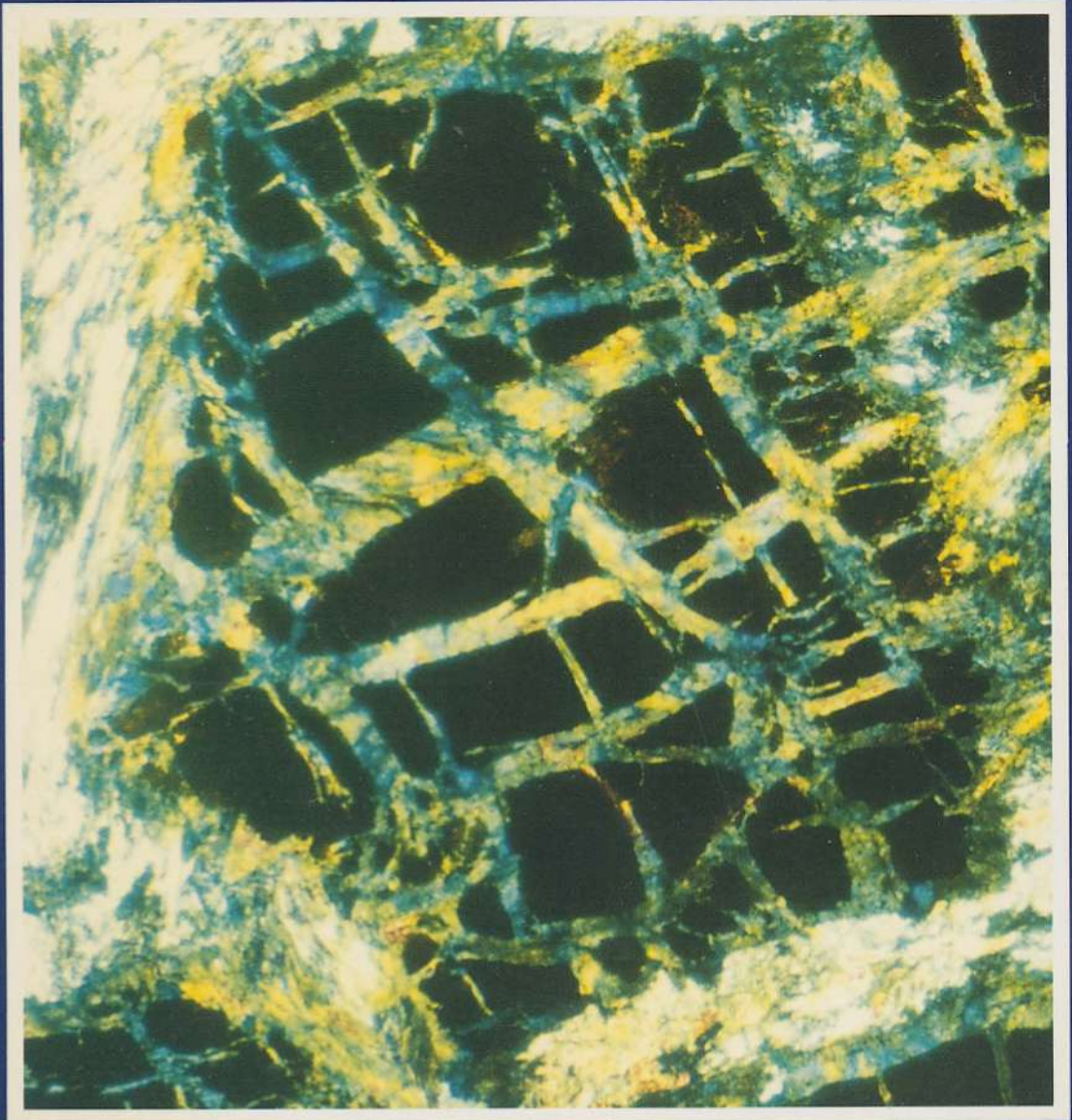


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Cover Picture

Photomicrograph of maw-sit-sit (MSS1) in plane polarized light. Kosmochlor (bluish-green and yellow, due to different orientation), amphibole (white) and chromite/magnesiochromite (black, opaque).

(See *Studies on kosmochlor, jadeite and associated minerals in jade of Myanmar*, p.315)

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In this issue...

The Far East again figures strongly in the papers published in this issue and there is new information on gems from Myanmar, Vietnam, Sri Lanka and Siberia.

The first paper deals with the relationship of jadeite with kosmochlor - the intense green mineral now found in maw-sit-sit but first identified in extra-terrestrial rocks. The composition of maw-sit-sit is discussed and the authors present the case for calling it jade.

The recent development of deposits of ruby at Mong Hsu, again in Myanmar, has been extremely rapid - amazingly so when one contrasts it with the several centuries of painstaking output from Mogok. However, this is a result not only of market hunger for the fine stones from this locality, but also of the improvement in communications, the removal of 'procedural' obstacles and the availability of new technologies. With such technologies it is possible at one end to quickly extract gem gravel by the ton and at the other to use a higher percentage of the product by heat-treating stones to improve their colour. Many rubies from Mong Hsu are heat-treated and the methods of distinguishing them from untreated stones, using - yes - new technology, are outlined by C.P. Smith.

The third paper deals with the history of pearl production in the Gulf of Mannar and Sri Lanka. A fascinating insight is given into how pearls were traded and who controlled the trade from the earliest times. An account of the fluctuations in production culminating in its cessation in the 1950s implicates misguided, if well-meaning, government interference.

Over the past thirty years Siberia has been best known in the gem world as the source of Russian diamonds. But over the centuries it has provided a wide range of gem and decorative materials, many of which were utilized in the Fabergé workshops and became well known. Not so well known, perhaps, are the reserves of Siberian jet, which was also a popular material for carving. The paper by S. Glushnev fills a gap in the general appreciation of the history and development of Siberian jet and comes at a time when interest in the potential of Siberian materials is reawakening.

Finally two papers on peridot and synthetic diamond provide topical information on stones that may well become more significant in the trade.

R.R.H.

Studies on kosmochlor, jadeite and associated minerals in jade of Myanmar

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Abstract

Physical, optical and X-ray data are given for jadeite, kosmochlor and other associated minerals in various jades of Myanmar. Jadeite jade is a monomineralic or polyminerallc crystalline aggregate. In the polyminerallc variety, jadeite occurs in intimate associations with edenite, richterite, tremolite, kosmochlor and enstatite. Maw-sit-sit is essentially composed of kosmochlor and chromite/magnesiochromite with or without amphiboles and enstatite, but devoid of pure jadeite.

The occurrence of kosmochlor is confirmed as a terrestrial mineral. Jadeite-kosmochlor solid solution suggests that the term 'jade' could be extended to include kosmochlor as a jade mineral in the gemmological sense.

Introduction

Jade of Myanmar (Burma) has a worldwide reputation for its fine quality. There are various jade types differing in colour, transparency and mineral association, and many quality grades including Imperial, commercial and utility, are produced from Myanmar. They are subdivided into subgrades in the jade trade. These qualities and varieties of jade may be directly related to the mineralogical and chemical

characters of jadeite, pure or impure.

By petrographic and X-ray diffraction studies, some amphiboles and pyroxenes including kosmochlor (previously known as ureyite, Fleischer, 1965) were found (Figures 1 and 2) in association with jadeite in some jade specimens (Naing, 1990). The present work has also confirmed the occurrence of kosmochlor as a terrestrial mineral (Ou Yang; 1984, Harlow and Olds, 1987) and supported the probable existence of jadeite-kosmochlor solid solution (Mével and Kiénast, 1986). However, the amphiboles associated with jadeite and described in the present work are different from those described by Mével and Kiénast.

In addition, neither albite nor quartz has yet been found in any of the true jade specimens studied, but some jade-like rocks do occur in the jade mine areas, for instance the locally called 'pa-lwan' resembles jade but contains albite, quartz and minor epidote. 'Maw-sit-sit' from Tawmaw is regarded as a kind of jade-like material (not real jade) by most jade dealers and by Myanmar Gems Enterprise, but the specimens shown in Figures 3, 4 and cover picture do not contain pure jadeite.

Nomenclature of jade

Gemmologically the term 'jade' is applied to only two mineral species - jadeite and nephrite. For some jades of Myanmar, the term jade will refer not only



Fig. 1. Sp. No. J4 consisting of jadeite, richterite/edenite, tremolite and kosmochlor.



Fig. 2. Sp. No. J13 consisting of jadeite, richterite/edenite, kosmochlor and tremolite.



Fig. 3. Sp. No. MSS 2. Maw-sit-sit consisting of kosmochlor, tremolite, edenite/richterite and chromite.



Fig. 4. Sp. No. MSS 3. Maw-sit-sit consisting of kosmochlor, enstatite, chromite and magnesiochromite.

to jades composed only of jadeite but also to jadeite plus other associated mineral or minerals. When a jade specimen is essentially monomineralic, the term 'jadeite jade' or 'pure jade' will be used. If the specimen is polymineralic the term 'impure jade' will be applied in the present work.

Mével and Kiénast have demonstrated by electron probe microanalysis that a wide range of solid solution exists between pure jadeite and nearly pure kosmochlor (i.e. kosmochlor 85 jadeite 15).

Physical characteristics of jade

Texture

Well formed, individual crystals of jadeite have not yet been found in Myanmar. All the jade samples are compact, massive and generally granular aggregates. The states of aggregation may be different from one specimen to another. Commonly, fine- and coarse-grained aggregates are associated in a single jade specimen. Lath-shaped, elongated or fibrous aggregates of prismatic crystals can be seen in hand specimens. The constituent crystals may be subparallel or randomly oriented and their textures are commonly best displayed on weathered crusts. X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses showed that the mineral and chemical compositions of crusts were not significantly different from those of fresher parts of the rock.

Lustre

Vitreous to subvitreous.

Diaphaneity

Ranging from transparent (highest degree of diaphaneity) through translucent to semi-opaque (lowest), except included grains of chromite/magnesiochromite which are opaque even at the thickness of petrographic thin sections (0.03mm).

Colour

Jades of Myanmar can be found in many hues ranging from almost white through purple, blue, green, yellow, red and pink in

variable saturations to nearly black.

Qualitative point analysis on vividly coloured specimens by JEOL JXA 840A electron probe micro-analyzer provided the following information on the chemical constituents which may be causing the colour:

Emerald-green to light green:

Cr (colour saturation depends upon Cr concentration). Kosmochlor itself is deep emerald-green especially in maw-sit-sit

Greyish-green and greenish-grey:

Fe, Mg, + Cr

Yellowish, brownish and reddish:

Fe (Ti, V, Cr and Mn were not detected in jades of these colours)

Mauve and pinkish:

Manganese

Dark green and greenish black:

Mg, Ca, Fe (constituent elements of amphiboles which may be responsible for these colours)

Hardness

The relative hardness varies in practice from slightly greater than 6 (coarse-grained aggregate) to 7 (for fine-grained aggregate).

Specific gravity

Ranges from 3.30 to 3.36 with a mean value 3.327 (by hydrostatic weighing method). The lower values are due to the presence of amphiboles.

Refractive index

Mineral grains from each specimen were immersed in liquid and the immersion liquid was adjusted to the RI of the grains. Thus, only a single mean value for each specimen could be measured on the Abbe

Refractometer with a sodium light source. The results from 21 specimens range from 1.6530 to 1.6556. The mean value is 1.6545.

Optical characteristics

Jade of Myanmar is either a monomineralic aggregate of jadeite or a polyminerallitic pyroxene-amphibole rock with some oxides. In polyminerallitic jades, edenite, richterite, tremolite, kosmochlor and enstatite may be intimately intergrown with jadeite.

Jadeite

In thin sections jadeite is colourless in plane polarized light (PPL), but some grains appear dusty with streaks mainly due to oriented, fine acicular inclusions. XRD methods indicate that these inclusions are probably rutile and ilmenorutile. Some jadeite grains also contain liquid inclusions, noticeably in wedge-shaped spherical and dumb-bell forms.

Crystal habit varies, stout prismatic granular forms are common, but columnar and fibrous aggregates also occur, sometimes bent and radiated like a cock's tail. Simple and lamellar twins are not uncommon. In thin section under a polarizing microscope the coarse grains usually show wavy extinction. Jadeite is distinguished from associated amphiboles by its pronounced pyroxene cleavages, higher extinction angles, lower birefringence and positive optic sign.

Kosmochlor (previously known as ureyite)

Kosmochlor occurs in some jadeite jades and in all maw-sit-sit specimens studied. In jadeite jade it is intimately intergrown with jadeite and with amphiboles. In maw-sit-sit it occurs as a replacing mineral around grain boundaries and along fractures of both chromite/magnesiocromite (Cover picture) and enstatite.

Its body colour ranges remarkably from vivid green in maw-sit-sit where chromite/magnesiocromite is predominant to less deep green where amphiboles

and kosmochlor are predominant over chromite/magnesiocromite, to light green when associated with jadeite. The deeply coloured kosmochlor (in maw-sit-sit) shows strong pleochroism from bluish-green, deep green to yellow, whereas the light green variety is weakly pleochroic from light green to light greenish-yellow (in jadeite jade).

Kosmochlor occurs as lozenge-shaped, rectangular or tabular square or as columnar crystals. In thin sections, its relief is higher than jadeite and associated amphiboles. It has characteristic pyroxene cleavages, one set being good while the other set is poor. Parting is common.

Edenite and richterite

Edenite and richterite are calcic and sodic-calcic amphiboles (Leake, 1978). In impure jades they are intimately intergrown with tremolite, jadeite and kosmochlor, but the amphiboles can be distinguished easily from pyroxenes in thin sections.

Both minerals are usually colourless in plane polarized light (PPL), but they show pleochroism from colourless to greenish-yellow when associated with chromite/magnesiocromite. They occur as rectangular, six-sided, tabular, bladed or fibrous forms and simple twins are sometimes present. Edenite and richterite show characteristic amphibole cleavages and moderately strong interference colours in thin sections. It is extremely difficult to differentiate between edenite and richterite and mineral species identification was based on XRD analysis, even though this is not entirely satisfactory.

X-ray powder diffraction data

Using a computer controlled Rigaku X-ray diffractometer intensities were measured between 10° to 70° 2θ at a scanning speed of 8°/min. The X-ray patterns of jadeite and kosmochlor were compared with the JCPDS(1986) standard data (Table I). Due to the high scanning speed of the

goniometer, very weak lines are not detected and are not listed in Table I.

Specimen J21 is a mineralogically pure jadeite and J14 is a polyminerally pure jadeite containing jadeite, kosmochlor and amphiboles. The jadeite results for J21 and J14 are almost the same within the accuracy limits of the method.

The X-ray patterns of kosmochlor occurring in maw-sit-sit (MSS) and jadeite jade (J13) are compared with those of natural ureyite (Fleischer, 1965) and synthetic kosmochlor (JCPDS, 1986). Six out of seven

diffraction lines given in Fleischer's report are almost the same as the present data, but their intensity ratios are different.

Compared with the JCPDS data, the presence and absence of diffraction lines and their intensities differ slightly as the compositions vary from MSS1 to J13. Some of the diffraction lines of kosmochlor overlap those of jadeite, and this tends to confirm that solid solution is possible between kosmochlor and jadeite as described by Mével and Kiénast (1986). Similarly, edenite, richterite and tremolite have overlapping

Table I. X-ray powder diffraction data

Table I. X-ray powder diffraction data													
Jadeite						Kosmochlor							
JCPDF 22-1338		J21		J14		JCPDF 26-1484		MSS1		MSS2		J13	
d(Å)	Int	d(Å)	Int	d(Å)	Int	d(Å)	Int	d(Å)	Int	d(Å)	Int	d(Å)	Int
6.22	15	6.232	11	6.267	12	6.3	29	6.311	29	6.258	18	6.293	11
4.5	5					4.57	3	4.458	31				
4.35	5	4.371	5			4.39	18	4.378	27	4.401	12		
4.29	45	4.304	29	4.3	26	4.35	25			4.362	13	4.354	19
3.25	5	3.262	7	3.25	10	4.06	15						
3.1	30	3.112	27	3.11	31	3.58	7						
2.922	75	2.928	73	2.926	76	3.15	5	3.14	83	3.133	100	3.144	62
2.831	100	2.836	100	2.838	100	2.958	100	2.963	90	2.984	24	2.992	87
2.527	2					2.87	65	2.87	69	2.875	33	2.861	48
2.49	20	2.499	17	2.495	27	2.519	28	2.518	100	2.52	24		
2.417	25	2.424	19	2.424	29	2.511	40					2.511	20
2.206	10	2.206	9	2.212	12	2.451	35	2.462	27	2.45	9		
2.161	5	2.164	8	2.16	11	2.235	5						
2.046	10	2.046	6			2.182	18						
1.993	2			1.998	6	2.1	22	2.105	32	2.101	11		
1.968	15	1.971	11	1.972	16	2.073	12	2.065	26	2.079	11	2.081	23
1.93	2					2.017	10						
1.887	5	1.889	5	1.891	6	1.965	6					1.977	19
1.839	2					1.915	9			1.9	15		
1.761	10	1.761	11	1.764	12	1.866	3						
1.684	10	1.685	10	1.687	11	1.809	5						
1.651	2			1.652	5	1.781	2					1.768	17
1.624	5			1.627	6	1.71	10	1.712	30	1.713	9		
1.611	5	1.613	6	1.611	8	1.708	8					1.691	15
1.572	20	1.573	15	1.574	18	1.671	5						
1.552	15	1.552	14	1.554	12	1.667	5			1.654	13		
1.499	10	1.5	8	1.5	10	1.646	6	1.652	35	1.652	13		
1.488	10	1.488	10	1.492	10	1.625	25	1.625	29	1.629	7		
						1.596	15	1.599	46	1.601	12		
J21	- Jadeite jade, almost pure												
J14	- Jadeite associated with amphiboles and kosmochlor												
MSS1	- Vivid green kosmochlor												
MSS2	- Green kosmochlor												
J13	- Light green kosmochlor associated with jadeite												
						1.576	5	1.577	31	1.573	10	1.576	28
						1.52	6	1.523	27	1.523	6		
						1.512	2	1.51	35	1.508	7		
						1.494	10					1.496	15
						1.482	4	1.472	39				
						1.466	2						
						1.452	7			1.432	15		
						1.391	4						
						1.382	12			1.378	9	1.369	23

diffraction lines since their mineral structures are very similar.

Conclusions

The jades of Myanmar may be defined as jadeite/kosmochlor-bearing rocks with or without other minerals. Jadeite occurs as a monomineralic aggregate or frequently in association with edenite, richterite, tremolite, enstatite and kosmochlor. As described by Mével and Kiénast (1986), kosmochlor and jadeite form a solid solution series, and so kosmochlor could be classed as a jade mineral. Maw-sit-sit is a jade variety essentially composed of kosmochlor and magnesiochromite/chromite with or without the associated minerals enstatite, edenite, richterite and jadeite.

The quality of a jade specimen mainly depends on colour, transparency and lustre. The emerald-green colour is due to Cr which is an essential component of chrome jadeite and kosmochlor. Other colours depend on impurity elements (colouring agents) and associated minerals present. Fine- to medium-grained texture with fused or sutured boundaries of granular jadeite commonly provide high degrees of transparency and glassy lustre.

The optical properties and X-ray diffraction patterns of kosmochlor occurring in jade and maw-sit-sit vary in such a way as to suggest a wide range of solid solution between jadeite and kosmochlor. This is consistent with the work of Mével and Kiénast (1986) and for gemmological purposes the term 'jade' should be extended to include kosmochlor as a jade mineral.

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References

- Fleischer, M. 1965. Ureyite. *American Mineralogist*, **50**, November
- Harlow, G.E., Olds, E.P. 1987. Observations on terrestrial ureyite and ureyitic pyroxene. *American Mineralogist*, **72**, 126-36
- JCPDS, 1986. Mineral powder diffraction file. *International Centre for Diffraction Data*, 1601 Park Lane, Swarthmore, PA 19081, USA
- Kohn, J.A., Comeforo, J.E., 1955. Synthetic asbestos investigations. II: X-ray and other data on synthetic fluo-richterite, -edenite, and -boron edenite. *American Mineralogist*, **40**, 5/6, 410-12
- Leake, B.E., 1978. Nomenclature of amphiboles. *American Mineralogist*, **63**, 11/12, 1023-52
- Mével, C., Kiénast, J.R., 1986. Jadeite-kosmochlor solid solution and chromian sodic amphiboles in jadeites and associated rocks from Tawmaw (Burma). *Bull. Mineralogie*, **109**, No. 6
- Morimoto, N., 1988. Nomenclature of pyroxenes. *Mineralogical Magazine*, **52**, 535-50
- Naing, A.M., 1990. Quantitative and qualitative studies of Myanmar jade. *Unpublished M.Sc. Thesis*, University of Yangon
- OuYang, C.M., 1984. A terrestrial source of ureyite. *American Mineralogist*, **69**, 1180-3

A contribution to understanding the infrared spectra of rubies from Mong Hsu, Myanmar

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Abstract

The infrared absorption of the rubies from Mong Hsu was analyzed in order to classify the absorption features recorded. In the mid-infrared region, it was possible to distinguish two separate types of spectra. The first type was recorded in non-heat-treated ruby samples in the region from 1900 to 3400 cm^{-1} , identifying inclusions of diaspore. The second type was recorded in heat-treated ruby samples in the region from 3100 to 3600 cm^{-1} , indicating structurally bonded OH groups. Detailed for the first time in corundum, the building of OH groups is accomplished as a direct result of the dehydration of diaspore inclusions, demonstrated through heat treatment experiments.

Key words

Corundum, Ruby, Infrared spectroscopy, Diaspore, Heat treatment, Structural OH groups

Introduction

Ever since its development in 1991, the mining region near the town of Mong Hsu (in Shan state, north-east Burma) has provided an intriguing new source of gem-quality rubies for the jewellery, gemmological and scientific communities. As a result, these rubies have received a lot of attention in the gemmological literature (see for example Hlaing, 1991, 1993, 1994; Laughter, 1993a,b; Clark, 1993; Henn and Bank, 1993; Peretti, 1993; Kammerling *et al.*,

1994; Smith and Surdez, 1994). The rough ruby crystals from this source are characterized by unique dark blue to violet core colour zones. These blue to violet colour zones can be readily removed with heat treatment, resulting in attractive, richly coloured rubies. However, within some crystals dense whitish clouds may form during heat treatment, reducing the transparency of the gemstones. In addition, various other forms of cross-hatch and flake-like cloud patterns as well as stringer formations and prominent sequences of growth structures, are the most typically observed internal features. For a further description of the inclusions observed in Mong Hsu rubies, the reader is referred to the publications listed above.

Hlaing (1991, 1993) indicated a primary marble source and secondary deposits with associated minerals including tourmaline, red-brown garnet, staurolite, pyrite, tremolite and quartz. The primary and secondary source minerals can provide important insights into the geology surrounding Mong Hsu. Mineral inclusions such as apatite (microprobe), dolomite (scanning electron microscope - energy dispersive system (SEM-EDS)), fuchsite and muscovite micas (SEM-EDS and X-ray diffraction (XRD)), serpentine (XRD), kaolinite (microprobe) and diaspore (SEM-EDS in combination with XRD), have been identified in the rubies from Mong Hsu and the initial findings have been published by Smith and Surdez (1994). In this paper, the absorption features present in the mid-infrared spectrum were also briefly

described. During subsequent research, it became possible to identify the causes of these absorption features as well as an interactive alteration which takes place as a result of heat treatment. It is the purpose of this paper to present this new information to aid in understanding the infrared spectral characteristics in rubies from Mong Hsu.

Infrared spectroscopy has been an important method of analysis for classification in mineralogy for several decades (see for example Frederickson, 1954; Farmer, 1974; Suhner, 1984; Rossman, 1988). Recently, it has also become an increasingly valuable tool in gemmology and is successfully applied for the identification of gem materials, the distinction between natural and synthetic gemstones, and identifying various treatments (see for example Suhner, 1979; Lind and Schmetzer, 1983; Fritsch and Stockton, 1987; Martin *et al.*, 1989; Schmetzer, 1989; Fritsch and Rossman, 1990; Schmetzer and Kiefert, 1990). The part of the spectrum of most interest to gemmologists is the region above 400 cm^{-1} , the mid-infrared region. This region is particularly useful because it is here that absorption features relating to structural OH groups and water stretching frequencies are located (Farmer, 1974; Fritsch and Stockton, 1987).

The infrared spectrum of corundum is dominated by absorption features resulting from Al-O stretch frequencies and lattice absorption, with peaks located at approximately 760 , 642 , 602 and 450 cm^{-1} (Wefers and Bell, 1972), while the mid-infrared region, where hydroxyl bands are typically located, is generally free of absorption features (see for example Rossman and Smyth, 1990).

The rubies from Mong Hsu possess the dominant absorption features typical of corundum, in the region of approximately 300 to 1000 cm^{-1} . In addition, they frequently display absorption bands in the region between 1900 and 4000 cm^{-1} . Two distinct combinations of bands in this latter

region were recorded and could be distinguished, with only slight variations occurring within the individual types. These two types of absorption spectra are distinctly separate, dependent upon the presence of certain mineral inclusions in non-heat-treated rubies and the influence of heat treatment.

Methods and materials

A total of 31 Mong Hsu rubies were examined in the near- to mid-infrared spectral region (approx. 200 to 7000 cm^{-1}). A Unicam 9624 FTIR spectrophotometer, utilizing a beam condenser and diffused reflectance unit for sample measurement, with a straight transmitted and internally reflected beam path, respectively (4.0 cm^{-1} increments, 200 scans), were used to test nine non-heated, partly polished crystals, eight heat-treated, partly polished crystals and 14 heat-treated faceted rubies. Polarized infrared spectral analysis was made with a Perkin-Elmer 1720 spectrophotometer equipped with stationary filters and a rotatable sample holder (4.0 cm^{-1} increments, 15 scans). Heat treatment experiments were performed in a Thermal Technology Group 1000A graphite hot zone furnace with temperatures of 1500°C in a pure O_2 atmosphere, without the use of 'Borax'-related coatings, for a period of five hours.

Non-heat-treated samples

A series of absorption bands in the mid-infrared range 1900 to 3400 cm^{-1} were recorded in several of the non-heat-treated Mong Hsu rubies. These included typically a series of peaks; one was located between approximately 1990 and 2040 and another slightly broader peak with the maximum positioned between 2120 and 2145 cm^{-1} ; in addition to two absorption bands with maxima located at approximately 2885 , 3025 cm^{-1} (Figure 1). Polarized spectral analysis revealed a pleochroic effect which consisted of more prominent absorption peaks recorded

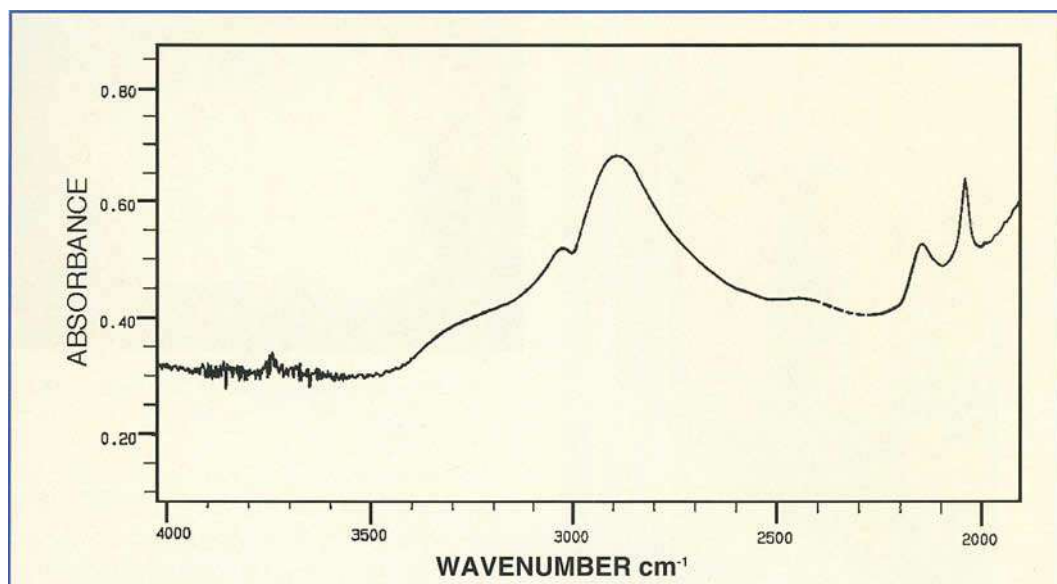


Fig. 1. The non-heat-treated Mong Hsu ruby samples commonly possess OH bending and stretching frequencies assigned to diaspore (αAlOOH), with absorption peaks in the infrared region from approximately 1900 to 3400 cm^{-1} superimposed on the spectrum of corundum. The dashed line indicates an area of the spectrum corrected for a spurious peak attributed to CO_2 .

along the vibrational path parallel to the *c*-axis of the corundum crystal and a weaker, yet identical, spectrum recorded along the vibrational path perpendicular to the *c*-axis of the corundum crystal. Features in this spectral area are commonly related to OH group absorptions (Farmer, 1974). Such absorption features are not generally seen in pure corundum, which is anhydrous (i.e. a mineral which does not possess water or hydroxyl groups in its structure).

For the identification of this additional mineral phase, only the spectral range above approximately 2000 cm^{-1} was available because of the dominant Al-O and lattice absorption which masks much of the region necessary to properly identify a mineral by this method. However, the mid-infrared region, which contains the structural OH stretching frequencies, has long been used as a means to identify and distinguish the several hydrous alumina phases (Frederickson, 1954). Therefore, it

was possible to positively identify the secondary mineral phase as the aluminium oxyhydroxide diaspore (see for example Farmer, 1974; p. 148, figure 9.8). As described in the introduction, diaspore was independently identified in the rubies from Mong Hsu by scanning electron microscopy in combination with XRD micro-sampling techniques, recorded with a Gandolfi camera. The diaspore occurred as 'veins' which penetrated and traversed the stones (Figure 3), as well as coatings at the surface of the crystals (Figure 4). It is very important to mention, however, that this infrared absorption spectrum was also recorded in crystals with polished parallel windows and no sizeable mineral inclusions, veins or external coatings (Figure 2). These absorption peaks were even recorded when the spectral analysis was taken through areas which were specially isolated (i.e. 'masked' in order to ensure that the areas measured were free of the inclusion features just described).

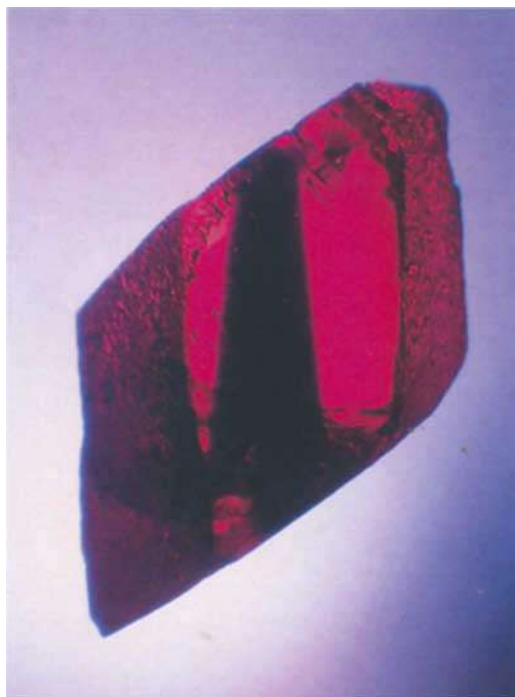


Fig. 2. The spectrum shown in Figure 1 was obtained from this high quality, partly polished, 2.21 ct Mong Hsu ruby crystal. This crystal possessed the unique dark violet core colour zone which is typical of the corundum crystals from this deposit, while no diaspore was found as coatings, in twin lamellae or in veins. Transmitted fibre-optic illumination, 9x.



Fig. 3. Mong Hsu ruby crystal (2.54 ct) traversed by irregular veins of diaspore. Overhead illumination, 22x.

A subordinate presence of boehmite was also indicated in the mid-infrared spectrum, with absorption bands centred at approximately 3080 and 3290 cm^{-1} (see for example Frederickson, 1954; Suhner, 1984; Häger and Greiff, 1994). Boehmite has been identified as an inclusion in corundum by other researchers (Sahama *et al.*, 1973; White, 1979), however, the identification of boehmite in the rubies from Mong Hsu has not yet been verified by X-ray diffraction.

Heat-treated samples

In contrast, many heat-treated Mong Hsu rubies were found to possess a more



Fig. 4(a) and (b). Many Mong Hsu ruby crystals are coated with diaspore

- a) A transparent essentially colourless coating of diaspore filling recesses at the surface of this 2.75 ct Mong Hsu ruby crystal prior to heat treatment. Overhead illumination, 20x.
- b) The same area of the 2.75 ct ruby crystal after heat treatment, where the diaspore coating has gone through a dehydration process and transformed into a translucent, whitish, polycrystalline mass. Oblique fibre-optic illumination, 20x.

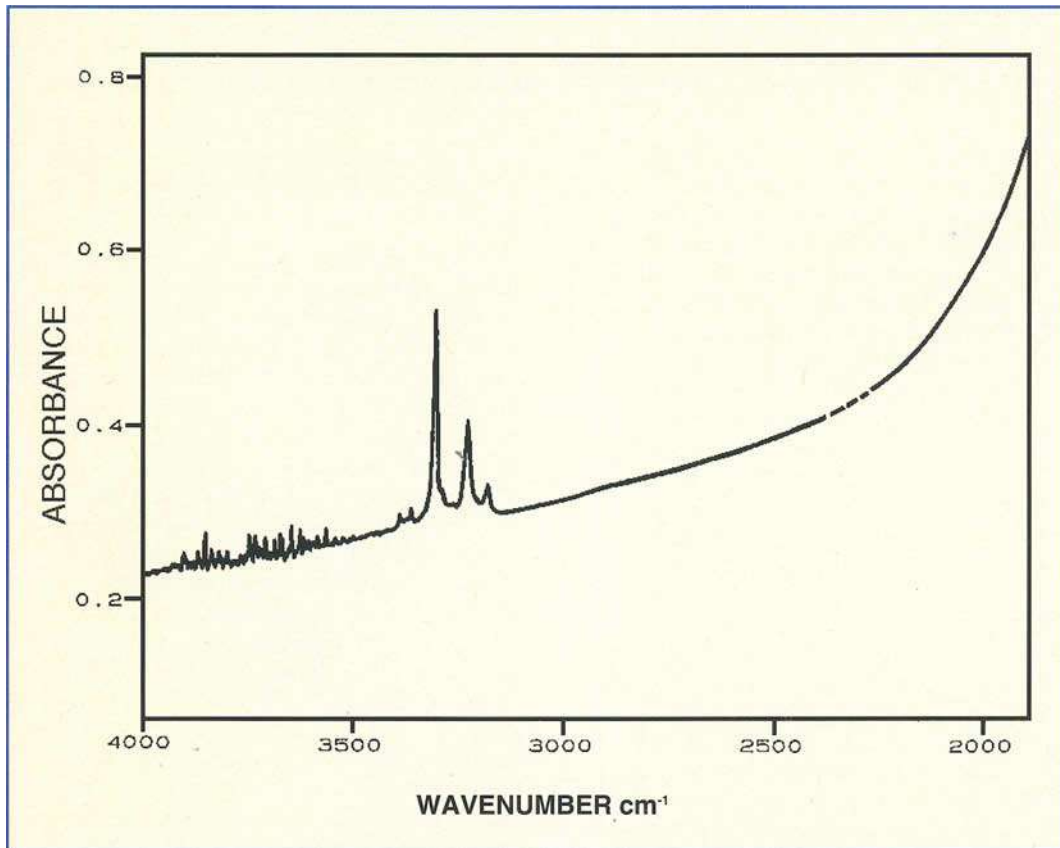


Fig. 5. Heat-treated Mong Hsu ruby samples typically display absorption peaks ascribed to structural OH groups bonded within the corundum lattice, in the infrared region between approximately 3100 and 3600 cm^{-1} . The dashed line indicates an area of the spectrum corrected for a spurious peak attributed to CO_2 .

localized concentration of absorption features in the region from approximately 3100 to 3600 cm^{-1} . These consisted of a series of sharp peaks, with the primary peak located at approximately 3310 cm^{-1} , accompanied by a shoulder at approximately 3292 cm^{-1} and weaker peaks at approximately 3232, 3187 and 3368 cm^{-1} (Figure 5). Polarized spectral analysis revealed these absorption peaks to be of a strongly pleochroic nature, with maximum peak intensity recorded when the vibrational path was perpendicular to the *c*-axis of the corundum crystal, while they were very weak when the vibrational path was parallel to the *c*-axis of the corundum crystal. These peaks were rarely super-

imposed on an underlying absorption band. The series of sharp peaks observed here are related to structural OH groups bonded within the corundum lattice (Eigenmann and Günthard, 1971; Eigenmann *et al.*, 1972; Volynets *et al.*, 1972, 1974; Beran, 1991; Moon and Phillips, 1994; Häger and Greiff, 1994; also refer to the panel on pages 326-8).

Not all heat-treated samples possessed the complete series of absorption peaks, while other samples indicated a complete lack of structural OH. OH was recorded in the translucent whitish clouds which had formed during the heat-treatment process and additionally in transparent areas of some rubies (Figure 7). Dependent on the

Additional comments on the structural bonding of OH in corundum

Although the incorporation of hydrogen in the structure of corundum is a subject not well known to many gemmologists, it has been a topic studied in great detail by past researchers, especially in Austria, Australia, the former Soviet Union and Switzerland. Most of the previous work detailing the structural bonding of OH groups in corundum has been carried out on Verneuil-grown synthetics of various colours and composition (see for example Eigenmann and Günthard, 1971, 1972; Eigenmann *et al.*, 1972; Volynets *et al.*, 1972, 1974; Beran, 1991). In addition, structural OH absorption peaks have been recorded in hydrothermally grown synthetic rubies (Belt, 1967; Peretti and Smith, 1993, 1994) and in natural corundums, including a ruby from Sri Lanka and a sapphire from Montana (Beran, 1991), sapphires from Australia (Moon and Phillips, 1994), sapphires from southern Vietnam (Smith *et al.*, 1994), rubies from the Mong Hsu mining region in Burma (Smith and Surdez, 1994), as well as corundums from various other sources (Häger and Greiff, 1994).

Past researchers have indicated that hydrogen atoms are typically incorporated within the structure of corundum as a charge compensation mechanism bound to various transitional metal ions present as trace elements, occupying an interstitial site between two oxygen atoms (O^{2-}) or also possibly trapped by cation vacancies (Eigenmann and Günthard, 1971, 1972; Eigenmann *et al.*, 1972; Volynets *et al.*, 1974; Beran, 1991; Moon and Phillips, 1994). Similar replacements have also been identified in other principally anhydrous minerals (see for example Martin and Donnay, 1972). The influence these traces of hydrogen have on the corundum's spectral properties is observed as a

series of sharp absorption peaks which are present in the mid-infrared region of the spectrum.

The prominence and number of absorption peaks recorded in the mid-infrared spectrum are dependent on the concentration of OH bonding. The individual wave number positions of the absorption peaks are dependent, either singly or in combination, upon which trace element the OH has bonded to; such as titanium (Ti), vanadium (V), magnesium (Mg), iron (Fe), silicon (Si), nickel (Ni) or cobalt (Co). The most typically encountered structural OH groups recorded in corundum are those attributed Ti, V, or Fe bonds, as illustrated in Figures 5 and 6 (Eigenmann and Günthard, 1971; Eigenmann *et al.*, 1972; Volynets *et al.*, 1972, 1974; Moon and Phillips, 1994; Häger and Greiff, 1994). Polarized infrared spectral analysis has shown these absorption traits to be highly pleochroic, indicating a crystallographic orientation of OH bonding, dependent on the element, either in a direction perpendicular or parallel to the *c*-axis (Eigenmann and Günthard, 1971, 1972; Eigenmann *et al.*, 1972; Volynets *et al.*, 1972, 1974; Beran, 1991; Moon and Phillips, 1994).

The rubies from Mong Hsu described in the present paper were found to possess structural OH groups only after heat treatment; however, non-heat-treated natural and synthetic corundums may possess similar structural OH groups. Verneuil synthetic corundum typically contains structural OH groups (see for example Eigenmann *et al.*, 1972; Volynets *et al.*, 1974). This is attributed to the high hydrogen supply involved with the Verneuil growth technique (Beran, 1991; see also for example Nassau, 1980). While Häger and Greiff (1994) and the present author have observed structural OH absorption in the

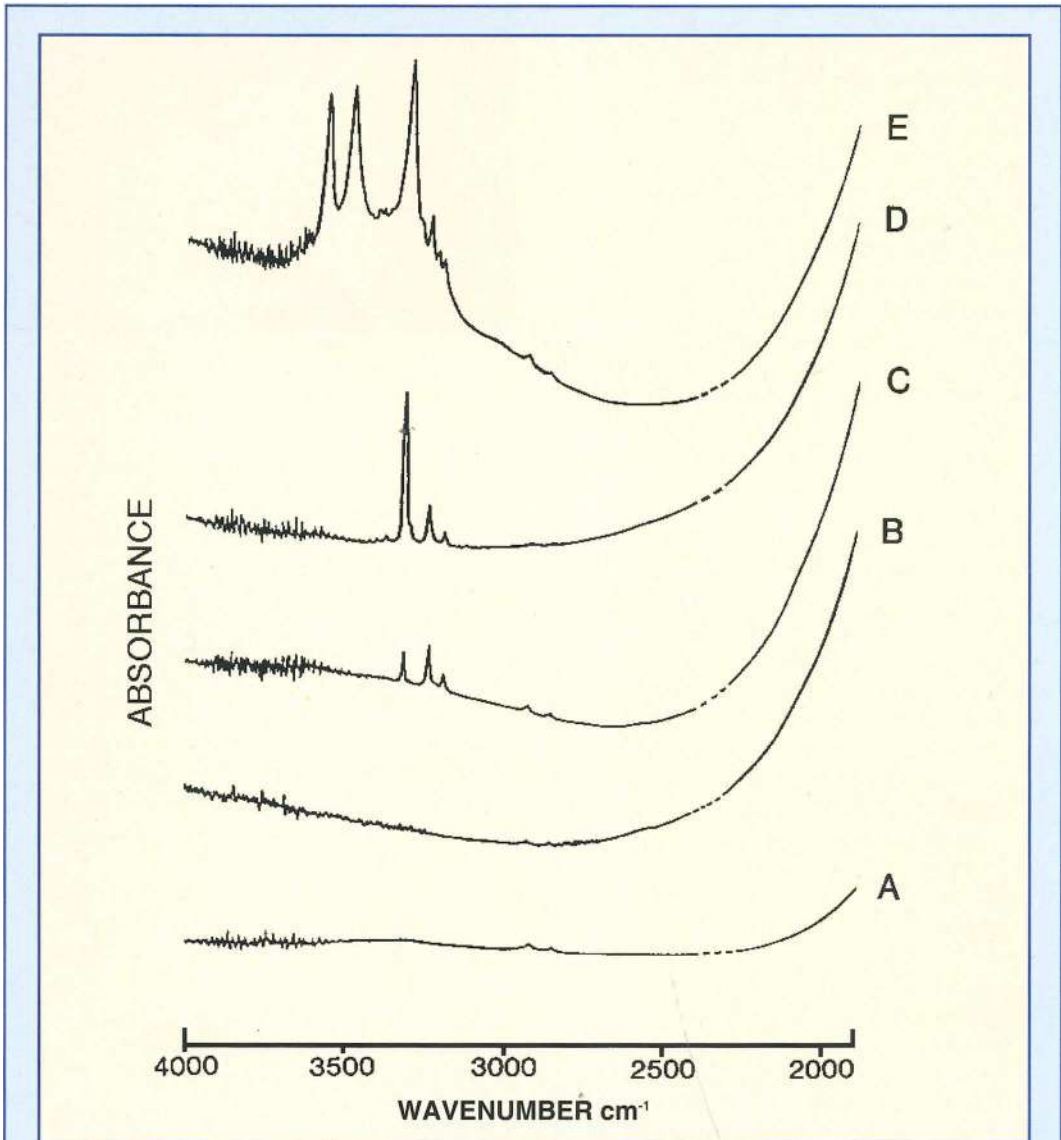


Fig 6: The structural OH absorption peaks illustrated here are attributed bonds occurring with metal ions (Ti,V or Fe) in a transitional state. Although they may be observed in non-heat-treated natural and synthetic corundum, more typically they are recorded in natural sapphires from basaltic sources, as well as in synthetic corundums grown by the Verneuil (flame-fusion) or hydrothermal growth methods. Non-heat-treated natural corundums from metamorphic sources typically do not show evidence of OH groups in the mid-infrared region of the spectrum, while unaltered flux-grown synthetic corundums are always free of structural OH. (A) Flux-grown synthetic ruby; (B) natural ruby from the Mogok stone-tract, Burma (Myanmar); (C) flame-fusion synthetic ruby; (D) natural blue sapphire from Thailand; (E) hydrothermally-grown synthetic ruby. Also note the difference in the intensity of the structural OH absorption peaks present in hydrothermally-grown synthetic corundum, compared with the pattern in natural corundum or flame-fusion synthetic corundum. The dashed line indicates an area of the spectrum corrected for a spurious peak attributed to CO₂.

mid-infrared spectra of non-heat-treated natural corundums as well, in the present author's experience the occurrence of structural OH in non-heat-treated natural corundum is more restricted than this general statement might at first imply. The structural OH groups attributed to Ti, V or Fe bonds are much more typically recorded in non-heat-treated blue sapphires from basaltic sources (for example Australia, Cambodia, Thailand, southern Vietnam, etc.) than in non-heat-treated rubies or sapphires from other types of sources (i.e. metamorphic). Additionally, structural OH is readily observed in non-heat-treated hydrothermal synthetic corundum; however, the concentration and intensity of the OH bonding and its absorption features are considerably stronger than those recorded in either natural or other synthetically grown corundum (Figure 6).

Heat-treatment experiments with both natural and synthetic corundums have shown that OH bonding can be increased or decreased depending on the precise conditions (see for example Eigenmann and Günthard, 1971; Eigenmann *et al.*, 1972; Moon and Phillips, 1994). The results of the work reported above indicate that hydrogen can be diffused into the corundum structure, forming OH groups, through annealing in a hydrogen atmosphere under different conditions, thereby producing or intensifying the respective absorption peaks. Whereas annealing in an oxygen atmosphere under certain conditions may reduce or eliminate structural OH bonding and its absorption features.

While the mid-infrared region of the spectrum for corundum has not been of great interest to gemmologists in the past, recent work has proved this to be a fruitful research area for rubies and sapphires.

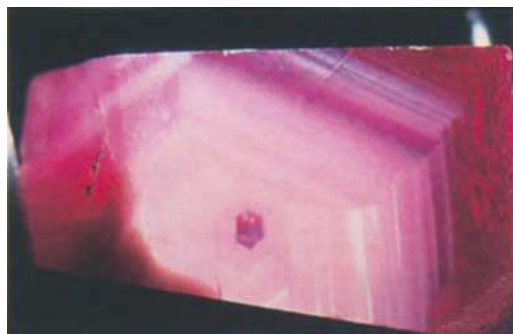


Fig 7. Whitish clouds in a partly polished 1.21 ct Mong Hsu ruby. Heat-treated Mong Hsu rubies frequently develop dense whitish clouds, which form along certain growth areas. Structural OH absorption peaks are typically present when a spectral analysis is taken through these clouds, and they may also be recorded in transparent areas of these stones. Oblique fibre-optic illumination, 12x.

concentration of OH, several samples possessed only a single peak located at approximately 3310 cm^{-1} ; others showed this in combination with a second peak at approximately 3232 cm^{-1} , while the most intense spectra also possessed an additional small peak located at approximately 3393 cm^{-1} . In all the tested samples of heat-treated rubies from Mong Hsu, the peak at approximately 3310 cm^{-1} was the strongest, with the next most prominent peak at approximately 3232 cm^{-1} being one fourth to one half the intensity of the first. The relative intensity of the peaks located at approximately 3187 and 3368 cm^{-1} varied depending on the sample, while the peak occasionally observed at approximately 3393 cm^{-1} was the weakest in all cases. Other researchers, however, have indicated different sequences of peak intensity recorded in various synthetic corundum samples (Eigenmann and Günthard, 1971; Eigenmann *et al.*, 1972; Volynets *et al.*, 1972, 1974; Beran, 1991; Peretti and Smith, 1993, 1994).

Experimental results

Once the two different types of mid-infrared absorption spectra had been

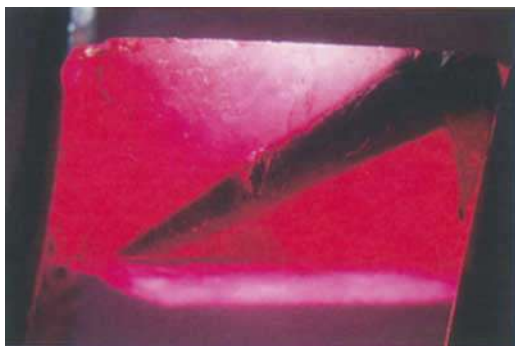


Fig. 8a. A 2.75 ct, partly polished Mong Hsu ruby crystal prior to heat treatment, possessing a dark violet core colour zone and a mid-infrared absorption spectrum related to diaspore. Oblique fibre optic illumination, 10x.

identified, it was concluded that the structural OH groups present in the heat-treated samples were being formed as a consequence of the alteration and dehydroxylation (dehydration) of diaspore particles within the 'host' corundum crystal. In order to verify and demonstrate this occurrence, specially selected Mong Hsu ruby crystals possessing the additional infrared spectral absorption features related to diaspore (from 1900 to 3400 cm^{-1}) were selected for heat-treatment experiments (Figure 8). Before the heat-treatment process was conducted, the partly polished crystals contained dark blue to violet core colour zones. In addition, one of the crystals possessed coatings of diaspore (Figure 4a). Upon completion of the heat-treatment process, the blue to violet colour zones had disappeared while in the areas just outside the original position of the core colour zones, dense whitish clouds had formed, drastically reducing the transparency of the crystals. Another special phenomenon noted on the surface polished prior to heat treatment and examined after heat treatment without repolishing, included the presence of shallow surface cracks or crazing. This surface crazing was associated with the whitish clouds which had become apparent upon heat treatment

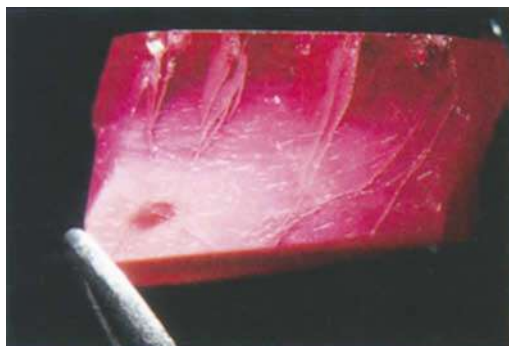


Fig 8b. The same crystal after heat treatment at 1500°C in a pure O_2 atmosphere, for a period of five hours. As can be readily seen, although the dark violet core colour zones were successfully eliminated, dense, whitish, clouds formed during heat treatment and greatly reduced the transparency and quality of this crystal. Structural OH groups are now present in the mid-infrared spectrum, while the spectrum related to diaspore is no longer present. Oblique fibre-optic illumination, 10x.



Fig 8c. Evidence of the stress such rubies may experience during the formation of these clouds can be seen by a special feature noted on the surfaces polished prior to heat treatment: the presence of very fine, shallow cracking or crazing which was most concentrated in the areas where the densest clouds reached the surface and was less concentrated where the clouds were less dense. Crazing is absent where there are no clouds, as can be seen when comparing the b and c images of this figure. Oblique fibre-optic illumination, 14x.

and present in higher concentrations when associated with the densest cloud formations reaching the surface, while more sparse when the clouds were less dense.

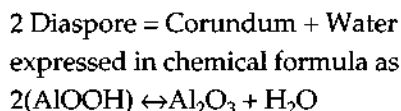
No surface crazing was present where no clouds had formed (Figure 8). In addition, the transparent, colourless coatings of diaspore had transformed into translucent, whitish polycrystalline masses (Figure 4b).

After heat treatment, the infrared spectra of these crystals were taken again under the same conditions as previously tested. The resulting spectra confirmed the formation of newly bonded OH groups within the structure of the corundum crystal with peaks in the mid-infrared spectrum, from 3100 to 3600 cm^{-1} , while the mid-infrared absorption relating to diaspore had disappeared. A pure oxygen atmosphere was essential during these heat-treatment experiments. This proves conclusively that the building of structural OH groups within these ruby samples is solely related to the alteration and dehydration of diaspore. Even though the concentration of OH may be decreased under these conditions, it is not possible for hydrogen to be diffused into the corundum lattice from such an atmospheric source (see also the panel on pages 326-8).

Discussion of non-heat-treated Mong Hsu rubies

In order to discuss and understand the simultaneous occurrence of corundum and diaspore together in these samples, a brief description of their interwoven nature and relationship is in order. To begin with, aluminium is an element which can be present in many different minerals, one of which is corundum, the alpha form of aluminium oxide (Al_2O_3). Additionally, there are several hydroxide forms of aluminium (oxyhydroxides and trihydroxides), including boehmite, diaspore, nordstrandite, bayerite, gibbsite, etc. (see for example Wefers and Bell, 1972). The similarity in structure between corundum ($\alpha\text{Al}_2\text{O}_3$) and diaspore (αAlOOH), with a close-packed hexagonal arrangement of aluminium and oxygen in the lattice, allows for a relatively easy transformation to occur between these two minerals due to the small rearrange-

ment necessary in the (Al) and (O) positions. Perkins *et al.* (1979) indicate the reaction as follows:



This is a process which can take place in either direction, with alteration and reverse alteration occurring as conditions fluctuate above and below the equilibrium curve (Haas, 1972; Perkins *et al.*, 1979), diaspore being the stable phase within the lower temperature field at similar pressures (Figure 9). The result of this alteration process is commonly observed in nature, where diaspore is frequently found as a coating on corundum crystals (see for example Haas, 1972; Wefers and Bell, 1972; Klein and Hurlbut, 1985; Deer *et al.*, 1993). An early description detailing this phenomenon was given more than a century ago by Kenngott (1866). Inclusions of diaspore in corundum have also been identified, occurring along irregular fractures (Schmetzer, 1987) and as a daughter mineral in three-phase inclusions (Schmetzer and Medenbach, 1988). It is important to mention that diaspore also forms as an independent mineral in several deposits around the world, in particular as a minor to major constituent of bauxite ores.

Once this relationship is understood, it is easier to discuss the coexistence of both minerals in the rubies from Mong Hsu. In general, the different formation conditions of these two minerals do not typically allow for the mineral diaspore to exist while corundum is still growing, with diaspore having formed either prior to or simultaneously with corundum. As described above, it is easy to explain the presence of diaspore as a coating on the ruby crystals from Mong Hsu, as an alteration product due to corrosion of the corundum crystal in the presence of water

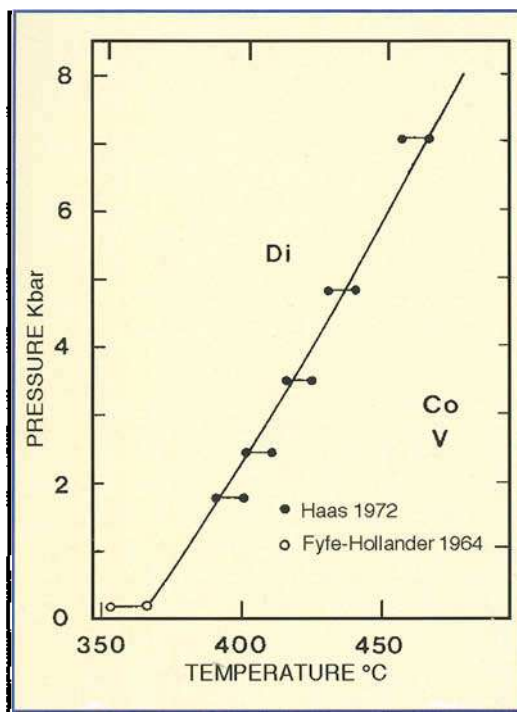


Fig. 9. The phase equilibrium between diaspore and corundum has been a topic studied in great detail by past researchers. This is a reversible reaction which is commonly encountered in nature. The phase trajectory indicated here, is shown as an example, in the presence of a pure water solution, between the temperatures of 350°C to 500°C and pressures of 0 to 8 kilobars. However, more complex fluids are typically encountered in nature. The relative concentrations of these mixtures will have a significant effect on the position of the phase boundary. Di = diaspore, Co = corundum and V = water vapour (H_2O) (reprinted from Perkins *et al.*, 1979)

at pressures and temperatures within the diaspore stability field. It is also possible to explain the presence of diaspore in veins penetrating cracks and narrow channels within the corundum crystal, by this same process (similar to the occurrence described by Schmetzer, 1987).

However, diaspore was additionally identified intergrown within the corundum 'host' as an inclusion at a presumably tiny microscopic to sub-microscopic level (i.e. visible as tiny pinpoint inclusions or

not visible, with a standard gemmological microscope). This can be explained by a growth in which a fluid is trapped within the corundum in the form of tiny inclusions. It has not been possible yet to determine whether the fluids were Al-rich (for an essentially primary formation of diaspore) or were a mixture containing water (for an essentially secondary formation of diaspore). Tiny particles of diaspore may form through a reaction taking place internally as the corundum crystal enters a new pressure/temperature environment within the stability field of diaspore. This reaction occurring in Mong Hsu is similar to that described by Schmetzer and Medenbach (1988) for sapphires but with a much smaller particle size and a higher concentration of diaspore. Polarized infrared spectroscopy of non-heated samples indicate a preferred orientation of diaspore within the corundum 'host'. Although a detailed discussion of this pleochroic effect is outside the scope of this paper, the degree of pleochroism signifies an epitaxial growth of diaspore and the 'host' corundum crystal.

The presence of diaspore in association with the corundum crystals of Mong Hsu plays a vital role in the subsequent presence of OH groups in the corundum structure resulting from heat treatment.

Discussion of heat-treated Mong Hsu rubies

In this section a brief description is given of the changes which occur in diaspore upon exposure to heat. In 1801 R.J. Haüy first described the mineral which he named diaspore, taken from the Greek word for 'scatter', because the mineral shattered when heated (Wefers and Bell, 1972). When exposed to temperatures and pressures above its stability field, diaspore will go through an alteration process, as explained in the previous section. This is a reactionary process where the temperature

plays a more critical role than the pressure (Weber, 1966). The mineral decomposition which takes place is a process of 'dehydration' (dehydration) producing the alpha form of aluminium oxide (corundum), while releasing the hydroxyl components in the form of water vapour. When the process is complete, the original diaspora crystal can lose up to 15 per cent of its original weight (see for example Fyfe and Hollander, 1964; Wefers and Bell, 1972). The resulting contraction of the remaining crystalline material causes cracks to develop and is responsible for the shattering of the specimens described by Haüy.

As is common practice with rubies from virtually all sources around the world, the rubies from Mong Hsu are typically heat treated. This is performed in order to remove the blue to violet colour zones as well as improve the apparent clarity. For non-heat-treated Mong Hsu rubies which possess inclusions of diaspora, this can be considered as a strong indication for the presence of structural OH groups after heat treatment. When the diaspora has access to the atmosphere (such as is the case when present as a coating on the corundum's surface or areas of the veins in close proximity to the surface), the excess atoms of hydrogen and oxygen released during the alteration process, form a water vapour (H₂O) which will enter the atmosphere. However, for the deeper recesses of the veins which penetrate the corundum crystals, as well as the inclusions of diaspora within the corundum crystals, there is no such avenue of direct escape for these molecules into the atmosphere and so it is considered that a slightly different alteration process takes place. Internally, diaspora particles alter to aluminium-oxide (corundum) and hydrogen is bonded within the corundum structure forming OH groups. In samples tested in this study, the concentration of structural OH bonding is apparently defined by the amount of diaspora present within the crystal prior to

heat treatment (in pure O₂).

The highly pleochroic nature of the OH groups measured in the heat-treated samples and the presence of OH groups in transparent areas of these crystals, supports the conclusion of not only a formation of OH groups within the newly formed aluminium-oxide particles, but also, and more intriguingly, an assimilation into structurally bonded sites within the surrounding 'host' ruby. The diffusion of hydrogen into the structure with the subsequent building of OH groups, during heat treatment experiments with both natural and synthetic corundums has been demonstrated by Eigenmann and Günthard, 1971; Eigenmann *et al.*, 1972; Moon and Phillips, 1994. OH groups in natural and synthetic corundum have been attributed to structural bonds occurring with various trace elements, such as Ti, V or Fe (Eigenmann and Günthard, 1971; Eigenmann *et al.*, 1972; Volynets *et al.*, 1972, 1974; Moon and Phillips, 1994; Häger and Greiff, 1994; also refer to the panel on pages 326-8). The rubies from Mong Hsu are evidently suitable for the transition of the aluminium hydroxide phase to structural OH bonding. The cause for this may be found in their major to trace element chemical composition. This is a unique source of corundum, where the rubies commonly possess high trace element concentrations of chromium, titanium and potentially vanadium, while iron is typically incorporated in only negligible amounts (Smith and Surdez, 1994).

An additional point of interest for gemmologists and people within the gemstone trade who are familiar with the rubies from Mong Hsu, has been the nature of the clouds which form during the heat treatment of the rubies from this source. From this work it seems likely that within the corundum crystals, concentrations of diaspora particles alter during exposure to elevated temperatures and form tiny whitish particles of aluminium-oxide, which in high concentrations, scatter the

light to cause the appearance of the clouds. Similarly, it has been noted in rubies from the Morogoro area, Tanzania, that planar lamellae of AlOOH (both diaspore and boehmite) became translucent and whitish in appearance during heat treatment (Dr K. Schmetzer pers. comm., 1994).

Conclusion

The rubies from Mong Hsu are a new source of corundum which is intriguing for several reasons. One such area of interest has involved the infrared spectrum. Although corundum is a typically anhydrous mineral, these rubies commonly possess absorption features in the mid-infrared region of the spectrum. Two distinctly different types of mid-infrared absorption spectra were distinguished: the non-heat-treated Mong Hsu rubies were found to possess associations of the aluminium oxyhydroxide diaspore by the presence of their OH bending and stretching frequencies in the region of the spectrum from 1900 to 3400 cm^{-1} ; and the heat-treated Mong Hsu rubies typically possessed absorption features from 3100 to 3600 cm^{-1} , related to structural OH groups bonded within the corundum structure.

Diaspore was found with the ruby crystals from Mong Hsu in a variety of associations including coatings on the exterior surfaces, irregular veins penetrating the ruby crystals and as tiny included crystals. Microscopic to sub-microscopic diaspore inclusions intergrown within the corundum crystals were also indicated by the mid-infrared spectra of samples, when no visible coatings, twin lamellae, veins or sizeable mineral inclusions were present.

The bonding of structural OH is occurring as a charge compensation mechanism for various transition elements present in trace quantities in the chemical make-up of the rubies from Mong Hsu. The building of structurally bonded OH groups in corundum, as a direct result of the dehydroxylation (dehydration) of diaspore inclusions was identified and subsequently

demonstrated through heat-treatment experiments for the first time in the gemmological literature. Recent work with other minerals (i.e. fluorite) lends support to this process for the formation of structurally bonded OH groups (Götzinger, 1992).

In this study of Mong Hsu rubies, the mid-infrared absorption related to diaspore has only been recorded in non-heat-treated samples, while the absorption features related to structural OH groups have only been recorded in heat-treated samples. This is also true for Mong Hsu ruby samples which have only received a slight degree of heat treatment, still possessing a pale blue to violet colour zone. This point could be of importance, because, although the blue to violet colour zones may be removed with temperatures as low as 900°C (R.E. Kane pers. comm., 1993), diaspore will go through the dehydration process at temperatures well below this (see for example Haas, 1972; Perkins *et al.*, 1979). Therefore, it would be incorrect to assume that a Mong Hsu ruby crystal is not heat treated simply because a pale blue to violet core remains; an infrared analysis may reveal that a low-temperature heat treatment has been performed.

It should be emphasized that although a large percentage of rubies from Mong Hsu (roughly 75 per cent of a random selection) possess diaspore or structural OH, the mere presence of these mid-infrared spectral features should not be used to indicate the place of origin of a particular stone.

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References

- Belt, R.F., 1967. Hydrothermal ruby: infrared spectra and X-ray topography. *Journal of Applied Physics*, **38** (6), 2688-9
- Beran, A., 1991. Trace hydrogen in Verneuil-grown corundum and its colour varieties - an IR spectroscopic study. *European Journal of Mineralogy*, **3**, 971-5
- Clark, C., 1993. Thai cooking class with chef Kwangmuang 'Gow' Bumrungrapanicharwom. *JewelSiam*, **4** (5), 57
- Deer, W.A., Howie, R.A. and Zussman, J., 1993. *An introduction to the rock forming minerals*, 2nd edition. Longman Scientific and Technical, England
- Eigenmann, K., and Günthard, Hs.H., 1971. Hydrogen incorporation in doped α -Al₂O₃ by high temperature redox reactions. *Chemical Physics Letters*, **12** (1), 12-15
- Eigenmann, K., and Günthard, Hs.H., 1972. Valence state reactions and biparticle formation of Fe and Ti doped sapphire. *Chemical Physics Letters*, **13** (1), 58-61
- Eigenmann, K., Kurtz, K. and Günthard, Hs.H., 1972. Solid state reactions and defects in doped Verneuil sapphires. *Helvetica Physica Acta*, **45**, 452-80
- Farmer, V.C., 1974. *The infrared spectra of minerals*. Mineralogical Society Monograph 4, London
- Frederickson, L.D., Jr., 1954. Characterization of hydrated aluminas by infrared spectroscopy. *Analytical Chemistry*, **26** (12), 1883-5
- Fritsch E., and Rossman, G.R., 1990. New technologies of the 1980's: their impact on gemology. *Gems & Gemology*, **26** (1), 64-75
- Fritsch E., and Stockton C.M., 1987. Infrared spectroscopy in gem identification. *Gems & Gemology*, **23** (1), 18-26
- Fyfe, W.S., and Hollander, M.A., 1964. Equilibrium dehydration of diaspore at low temperatures, *American Journal of Science*, **262**, 709-12
- Götzinger, M.A., 1992. Einschlußuntersuchungen mittels Infrarot-Spektroskopie - Methodik und Anwendung. *Neues Jahrbuch Miner. Abh.*, **165** (1), 97-110
- Haas, H., 1972. Diaspore-corundum equilibrium determined by epitaxial of diaspore on corundum. *American Mineralogist*, **57**, 1375-85
- Häger, T., and Greiff, S.K., 1994. (A study of hydrous components in corundum. Submitted for publication)
- Henn, U., and Bank, H., 1993. Neues Rubinvorkommen in Myanmar (Burma). *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **42** (2/3), 63-5
- Hlaing, U.T., 1991. A new Myanmar ruby deposit. *Australian Gemmologist*, **17** (12), 509-10
- Hlaing, U.T., 1993. Mong Hsu update. *Australian Gemmologist*, **18** (5), 157-9
- Hlaing, U.T., 1994. A trip to Mong Hsu. *JewelSiam*, **5** (1), 54-7
- Kammerling, R.C., Scarratt, K., Bosshart, G., Jobbins, E.A., Kane, R.E., Gübelin, E.J., and Levinson, A.A., 1994. Myanmar and its gems - an update. *Journal of Gemmology*, **24** (1), 3-40
- Kenngott, A., 1866. *Die Minerale der Schweiz*. Leipzig
- Klein, C., and Hurlbut, C.S., 1985. *Manual of mineralogy*. 20th Edn. John Wiley and Sons, Inc., Canada
- Laughter, T., 1993a. The Mong Hsu mix-up. *JewelSiam*, **4** (5), 34-7
- Laughter, T., 1993b. How do you do? I'm from Mong Hsu. *JewelSiam*, **4** (5), 38-41
- Lind, T., and Schmetzer, K., 1983. A method for measuring the infrared spectra of faceted gems such as natural and synthetic amethysts. *Journal of Gemmology*, **18** (5), 411-20
- Martin, R.F., and Donnay, G., 1972. Hydroxyl in the mantle. *American Mineralogist*, **57**, 554-70
- Martin, F., Mérigoux, H., and Zecchini, P., 1989. Reflectance infrared spectroscopy in gemology. *Gems & Gemology*, **25** (4), 226-31
- Moon, A.R., and Phillips, M.R., 1994. Defect clustering and colour in Fe, Ti: α -Al₂O₃. *J. Am. Ceram. Soc.*, **77** (2), 356-67
- Nassau, K., 1980. *Gems Made by Man*. Chilton Book Company, Radnor, Pennsylvania, USA
- Peretti, A., 1993. Foreign substances in Mong Hsu rubies. *JewelSiam*, **4** (5), 42
- Peretti, A., and Smith, C.P., 1993. A new type of synthetic ruby on the market: offered as hydrothermal synthetic rubies from Novosibirsk. *Australian Gemmologist*, **18** (5), 149-56
- Peretti, A., and Smith, C.P., 1994. Letter to the editor. *Journal of Gemmology*, **24** (1), 61-3
- Perkins, D. III, Essene, E.J., Westrum, E.F. Jr., and Wall, V.J., 1979. New thermodynamic data for diaspore and their application to the system Al₂O₃-SiO₂-H₂O. *American Mineralogist*, **64**, 1080-90
- Rossmann, G.R., 1988. Vibrational spectroscopy of hydrous components. *Reviews in Mineralogy*, **18**, 193-206
- Rossmann, G.R., and Smyth, J.R., 1990. Hydroxyl contents of accessory minerals in mantle eclogites and related rocks. *American Mineralogist*, **75**, 775-80
- Sahama, T.G., Lehtinen, M., and Rehtijärvi, P., 1973. Natural boehmite single crystals from Ceylon. *Contr. Mineral. and Petrol.*, **39**, 171-4
- Schmetzer, K., 1987. Lamellare Einschaltungen von Diaspor in Korund. *Der Aufschluss*, **38**(3), 335-7
- Schmetzer, K., 1989. Types of water in natural and synthetic emerald. *N. Jb. Miner. Abh.*, (1), 15-26
- Schmetzer, K., and Kiefert, L., 1990. Water in beryl - a contribution to the separability of natural and synthetic emeralds by infrared spectroscopy. *Journal of Gemmology*, **22** (4), 215-23
- Schmetzer, K., and Medenbach, O., 1988. Examination of three-phase inclusions in colorless, yellow and blue sapphires from Sri Lanka. *Gems & Gemology*, **24** (2), 107-11
- Smith, C.P., and Surdez, N., 1994. The Mong Hsu ruby: a new type of Burmese ruby. *JewelSiam*, **4** (6), 82-98
- Smith, C.P., Kammerling, R.C., Scarratt, K.V., An, N.X., Keller, A.S., and Repetto, S., 1994. (Sapphires from southern Vietnam. Submitted for publication.)
- Suhner, B., 1979. Infrarot-Spektren in der Gemmologie. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **28** (2), 55-68
- Suhner, B., 1984. Infrarot-Spektren von Mineralien. Doctoral Thesis, Philosophisch-Naturwissenschaftliche Fakultät der Universität Basel

Volynets, F.K., Vorob'ev, V.G., and Sidorova, E.A., 1972. Infrared absorption bands in corundum crystals. *Journal of Applied Spectroscopy*, 10, pp 665-7. Translated from *Zhurnal Prikladnoi Spektroskopii* 1969, 10 (6), 981-4

Volynets, F.K., Sidorova, E.A., and Stsepuro, N.A., 1974. OH-groups in corundum crystals which were grown with the Verneille technique. *Journal of Applied Spectroscopy*, 17, pp 1626-8. Translated from *Zhurnal Prikladnoi Spektroskopii* 1972, 17(6), 1088-91

Weber, J.N., 1966. Dehydration of diaspore at water pressures from 15 to 15,000 psi. *American Mineralogist*, 51, 235-8

Wefers, K., and Bell, G.M., 1972. *Oxides and Hydroxides of Aluminium*. Technical Paper No. 19, Alcoa Research Laboratories, USA

White, J.S., 1979. Boehmite exsolution in corundum. *American Mineralogist*, 64, 485-91

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The story of the Sri Lankan pearl

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Abstract

Sri Lankan pearling has had a history of over two millennia, though it is no longer commercially viable. In addition to their intrinsic value, pearls were considered auspicious objects in ancient and medieval Sri Lanka. Hence, kings gave pearls great importance. When Portugal, the Netherlands and Britain, successively became paramount powers in Sri Lanka, the auspicious qualities of pearls declined in favour of their economic value which feature had always been dominant in international trade. Pearls were classified according to their size, shape and purity. The failure of the pearl industry in Sri Lanka is due to well-meaning attempts of Government to rationalize and place it on a scientific basis in the first part of the twentieth century.

Introduction

Today the pearls of Sri Lanka are a part of history, as pearling no longer takes place.¹ However, Sri Lankan pearls surface occasionally when old collections are dispersed or when new settings replace older ones or heirlooms go on exhibition. Yet, for a thousand years and more, the Sri Lankan pearl was well-known and much in demand. Referring to the period 500BC to AD400, usually known as 'the civilization of the early Anuradhapura period', the standard history of Sri Lanka says,

'The pearls found on the north-western coast, the chanks* found in the sea further north and the precious stones which were the products of the southern regions of the Island attracted merchants to Ceylon from ancient times. The pearls of Ceylon are referred to as kauleya in an ancient Sanskrit text and are said to have been produced in a river near the village *Mayura (Modaragam)*!²

These pearls would have been riverine pearls not considered in the trade as equivalent to pelagic (sea) pearls either in size or colour. They fetched lower prices.

During the late Anuradhapura period, usually the years between circa AD400 and AD1000, the Sinhalese kings, who ruled Ceylon, sent embassies to China between the years 405 and 762. Trade was one of its purposes. Among the gifts of the Sinhalese kings to the Chinese Emperors were pearls, filigreed gold, gems and ivory.³ By that time, the skill of Ceylonese craftsmen was well-known to Asia and the world beyond - the Chinese, the Indians and the Japanese of the early Middle Ages recognized and valued their fine craftsmanship. Admiring comments, for instance, are found in Chinese works such as *Kao-Seng-Chuan*, *Liang-Shu*, *Kuang-Ming-Ming-Shih*.⁴ Since pearls formed an essential item of the clothes of royalty and the aristocracy, pearl enhancement and adornment in clothes were established technologies.

* A large kind of shell, *Tarbinella rapa*, prized by the Hindus, found especially in the Gulf of Mannar.

Incidentally, the usual mode of transporting pearls at that time was to ensconce them in very fine fabrics and carry them on the person.

Status and role of the classical Ceylon pearl

Apart from its intrinsic value, the pearl has been admired in medieval Ceylon and even today. For instance, some place-names in Sri Lanka have 'pearl' in their names.⁵ 'Muthu', the term for pearl in Sinhala and Tamil, the indigenous languages of Sri Lanka, also means 'acme' or 'excellence' in these languages.⁶ Many members of the Sinhala and Tamil communities in Sri Lanka have 'muthu' prefixed to their names. This term also finds its place in the Hindu pantheon.⁷

The pearl is also a symbol of good luck in classical Ceylon. That perhaps is why we get so many references to pearls in ancient and medieval literature of Sinhala and Tamil. Like the lotus and the peacock, but at a higher level, the pearl is or was, an auspicious object.

Ancient Ceylonese chronicles associated auspicious events such as the coronation of kings or the births of princes with the 'serendipitous' finding of pearls. For instance, the 'Mahavamsa' ('the Great Chronicle'), a work in the Pali language written by the Buddhist monk Mahanama in the sixth century and which tells the history of Sri Lanka from 483BC onwards, records such events. Describing the coronation (really the consecration) of King Devanampiya Tissa (247-207BC), an exact contemporary of the Buddhist Emperor Asoka of India, the Mahavamsa records,

'Pearls of the eight kinds, namely horse-pearl, elephant-pearl, wagon-pearl, myrobalan-pearl, bracelet-pearl, ring-pearl, kakuda fruit-pearl and common (pearls) came forth out of the ocean and lay upon the shore in heaps.'⁸

Further, detailing the desire of King

Duttha Gamini (101-77BC) to build a 'thupa' to house the relics of the Buddha, the Mahavamsa writes,

'In a westerly direction from the city, at a distance of five "yojanas", near the landing-place Uruvela, pearls in size like to great myrobalan fruits mingled with coral, six waggon-loads, came forth to the dry land. Fishermen who saw them piled them together in a heap and taking the pearls together with coral in a vessel they went to the king and told him of this matter.'⁹

From a review of the detailed descriptions of pearls in the ancient chronicles, it is possible to sketch in some of the principles of pearl classification in classical (i.e. medieval) Ceylon. The classification was based mainly on size and, often but not always, colour gradations.

Basic to the classification was the definition of a pearl of the best kind in Sanskrit literature.¹⁰ They usually call those pearls 'muthu' (first class) and see them as perfectly rounded globes of dazzling white colour. That tradition came down to Sri Lanka and entered the lexicons and the sauri of the Sinhala language.¹¹ The Tamil language, working on a tradition from South India equally well-known for its pearls, calls them 'aani-muthu' (literally 'nail or tap-root pearl'). Such splendid pearls were rare, however.

The normal pearl was called the common pearl, that is from the point of view of poets who habitually lived in the world of the imagination. Human biology forms a useful yard-stick in the taxonomy of the pearl in classical Ceylon, for several parts of the body were expressed in 'pearly' terms. In those days a Beauty Queen, or any excellence in feminine shapeliness, was called 'pancha kalyani' (a Sanskrit word meaning 'the five excellences'). These were long, lustrous, dark hair reaching down to the hips; reddish, perfectly shaped lips; soft skin; youth; and 'white, regular teeth'.¹² Since very small, white, regular teeth were compared to grains of

rice, it is fair to conclude that the modal pearl in the market of ancient and medieval Ceylon approximated to the size of female, regular teeth, white and sparkling.¹³ However, very small pearls are not impressive by themselves in a tropical climate; even 'en pave', they tend to look 'shabby-genteel'. Incidentally, the most expensive rice in Sri Lanka is called 'muthu samba' (pearl collection).

Ancient and medieval Ceylonese jewellers and goldsmiths (and the upper-class and upper-caste elite who were their regular and often their only customers) divided other pearls into regular ones for ornaments such as ring-pearls and bracelet-pearls. The biggest, most lustrous and (almost) perfectly shaped pearls were used for necklaces (specially for royals) and diadems and plate-crowns.

Two ornaments need special mention. One was the 'sacred' royal necklace composed of the largest available pearls of very good quality, 'corded' on gold thread, in descending order of size with the largest pearl in the centre as the pendant. The antipodal pearl of the pendant was the next largest pearl in the necklace. This necklace was 'sacred' in the sense that it was the insignia or the most important part of it and could only be used by the sovereign.¹⁴ (It also came in handy when a long-lost heir to the throne had to prove his legitimacy.)

Another important ornament usually worn by kings was the golden breast-plate which covered the upper part of the chest. Buffered on a thick plate of gold and encrusted with corundums of different colours and with spinels, it was as much a protective device as an ornament. Pearls formed a part of this ornament mainly for the purpose of setting off the splendour of the other gems.

Misshaped pearls of limited size and small pearls of dull colour were often used as leg and foot ornaments by upper-class (and so mainly upper-caste) women. These pearls were enclosed in the hollow

tubes of gold anklets. These tinkled as the women walked and at least on one occasion were the source of great tragedy and a great literary masterpiece.¹⁵ Irregular pearls were generally large and human ingenuity found for them similarities with horses, waggons and elephants in their suggestive shapes. These pelagic elephant pearls should not be confused with real elephant pearl, a roundish encrustation rarely found in the tusks of elephants.¹⁶ Its value is purely exotic.

The myrobalan-pearl is of more interest. It is frequently mentioned in the ancient *Chronicles*. For instance, the Mahavamsa recounting the building of the relic chamber of the 'thupa' as directed by king Duttha Gamini, said that the platform of the Bodhi tree was paved with great myrobalan-pearls.¹⁷ The myrobalan is a fruit, used extensively in Sinhala traditional medicine and is one of the three 'panacea' herbs.¹⁸ It is an auspicious article and a recognized royal gift in ancient times.¹⁹

The sanctity of myrobalan attached quite naturally to the pearls of that name and shape. The myrobalan pearl or 'pearl the size of Amalka fruit' is a large pearl, often the size of three ordinary pearls. Some ancient and medieval poets in the East, with poetic licence, describe these as pearls 'exceeding the size of ducks' eggs'. These descriptions seem to have got into several stories in the Arabian Nights as well.

The median myrobalan-pearl was 'yellowish' and imperfectly rounded, like those of the South Indian coast. A perfectly-shaped myrobalan pearl, with good texture, was rare. A string of such pearls cost much. Even in the second century BC, according to the Mahavamsa, a string was worth nine-hundred-thousand pieces of money.²⁰ Even assuming that the chronicler was referring to the copper coin rather than the silver coin in use at that time, the price was high enough.²¹ These strings of pearls also had another royal purpose. A king or some other royal taking refuge in

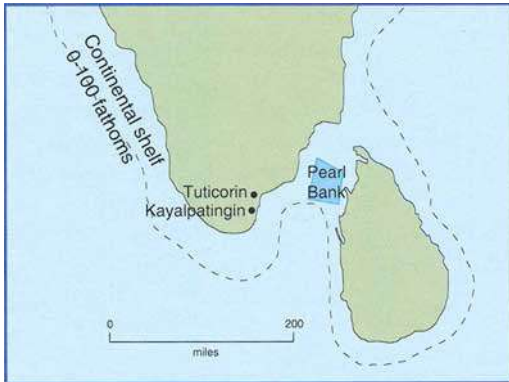


Fig. 1. Continental Shelf between S. India and Sri Lanka: pearling locations

another king's territory could always placate his host with a few strings of pearls.

The organization of pearling in classical Ceylon

Pearling differs from gemming of terrestrial stones in four ways. Pearling is confined to some specific off-shore sites; pearling takes place at irregular intervals and sometimes, such as currently in Sri Lanka, ceases altogether; there are seasonal variations in the supply and quality of pearls; and pearl-diving is a hazardous activity.

In classical Ceylon, pearls had some in-built advantages. Only the divers and pearl merchants came into contact with the pearl in its original condition. From them, by sale, gift or transfer, it passed into the hands of the royalty, the aristocracy and the rich, all of them belonging to the upper-castes. Naturally, its use was limited to these people. Sumptuary rules denied the use of the pearl to the ordinary man, assuming that he ever came into contact with one. While it was possible for the ordinary man to come across precious stones by chance, that did not happen in the case of pearls. Such a chance 'discoverer' could secrete the gem - even bury it - hoping for better times. Such entombment of pearls in a tropical country like Sri Lanka, would dry them out to the equiva-

lent of fish-eyes.

The traditional people involved in the pearling industry could be classified as follows:

- a) the owners and members of the fishing fleet;
- b) the pearl divers - local and foreign;
- c) the officers of the king, whose duty was to delineate, organize and distribute the shares of the pearl oysters and be in charge of the administration and security of the area. Also, they would take charge of the king's share;
- d) the king's administrator under whom the pearling territory came;
- e) the pearl merchant at the spot;
- f) the final pearl merchant who exported the pearls.

Incidentally, the pearl divers received the least reward and the final pearl merchant the highest.

Pearling was carried out on the north-west part of the continental shelf (Figure 1), (that is, where the depth of the sea averages a hundred fathoms or less) which surrounds Sri Lanka and South India.²² The continental shelf fans out from Cape Comorin (India) and surrounds Sri Lanka as a fairly narrow strip. The area was usually called the Pearl Banks of Sri Lanka (Ceylon), currently known as the Gulf of Mannar and Puttalam (i.e. to the north-west of Sri Lanka).²³

The shallow waters and the consequent high solar heating seem to have brought about a great increase in marine microflora and micro-fauna which benefited the pearl-oyster. While, the pearl-oyster was pervasive throughout this marine zone, there were also specific concentrations. The oysters were more abundant on rocky 'paars' in five to six fathoms.²⁴ Apparently the food-chain of the waters, in which the oyster was a part, fluctuated throughout the years. And this meant that pearling could take place only when the oysters were plentiful. The pearl-oyster (*Pinctada*) 'which is more nearly related to the mussel than to the edible oyster' is (or really was)

an erratic breeder of pearls, as Leonard Woolf, colonial administrator in Ceylon in 1907 and later a writer and publicist, noted.²⁵

When the seat of the Sinhala kings of Ceylon was in Anuradhapura between 555BC and AD1000, the government had close control of pearling (Figure 2). This was so because the pearl banks were only 60 miles north-west of Anuradhapura. However, the incursions of invaders from South India forced the Sinhala kings to shift their capital away from the north. Thus in medieval Ceylon the capital shifted in turn to Pollanaruwa (25 miles south of Anuradhapura), Kurunegala (40 miles south of Anuradhapura), Gampola (50 miles south of Anuradhapura) and Kandy (close to Gampola), the last three being in fairly hilly areas. At each shift of the capital, the central authority moved further away from the pearl banks.

Thus, as time went on, more intermediaries were interposed between the pearl-divers and the royal authority.

It was in exceptional circumstances, if ever, that pearl-oysters were cast on the shore. Hence, government had to organize or let others organize the pearling. The medieval governments of Sri Lanka, constrained by considerations of distance, preferred to do the latter, regulating those who actually organized the pearling. In the later Anuradhapura period, state officials called 'danda-nayaka' were appointed and established near pearl banks with civil powers of administration as well as with coercive authority, as their title of office 'Masters of Punishment' indicates. This was intended to be a corrective to the tendency of some divers or pearl extractors to hide or secrete some very large pearls.

In a later period, largely owing to the strength and dynamism of King Parakrama Bahu I (AD1153-86), pearling as well as terrestrial gem development came under a royal official close to the King. His official title was 'antaranga-dhura' (confidential secretary or head of secret service).²⁶ This

official had his servants all over the environs of the pearl banks and so could have a rough tally of the number and value of the pearls after each pearling. Parakrama Bahu I was a worldly-wise king and realized that pearls not under his control were against his interests.

Whatever might have been the chain of control over pearling, the most important aspect of Sri Lankan pearling was its export significance. The ancient and medieval trade routes which carried Sri Lankan pearls to Europe, the Middle East and the Far East were frequently changing, subject as they were to natural obstacles such as floods, pestilence and political problems like the oppression of kings and princes. Still, some traditional trade routes can be traced. There was the overland route which, though encroached upon by the sea route from Europe to the lands of the Indian Ocean later, continued to be significant. This route connected Mannar or Mantai, the township on the Mannar mainland, through the narrow sea channel between India and Sri Lanka, to the Indian sub-continent.

The overland route pushed west through Kerala, Gujerat (both districts and now



Fig. 2. Sri Lanka: pearling location and principle merchandising centres (towns).

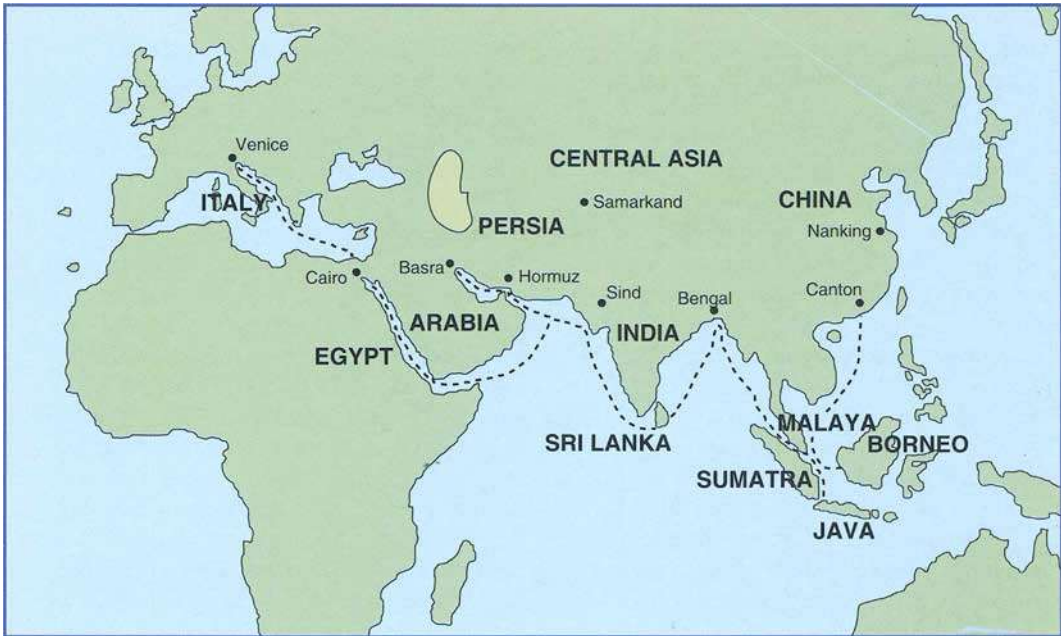


Fig. 3. Pearl route up to *circa* 1500

states of India), Sind (now in Pakistan) and continued west to Persia, Iraq and into Turkey, and then either joined the sea route to Venice and thus into Europe, or it branched to the east through Central Asia and became part of the Silk Route to China. Another branch of the overland route moved east from Kerala and joined up to Bengal and then again to a branch of the Silk Route to China. However, there was great scope for the sale of Ceylon pearls among the kings and rulers of principalities in India itself, theirs being an insatiable demand. Pearls, however, were not highest among gems from the Chinese point of view - they prized jade above all. At any rate, the overland route was not disadvantageous to the pearl trade. Pearls were easily concealable on the person and traders could sell stock either to the other merchants in the locality or to the potentates of the area.

The importance of pearls to the sea route linking Europe to the countries of the Indian Ocean, which Barolomea Dias and Vasco Da Gama pioneered following Arab

navigational procedures, only came as one among the luxury articles (with high value/weight differential) including cinnamon, gems, cloves and pepper which European adventurers and merchants either purchased or commandeered from the indigenes of Asia.

In the early part of the Middle Ages, the Arabs were perhaps central to the pearl trade in Ceylon and associated countries of the region. Mannar, the base of pearling operations, soon became an important junction for the Arab trade. A well-informed observer who was also Chief Justice of the Supreme Court of Ceylon in 1811 wrote of Mannar in the Middle Ages that it was the great emporium of all the trade of the Arabs (Muslims) with Egypt, Arabia, Persia, the coasts of Malabar on the west side and of Coromandel, the eastern shores of the Bay of Bengal, Mallaccas, Sumatra, Java, the Moluccas and China on the east.²⁷ The Mannar merchants obtained pearls from their agents at Cooderamale.²⁸ The majority of the pearl trade reached the Middle East, Europe and many Asian

countries through their hands.

Ibn Battuta, the Moroccan jurist and traveller who visited Sri Lanka after 1325, gives an insight into the nature of the pearl trade and administration of those days. Though Ibn Battuta was not a professional student of pearls or a jeweller, he had the practical knowledge of the cultivated man of his time. Speaking of the Prince who controlled the region in which pearling took place, he wrote,

'One day I went to him [the Prince] while there lay about him a large number of pearls which had been brought to him from the pearl fishery in his dominion. His employees were busy sorting out and classifying the best pearls from the rest. "Have you seen any pearl-fishery in the countries you come from?" he enquired of me. "Yes," said I, "I saw them in the islands of Qais and Kish, which belong to Ibn-us-Sawamli." "I have heard about," said he. Then he picked up a few pearls out of the lot and said, "Are the pearls in those islands like these?" "The pearls I saw," I replied, "were inferior to these." He was delighted at this and said, "These pearls are yours; do not be shy. You can demand of me whatever you desire."'

The translator notes that the islands of Qais and Kish later became the sites of Hormuz and Bandar Abbas.³⁰

The excerpt, perhaps, brings out the presence of the nagging anxiety of the rulers and pearl merchants of Ceylon that pearls from the Persian Gulf were frequently larger and more rounded than those from Ceylon. Some people believed that the tiny detritus which entered the pearl-oyster and caused the pearl to form, was more abrasive in the Gulf than in the waters off Mannar.

When the central authority of Ceylon was strong, the government share of pearling was dutifully forthcoming. Sometimes an energetic sub-king took the initiative. For instance, in the middle of the fifteenth century, when King Vikrama

Parakrama Bahu III was reigning in Gampola, he authorized the sub-king Alagakonnara III to regulate the foreign trade that was being carried out at Colombo, then (and now) the principal port of Sri Lanka.³¹ Alagakonnara was equally strict and unforgiving to his craft vassals. Hence, the pearl fishers of Chilaw, among purveyors of exotic products, delivered the government's share to the sub-king's palace.³²

When the central authority was weak, even merchants and adventurers from South India were not averse to interfering in the pearling in Sri Lanka. The *Rajavaliya* (meaning, in the Sinhala language, 'Dynastic History') is a chronicle written in the seventeenth century, and is of high historical authority. It says of an incident early in the sixteenth century:

'During the reign of Dharma Parakrama Bahu, a Moorish pirate, Kadiriya by name, coming from the seaport Kayala, landed at Chilaw, accompanied by a large body of Moors, for the purpose of forcibly fishing for pearls at Chilaw and capturing elephants. Dharma Prakrama Bahu sent for Prince Sakala kala walla, entrusted to him a large army and gave him permission to attack.'

From this excerpt, the following suppositions could be drawn. Kayala (today called Kayalpattinam) is a South Indian town in the Tinneveli district (of present-day Tamil Nadu), directly facing Mannar across the Gulf of Mannar. It was and is a town traditionally known for its expertise on pearl and terrestrial gems, having a solid body of pearl and gem merchants with a great deal of capital. That a body of merchants could mount an attack was an indication of their resources and resource. It was widely believed that the pearl merchants of Kayalpattinam amalgamated Ceylon pearls with South Indian ones and sold these off to the many princes and princelings of the Indian sub-continent. Incidentally, the exotically named Sakala

kala walla (it means 'an expert in all arts and sciences' in Sanskrit) stood up to his name and put down the Kayalpattinam incursion.

Ceylon pearling under the European Dispensation

Ceylon, or at least its littoral, came under European colonial powers from 1505 to 1948. The Portuguese ruled from 1505 to 1656 when they were replaced by the Dutch - really the VOC, the Dutch East Indies Company. In 1796 the VOC was replaced by conquest by another company - the British East Indies Company. The British Crown assumed responsibility in 1802 and by annexing the Kingdom of Kandy, the surviving indigenous monarchy in 1815 brought Ceylon under a single rule. Ceylon became independent in 1948.

The three colonial Powers looked upon pearling as sometimes lucrative but essentially an adventitious source. They preferred cinnamon, which had great demand in Europe. The Portuguese army which controlled the littoral and which was officered by a few hidalgos on a base of Portuguese landless labourers and lumpen-proletariat, did not have much expertise on pearls. Further, the frequent incursions into the Gulf of Mannar by the fleets of the Zamorin, the indigenous Prince of Calicut, often disrupted pearling. The Zamorin, of course, was a declared enemy of the Portuguese. The VOC, whose senior officials were styled 'over-merchants', 'merchants' and 'under-merchants' in Dutch, were more business-like. But they preferred to use Ceylon more as a transit station for cloves, pepper and other spices they garnered from the Dutch East Indies.

However, information of pearl and pearl trading in Ceylon during that period is available in the histories, the annals and diaries which European travellers to Ceylon wrote after their sojourn in that country. An important figure in this regard is Caesar Fredericke, the Venetian merchant-adventurer who visited Ceylon

after 1563. He has left a full account.

Caesar Fredericke noted that pearling in Ceylon was done in the sea between Cape Comorin (in India) and off Chilaw.³⁴ All the fishermen, that is those who plied the boats, were Christians (Roman Catholics) of the fisher caste and they paid dues to the King of Portugal and the Churches of the Friars of St Paul. The pearl-fishing boats were usually guarded by three or four fursts (i.e. lightly-armed sloops). Three or four fishing vessels, which he calls barks and 'are like to our little Pilot boates' go out to the sea and anchor. The depth of water in those parts is only fifteen to eighteen fathoms. There are seven or eight men in each barke and they comprise the entire crew involved in this operation.

Caesar Fredericke saw the actual pearling which he described. Each barke cast a rope with a big stone at its end into the sea. The diver descends into the sea along this rope. The diver has his ears and nose stopped and 'anointed with oil'. He has a basket about his neck or under his left arm. Within the limited time he is under water, he collects the oysters into the bag and tugs at the rope. He is pulled up and into the barke. In the evening, the barks sail back to the shore. Fredericke noted that each barke dumped its oysters into a heap, separated from the others. These heaps lie till the end of the fishing season when each crew opens its heap. Sometimes there are more pearls in one season and sometimes less. Caesar Fredericke, explained the matter of grading.

'There are certain experts in the pearls whom they call Chitini which set and make the price of pearls according to their carats, beauty and goodness, making four sorts of them. The first sort are the round pearls and they are called Aia of Portugal, because the Portuguese do buy them. The second sort which are not round, are called Aia of Bengal. The third sort which are not so good as the second, they call Aia of Canara, that is to say the Kingdom of Bezenegar. The fourth and the last sort which are the least and worst sort, are

called Aia of Cambaia. Thus the price being set, there are merchants of every country which are ready with their money in their hands, so that in a few days all is bought up at the prices set according to the goodness and carats of the pearles.³⁵

The grading of the pearls had the exotic Indian names because the merchants involved in pearling and substantive purchasers of pearls were Indian potentates.

The finest kind of pearls were so called because the Portuguese officers in control of the area of pearling had the pick of the best pearls. It is not clear how much of this went to the Royal Portuguese treasury maintained by the Captain-General, the head of the Portuguese establishment in Ceylon, and how much to private hands. The Bengala in the second variety probably refers to Bengala (Bengal in India), traditionally known for its high level of craftsmanship. The third sort are those named after 'Canara' or 'Bezeneger'.

These, presumably, stand for Kannada and Vijayanagar, respectively. The eponymous capital of the Vijayanagar empire, founded by the two brothers, Bukka and Harihara in 1336, was situated in the Deccan region of India and inhabited by people who spoke the Kannada (Canarese) language, one of the Dravidian group of languages which includes Tamil.³⁶ The Vijayanagar empire was famous for promotion of fine arts and a delight in jewellery.

Cambaia has the dubious honour of being named for the worst sort of pearls in Caesar Fredericke's estimation. It is presently called Diu and is in the Gulf of Cambay, about 150 miles north-west of Bombay. In Caesar Fredericke's time it was a small town, a place where Portuguese influence was felt.³⁷

In spite of the Indian 'naming of pearls', a correlation could be made between this classification and that of the medieval chroniclers of Sri Lanka. The Aia of Portugal is the first-class pearl or the 'animuthu' in Tamil. The Aia of Bengal is the

myrobalan-pearl. The Aia of Canara is the common-pearl. The Aia of Cambaia are those malformed pearls defying all classification.

Caesar Fredericke's Chitini, the experts who classified pearls, were obviously the present-day Chetty community, found in South India and Sri Lanka. They are a subgroup of the Vaisyas who are held to be the third group of the Indian caste-structure engaging themselves in agriculture, cattle-breeding and trade.³⁸ Sometimes called Nattu kottai Chetties in Tamil Nadu (South India), they were market-leaders in the import-export business, banking and gold, and the gemstones and pearl trade. They were businessmen of the utmost integrity. This is an essential requirement as the pearl-trade is largely carried out without recourse to legal documents. The actual crafts of the goldsmith, the silversmith and of pearl-enhancement jewellery, however, are practised by the caste-groups, called asari.³⁹

Caesar Fredericke was a well-informed observer. He himself says that he 'has sold rubies well there [in Sri Lanka] brought with [him] from Pegu'.⁴⁰ After Caesar Fredericke's time a large number of Aia of Cambai (Caesar Fredericke's term for Ceylon pearls) including the poor grades of bluish-greys went into South India. This was after the middle-1700s, when the colonial wars between Britain and France had pushed up a client-population of feudatories, called 'poligars'. When the British had settled the situation in their favour and had disbanded the levies of the poligars, forcing the poligars into simple land-ownerships as 'zamindars' and wealthy 'country gentlemen', these men took to conspicuous expenditure to keep up their status. And pearls were an important part of such aspirations.

Throughout the centuries, a large number of pearls from Ceylon went to the Middle East and not Europe. Some of these pearls were taken up by Arab traders who bought the oysters, either by them-

selves or through their agents. Another group of pearls were those bought by merchants of Indian towns such as Kayalpattinam and sold, together with those of South Indian pearls, to Middle East traders. The divers, a large number of whom were Arabs, took pearls from their share of the oysters to their native towns. (Since they knew the trade, they could get good prices.) For instance, during the pearling in Sri Lanka in 1906, which lasted from 20 February to 3 April, there were 4090 Arab divers from the Persian Gulf out of a total of 8667 divers.

A persistent feature of pearl-fishing is the hazardous nature of the occupation, and Caesar Fredericke's description of diving continued to be true all along. This lack of change was a result of several factors. First, governments did not see the point in rationalizing an uncertain trade. Secondly the pearl traders and middlemen did not care to add to their prime costs. This was understandable since the British Government insisted on dividing the whole harvest of oysters into three equal parts, taking two parts which it subsequently auctioned off at the site.

Thirdly, the strongest opposition to any reform of diving came from the divers themselves. Divers were hardy, whipcord-like individuals with ice-cold nerves and proud of their powers of endurance. James Steuart, Master Attendant during the first part of the nineteenth century and well-informed in matters of pearl-fishing, noted that the divers remained under water for only 53-57 seconds, if they were working at a depth of nine fathoms.⁴¹

During the nineteenth and twentieth centuries there was increasing centralization in the trade of pearls and the decreasing number of leaders in the trade became correspondingly more important. They became the ultimate possessors of all good-quality pearls resulting from Ceylon pearling. Questions of economics and geography determined this situation in the following way: outsiders lacked the exper-

tise and the ability to hold on to pearls for a long time. And further, every mile away from the pearling area added to the chances of the outsider being robbed or questioned about how he got the pearl. So most outsiders disposed of their finds as soon as they could, receiving only one to ten per cent of the actual value of the pearls.

The strangulation of the Ceylon pearl fishing

The end of the pearl fisheries in Ceylon was the result of apparently excellent motives. The Government of Ceylon, at that time under the *de facto* authority of the British Governor and subject ultimately to the Secretary of State for Colonies at Westminster, decided to apply science to this field of activity. The declared purpose was the development of the pearling area in the north-west of Ceylon,

'to make it a busy scene of scientific operation in pearl-fishery economy, to locate pearls in live oysters without opening them, and to induce those oysters which are barren, to produce pearls.'⁴²

Reviewing the official and private documents in this matter, four strands in the Government's thinking could be traced. First, there seemed to be a time correlation in the barren periods (i.e. when no pearling took place or when the 'harvest' was negligible). For instance, during the British period, after the pearl-fishing of 1815 there was a gap of 13 years which ended in 1827. There followed further gaps between 1837 and 1854, 1864 and 1873, and 1892 and 1902. 1903 signalled very successful pearl-fishing which in 1905 netted the Government a sum of Rs. 3,500,000 which would be an astronomical sum in today's money.

Secondly, these time gaps could be ascribed to biological and geo-thermal (really, marine-thermal) conditions such as the availability of nutrients to oysters, lack

or plenitude of predators and with this knowledge remedial action could be taken. Provision of salt-water lagoons appeared to be one solution.

Thirdly, there was a widely held belief that pearling in Ceylon was over-extended, that too many individuals were concerned with it, and that this had led to the subsequent pollution of the beaches and the surrounding area of the pearling zone. Fourthly, some rationalization should be introduced into pearling, an occupation which had been unchanged for upwards of two millennia.

Hence the Government of Ceylon wished to privatize pearling. A former Surveyor-General of Ceylon, an expert on geography and geographical systematics, wrote that in the early years of this century, the Government of Ceylon sold its monopoly of pearling in the Gulf of Mannar and Portugal Bay to the Ceylon Company of Pearl Fishers.⁴³ It was believed that the highest officers in the country took a part in the floating of the company and that two Americans, Mr John I. Solomon and Mr Dale, were the financiers. On the recommendation of James Hornell, the Government Marine Biologist, it was decided to appoint Louis Siedle, then a famous gemmologist, to 'pioneer the implementation of their plans'.⁴⁴

These plans were not successful and some thought that the main cause was the step which the company took of cleaning the fishery banks which 'resulted in the disturbance of the oysters'.⁴⁵ The Marine Biologist, it was reported, however, was of the view 'that the dearth of oysters is due to premature decay of oysters'.⁴⁶

The Pearl Fisheries of Sri Lanka never recovered from this project. Since pearl-fishing has taken place for two thousand years on the South Indian part of the Gulf of Mannar, it is fair to postulate that it was the cleansing efforts of the company that had upset permanently the ecology of the pearl banks of Mannar. (In Tuticorin, in the Chidambaran district of Tamil Nadu,

pearl fishing has been noticeably flourishing since 1955 and about 2000 persons are engaged in the industry.)⁴⁷

At a social level, the loss of the pearl industry in Sri Lanka did not seem to have had much impact on those who would normally buy and wear pearls. After the disappearance of the Kandyan kingdom in 1815, pearls as articles of ornamentation and ceremonial decoration of the elites, declined in importance. In modern times, the pearl has been an article of feminine wear. However, it does not go well with the sari, and most women in Sri Lanka wear the 'thali', the chunky gold necklace as a symbol of marriage. This obviates the wearing of a string of pearls about the neck.

Despite the low-profile of pearls in the jewellery of Sri Lanka and its tragic end as an industry, pearls in Sri Lanka have had 'a storied past undreamt in history'.⁴⁸

Notes

1. Sri Lanka, the island lying off the tip of South India, was known as Ceylon till 1972 when it became a republic. In this article, 'Ceylon' and 'Sri Lanka' are used according to context.
2. C.W. Nicholas and S. Paranavitana, *A concise history of Ceylon from the earliest times ... 1505* (Ceylon University Press, Colombo, 1961) p. 102. I have discussed relevant gemmological topics in M.M.M. Mahroof (a) 'The Muslim lapidary; some aspects of the gem folkways in Sri Lanka' *Journal of Gemmology* 1989, 21, 7, 405 (b) 'The Sri Lankan ruby; fact or fable' in *Journal of Gemmology* 1992, 23, 1, 20.
3. Nicholas and Paranavitana, *ibid.*, p. 164.
4. Sylvain Levi, 'Chino-Sinhalese Relations in the Early and Medieval Ages' tr. John M. Seneviratne in *Journal of the Royal Asiatic Society, Ceylon Branch* (JRASCB), Colombo (1915/1916) xxiv, 74.
5. 'Muthu' is the term for pearl in the Sinhala and Tamil languages which are indigenous to Sri Lanka. The thirteenth century Sinhala thesaurus, the *Amarakoshā Ven*. Meddepola Wimalajothi ed., Bastian & Co., Colombo 1934, gives the Sanskrit form 'mowkthikam' as equivalent to 'muthu' in Sanskrit (p. 149). This *Amarakoshā* is thought to be a particular revision or version of the work of the same name by the Sanskrit writer of the sixth century, Amarasinha.
6. For instance, 'muthu mandapaya' (in Sinhala) and 'muthu mandapam' (in Tamil) stand for 'grand palace'. 'Muthu Silavam' (NW coast of Sri Lanka) and 'Muthu Raja wela' (SW coast, close to Colombo) are among the 'pearly' geographical names.
7. 'Muthu Kumaran' (pearl prince) is one of the names of Skanda, the younger son of Siva in the Hindu pantheon.
8. Ven. Mahanama, *The Mahāvamsa or the Great Chronicle of Ceylon*, tr. and ed. Wilhelm Geiger and M.H. Bode.

- Government Information Department, Colombo. 1950 reprint of original 1912 edition, p. 78.
9. *Ibid.* p. 189. Uruvela was a port about forty miles away from Anuradhapura, the capital of ancient Ceylon.
 10. Kallidasa, one of the greatest of Sanskrit poets, lived in the fifth century. (All dates unmarked in this article are AD.)
 11. *Amarakoshu*², p. 149.
 12. R.L. Brohier, *Discovering Ceylon*, Lake House Investments, Colombo, 1973, p. 82.
 13. The rice grain averages one-seventeenth inch in width. Perhaps the 'pancha kalyani' tooth is twice that width.
 14. From the sixth century, 'ekavali' or string of pearls was one of the five items of the Sri Lankan royal insignia. (Nicholas and Paranavitana, p. 166).
 15. The 'Silappadikaram' (which means in Tamil 'the chronicle of the ankle'), a classic Tamil epic of the fourth century, is based on such an event. The hero is accused of stealing the queen's anklets, when he was really trying to sell his wife's anklets. The king in the story orders the hero killed. The hero's wife smashes her remaining anklet in the presence of the king. Sapphires in it leap out - the queen's anklets had pearls. The king dies in mortification, as does the queen. V. Cheivanayakam, *Tamil Itikiyya Varalaru* ('History of Tamil Literature'), Sri Lanka Achakam, Jaffna, Sri Lanka, 1965, ff. 66.
 16. There is a photograph of an elephant pearl (ivory pearl) with the caption 'the elephant pearls are more expensive than oyster-pearls and hence very highly prized in the East' in S.E.N. Nicholas *Commercial Ceylon*, Times of Ceylon, Colombo, 1933, p. 29.
 17. *Mahavamsa*³, p. 203.
 18. Myrobalan is called 'kadukkai' in Tamil, literally 'bitter fruit'. Tamil literary works, either in Sri Lanka or South India, never compared pearls with 'kadukkai'. This information came from Mr M.A. Othman of Schofield Place, Colombo, who specializes in the literature on medical herbs.
 19. *Mahavamsa*⁴, p. 80.
 20. *Mahavamsa*⁵, p. 203.
 21. Nicholas and Paranavitana², p. 102. H.W. Codrington, *Ceylon coins and currency*, Colombo Museum Series no. 3, Government Printer, Colombo 1924, *passim*.
 22. P.G. Cooray, *An introduction to the geology of Ceylon*, National Museums of Ceylon, Colombo 1967, p. 73.
 23. L.J.B. Turner (Superintendent of Census and Director of Statistics, Ceylon), *Handbook of commercial and general information for Ceylon*, Government Printer, Colombo 1922, p. 89.
 24. *Ibid.*
 25. Leonard Woolf, *Growing: an autobiography of the years 1904 to 1911*, Hogarth Press, London 1977, p. 86.
 26. Nicholas and Paranavitana², p. 250.
 27. Sir Alexander Johnston C], 'Letter to the Secretary ...' *Transactions of the Royal Asiatic Society of Gt. Britain*, 1827, i, ff. 537, reprinted in I.L.M. Abdul Aziz, *Ethnology ...*, MICH, Colombo, 1957 reprint, p. 57. Also, M.M.M. Mahroof and M. Azeez, *An ethnological survey of the Muslims of Sri Lanka*, Sir Razik Fareed Foundation, Colombo 1986, Chap I (by M. Azeez).
 28. *Ibid.*, Sir Alexander, Coodera maile is a town south of Mannar. It means in Tamil, 'horse mountain'.
 29. Mahdi Hussain, *The Rehla of Ibn Battuta (India, Maldiva Islands and Ceylon)* (translation and commentary), Orient Institute, Baroda, India, 1976, p. 218.
 30. See notes 3 and 4.
 31. Nicholas and Paranavitana², p. 299
 32. B. Gunasekera (ed.), *Rajavaliya, or A historical narrative of Sinhalese Kings ...*, Government Printer, Colombo 1900, p. 212. Chilaw is a port some forty miles north of Colombo; Wannu is north of Anuradhapura; Sabaragamuwa is a province east of Colombo.
 33. *Ibid.* The Rajavaliya is a sixteenth century work, in historical authority next to the *Mahavamsa*⁶.
 34. 'The voyage and travell of M. Caesar Fredericke, Marchant of Venice, into the East India and beyond the Indies ...' in Hakluyt's Voyages (with an introduction by John Masefield, Everyman's Library, Dent/Dutton, London, vol. iii, p. 224. Where necessary, the English spelling of the original has been modernized in this article.
 35. *Ibid.*
 36. Nicholas and Paranavitana², p. 308.
 37. Caesar Fredericke⁷, p. 205.
 38. Nicholas and Paranavitana², p. 36.
 39. Goldsmiths including pearl enhancers are called 'asar' in the Tamil language; meaning 'artificer'. They are called 'naide' in Sinhala caste-structure. See the two lists of caste-stratification in Ralph Pieris, *Sinhalese social organization; the Kandyan Period*, University Press, Colombo, 1956.
 40. Caesar Fredericke⁸, p. 227.
 41. Cited in R.L. Brohier⁹, p. 49.
 42. *Ibid.* p. 46.
 43. *Ibid.*
 44. *Ibid.*
 45. S.E.N. Nicholas¹⁰, p. 49.
 46. *Ibid.*
 47. L. Thamilvaanan, *Thamilaka Mavatta Nool Varisai; Chidambaranar Mavattam* (in Tamil) (District Gazeteers of Tamil Nadu Series: Chidambaram District), Manimekalai Publications, Madras, 1986, p. 68.
 48. The present writer is working on an extensive history of gems and gemcrafts in Sri Lanka from which the present article is an excerpt.

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Siberian sapropelic coal: a unique type of workable jet

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Abstract

The composition and workable properties of sapropelic coal from Eastern Siberia and referred to as 'jet', is discussed. Apart from Eastern Siberia, jet is found in other parts of the former USSR, in the Crimea, the Caucasus, Kamchatka, Sakhalin and Central Asia. Jet from the Caucasus, the Crimea and Eastern Siberia was used mainly for the manufacture of artifacts. In the 1930s, for about ten years, a jet industry existed in the USSR aimed at the production of consumer and industrial goods from Siberian sapropelic coal. Interest in certain types of jet for the manufacture of artifacts has now reawakened.

Introduction

In 1987 a book by Helen Muller entitled *Jet* was published by Butterworths¹ and was translated into Russian by the author. Muller collected information on jet from the UK, France, Spain, Germany and the USA but did not have access to information on Russian jet. This is the reason why the present author, a senior scientist of the Institute of Fossil Fuels, decided to study the history of jet working in the former USSR. In Moscow and Irkutsk a jet industry using the workable jet from deposits of Siberian sapropelic coal was organized, which operated for ten years. At other times jet-working centres existed in the Caucasus and the Crimea. The industry was engaged in the production of con-

sumer goods, industrial goods and jewellery.

Terminology

In 1934 the Russian petrologist Y. Zhemchuzhnikov wrote the following about jet:

Perhaps it is difficult to find another fossil fuel, which is associated with so many false and vague concepts as jet. Even the definitions of this 'mineral' in the various encyclopedias, reference books and handbooks are very different and often contradictory. The essential characteristics of this type of coal are hardly ever given. Therefore, this material under the name 'jet' (author: Siberian sapropelic coal), which is used in industry, has nothing in common with the jet known for many centuries in different countries.²

The Siberian sapropelic coal having the characteristics of workable jet, is basically different from true jet. Classical jet is a compact, hydrocarbon impregnated black wood (vitrain would be more precise petrologically) having a conchoidal fracture and an attractive lustre. It is easily worked and polished. These properties may be due to the bituminization of the original raw material.

True jet consists of carbonaceous fragments of the ancient conifer genus *Araucarioxylon* subjected to bituminization^{3,4}. The wood had been bituminized by the permeation of hydrocarbons. In the Siberian sapropelic coal referred to as 'jet', there are virtually no traces of any woody

structure and it consists entirely of components of sapropelic origin.

Sapropel is an unconsolidated mud or mire with the consistency of jelly and is composed of plant remains, chiefly algae, which have putrefied in anaerobic conditions on the beds of shallow lakes or seas. Sapropelic coal (or sapropelite) is a coal originating from these muds and includes the varieties cannel, boghead and torbanite. Among the vast deposits of sapropelic coal in eastern Siberia are the jet-sapropelites which differ from the coals in their compact texture, low ash content, conchoidal fracture, brownish colour and brown streak.

Some characteristics of Siberian jet or jet-sapropelite.

Pieces of Siberian jet had been found in the vicinity of Irkutsk for many years, and by the end of the nineteenth century several dozen tons had been taken to Irkutsk. Here the cathedral of the Virgin of Kazan was built, containing a remarkable icon. Its panels were decorated with jet and adorned with gold and silver. Carved ornamentations of jet embellished the interior and also some exterior parts of the cathedral. Skilful local craftsmen fashioned chibouks (long Turkish tobacco pipes), spoons and food bowls from jet, and the peasants took chips of jet and burnt them as substitutes for candles and kerosene lamps. The first deposit of workable sapropelic coal - Siberian jet - was discovered in the Irkutsk coal basin near the settlement of Matagan in 1931.

The 'jet' in the deposit rarely consisted of the finest material. There were significant components of sapropelic coals of different kinds, heterogeneous carbonaceous rocks, combustible shales, and bogheads of different ash contents, cleavages and densities. In a sizeable lump of good quality Matagan jet it was not possible to distinguish any signs of cleavage or any other break in its uniform structure.

The jet-bearing beds occurred in two

main horizons in the sedimentary succession - an upper and a lower. Both upper and lower jet-bearing beds consisted of sapropelic formations different in density and hardness and presented a gradual transition from a hard and compact mass to an evidently shaly structure. Jet suitable for working was excavated from the Matagan field and freed from adhering shaly material with an axe. The jet occurred in the form of plates, 20 to 25cm thick, up to 1m wide and 2m long. After some time, a dried slab of jet became so hard that it could not be cut with an axe, but only broken into irregular pieces displaying conchoidal fracture and a dull lustre.

The Siberian jet is generally a beautiful black and leaves not a black but light brown, almost yellow streak on a porcelain plate. In places pieces of blackish-brown and brown jets with spots have been found in the coal beds.

Siberian jet is characterized by a plasticity eminently suitable for working. Thin plates were easily folded. Such a plate when heated to 90-100°C was so soft, that under slight pressure it could be folded into a ring or turned into a spiral. Heated jet-sapropelite was very easily worked with various cutting, planing and drilling tools. The characteristic plasticity and elasticity were especially valued by the master craftsmen because they could cut and turn the finest sculptures and bas-reliefs from the heated jet, and their tools for such fine work were specially adapted for these properties.

Siberian jet appears to be resistant to air and water and was not affected by 50 per cent sodium hydroxide at room temperature, nor by 35 per cent hydrochloric acid at 80°C. Sulphuric acid began to react with it at concentrations above 50 per cent. Nitric acid reacted with it below 0°C at concentrations above 20 per cent. Ethanol and acetone did not react with the jet below zero, but benzene, toluene, ether and chloroform dissolved it.

Plates of jet could be glued together and

also to wood and similar materials by the use of simple joiner's glue or waterproof adhesive. Jet could also be decorated with many paints or lacquers, and some glazes adhered to it very firmly. Thus Siberian jet has shown itself to be an extremely adaptable material.

Chemistry and petrography of Siberian jet

The Siberian jet is an end member of a series of sapropelic coals. Simple and approximate analyses of jet samples have given the following results: moisture 0.94-1.4%; volatiles 71.3-73.7%, coke 14.0-15.3%, ash 11.8-12.0%. The composition of the organic matter of Matagan jet was: carbon 61.5-72.7%, hydrogen 9.1-9.6%, oxygen 15.5-25.4%, and nitrogen 2.4-3.0%.

Some physical properties of Siberian jet are as follows: density 1.1-1.22g/cm³, Mohs' hardness 2.5-3.0, limit of durability (kg/cm²) on compression 650-1100, on expansion 110-154, on winding 100-325. The shock velocity (kg cm/cm²) is 5-6.

In a transparent microscopic section, the Matagan jet shows a basic mass of horizontally orientated clots of sapropel of flattened lenticular shape and slices of dispersed thin threads of darker organic matter. In the basic material indistinct, yellow bodies without sharp contours were observed, but their identity is unknown. They are probably algae of the genus *Pila*, which had undergone partial decomposition. Perhaps the yellow, oval bodies were a product of coagulation of the sapropelic constituent. In any case, the pure, sapropelic character of the Matagan jet is evident.

It is interesting that Y. Zhemchzhnikov, who recognized the useful qualities of Matagan sapropelic coal, was disinclined to call it 'jet', because the former had been closely associated with algae and not with trees. Incidentally, as regards technological properties, foreign as well as Russian jets of mixed humus-sapropelic nature are quite different from Siberian jet, because the former are more fragile and not suit-

able for the manufacture of large items. (Jet had been imported to Russia from England during the New Economic Policy (NEP), before the Siberian jet deposits had been discovered.)

Articles made from Siberian jet



Fig.1. Cigarette case of Siberian jet which belonged to V. Petrov. c. 1933

Matagan sapropelic coal has received its reputation as an important workable material as a result of the work of a group of engineer-innovators headed by the mining engineer V. Petrov⁵. They laid the foundation of the jet industry based on the Siberian sapropelic coals of the Matagan deposits. In consequence, the factory 'Gagat' (Jet) was built in Moscow, and several 'Artels' (Association for common work) such as 1st May, Medsanlabor, Universalnye izdeliya and Utiltokar sprang up. At these enterprises a large range of more than 70 different artifacts was produced. These included inkstands (Figure 2), caskets, tobacco pipes, cigarette cases (Figure 1), soap containers, buttons, vases, candlesticks, chess sets, salt cellars (Figure 3), knife handles, forks, walking sticks and umbrella handles. In addition, master engravers also made from Siberian jet a range of ornaments including rings, beads, pendants, cameos and gems (Figures 4a, b and c).

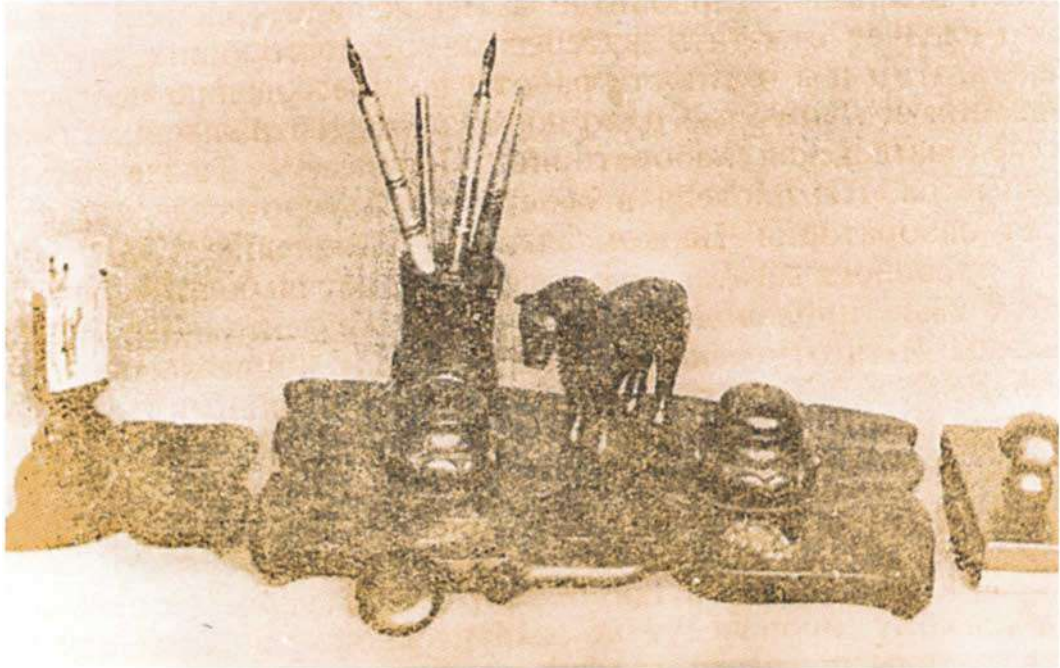


Fig.2. Inkstand of Siberian jet made by the factory 'Gagat'

The Artel '1st May' manufactured jet ornaments which found a ready market with fashionable women in France, Germany and the USA. Francs, marks, and dollars to the total sum of 50 000 roubles were transferred quarterly to the Artel account. Such a sum in the 1930s was very considerable.



Fig.3. Salt cellar of Siberian jet

Siberian jet has attracted the attention of scientists and engineers because of its resistance to acids and alkalis and its dielectric properties. Research teams have studied the replacement by jet of non-ferrous metals and their alloys such as copper, aluminium, type metal, brass and Babbit's metal.

The industrial concern 'Metallob'edine' succeeded in saving several dozen tons of pure copper by using jet in the manufacture of 300 000 door handles. The concern 'Poligraphob'edinenie' ordered 600 tons of jet to produce print type. The workshops of the trust 'Promsviaz' produced jet panels for radio equipment. In addition to Moscow, there were jet factories in the Siberian towns of Irkutsk and Chermkhovo.

Unfortunately, by 1939 the jet supplies in the Matagan deposit were completely exhausted, and the jet industry had to find other raw material. The Burtin jet deposit situated 70km to the North-West of Irkutsk



Fig.4a. Jet jewellery. Jet ring with agate and two types of earrings

was urgently inspected and geologists estimated its jet supplies to be 30 000 tons. Jet in this new deposit differed from the Matagan jet in hardness, but nevertheless yielded good quality articles.

Beds of excellent jet were also found in the Khakharei deposit in the Irkutsk coal basin. However, the Second World War started soon after, and put an end to the jet industry on a large scale in the USSR.

Conclusion

Over half a century has passed since Russian jet workshops ceased to function and in the popular domain the kind of artifact once made in jet is now made with synthetic polymers. Nowadays it is expedient to use the Siberian jets only in the traditional way for a specialized market in personal ornaments and other carved items⁶, although there is enormous potential for new sources of jet-sapropelite among the coals in the remote regions of eastern Siberia.

Acknowledgements

The author is greatly indebted to Mrs Helen Muller who showed great interest in the history of Siberian jet, and to Yaroslavna Petrova, the daughter of the



Fig.4b. Siberian jet ring with agate



Fig.4c. Two bracelets with Caucasian jet

mining engineer V. Petrov. She presented the material about the Siberian jet, which belonged to her late fathers to the photographer Serge Ivanov, who took the photographs.

References

1. Muller, Helen, 1987. *Jet*. Butterworths, London
2. Zhemchuzhnikov, Y.A., 1934. Materialy k poznaniyu prirody gagata. *Khimiya tverdogo topliva*, tom V, vyp.5, stro. 404-414
3. Seward, A.C., 1904. *The Jurassic flora*. British Museum Publication, Part II. London
4. Fox-Strangways, C., 1892. *The Jurassic rocks of Britain*. Vol.I, *Yorkshire Memoir of the Geological Survey*, HMSO, Yorkshire
5. Petrov, V.N., 1933. *Gagat*. Chast I. Gizlegprom, Moskva
6. Glushnev, S., 1991. Khochu naiti gagat-chudo chyornoe. *Gazeta Moskovskaya Pravda*, N 150

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A preliminary investigation of peridot from Vietnam

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Abstract

Gem-quality peridot is being obtained from two areas in Vietnam. This article reports on the gemmology of that material being mined in Lam Dong Province. Classical gem testing procedures reveal properties consistent with those reported in the gemmological literature for peridot from other sources and none was found to be diagnostic of this particular locality.

Introduction

Peridot is a gem material whose use dates back to antiquity. It is first documented from the island in the Red Sea known variously as Zeberget, Zabargad or the Island of Saint John (Webster, 1983). A very good and fairly recent report on this deposit and the gemmology of its peridot can be found in Gübelin (1981). Although small amounts of this material still occasionally appear in gem markets, apparently no commercial mining has been undertaken since nationalization in Egypt under Nasser in the 1950s (Koivula *et al.*, 1993a). In terms of volume, today's major commercial sources are the San Carlos Apache Reservation in Arizona, USA (Koivula, 1981; Koivula *et al.*, 1992a) and China (Koivula and Fryer, 1986), while Myanmar (Burma) continues to produce limited quantities of stones that are exceptional both in size and quality (Kammerling *et al.*, 1994). Other commercial or potentially commercial sources of peridot include

Ethiopia (Koivula *et al.*, 1993b), New Mexico, USA (Fuhrbach, 1992), Sri Lanka (Gunawardene, 1985) and Tanzania (Stockton and Manson, 1983). Peridot from other localities is occasionally cut into gemstones, including material from pallasitic meteorites (Sinkankas *et al.*, 1992).

Background to study

While on a visit to Vietnam in November 1992, one of the authors (RCK) visited the gemmology department of the Research Centre for Industrial Mineralogy, Hanoi University. Here he was shown a wide assortment of gem materials that had been recovered from areas throughout the country and that were felt by university staff members to have commercial potential. Among this collection of rough gemstones were what appeared to be several hundred carats of rough peridot.

Additional information about Vietnamese peridot was subsequently provided in July 1993 by Saverio Repetto of the Gemological Institute of Vietnam (GIV), a Hanoi-based joint venture firm involved in the purchasing, cutting and marketing of gem materials. According to Saverio Repetto, two deposits were discovered in mid-1993, one in Lam Dong Province, southern Vietnam, and another in Gia Lai Province, central Vietnam, near the Cambodian border (Figure 1). In their first few weeks of operation, the two localities reportedly produced an estimated 100-200kg of peridot.

On a subsequent visit to Vietnam in



Fig. 1. Local miners remove peridot from what would appear to be a gem-encrusted nodule of basalt in Gia Lai Province, central Vietnam, near the border with Cambodia. Photo courtesy of Saverio Repetto.

November 1993, one of the authors (RCK) learned that the deposit near the Cambodian border was at the time being mined by the local populace. The rough peridot was reportedly taken by vehicle over rough roads from the mining area to the city of Pleiku where, the author was told, Thai buyers were coming to make purchases.

Current investigation

The test sample for this investigation consists of five faceted peridots ranging from 1.60 to 5.56 carats (Figure 2). These were provided by Saverio Repetto and are reported to come from the Lam Dong locality. Their properties, determined using standard gem testing equipment, are described below.

Appearance

All five stones were transparent. They ranged in hue from yellowish-green to

brownish-green of low to moderate saturation in medium light to medium dark tones.

Refractive indices

RI readings were taken using a GIA GEM Instruments Duplex II refractometer and near-sodium equivalent light source. The values determined were $\alpha = 1.650$, $\beta = 1.665$ - 1.667 and $\gamma = 1.687$ - 1.688 , with resulting birefringence of 0.037 to 0.038.

Pleochroism

Using a calcite dichroscope with a fibre-optic illuminator, weak pleochroism in very slightly brownish-green and yellowish-green was observed.

Absorption spectrum

A Beck desk-model prism spectroscope revealed iron-related absorption bands typical for peridot at approximately 453, 473 and 493nm.



Fig. 2. These five faceted peridots, ranging from 1.60 to 5.56ct are the study sample used in the current investigation. Photo by Maha DeMaggio, GIA.

Chelsea colour filter

When viewed through the Chelsea filter, all stones appeared yellowish-green.

Specific gravity

SG determinations by the hydrostatic weighing technique produced values ranging from 3.33 to 3.35.

Inclusions

The five specimens were examined microscopically in order to document their suite of internal features. As with peridots from other localities such as Egypt (Gübelin, 1981), Arizona (Koivula, 1981), China (Koivula and Fryer, 1986) and New Mexico (Fuhrbach, 1992), the geological mode of formation of Vietnamese peridot limits the types of possible inclusions that may be found therein. While not diagnostic of their Vietnamese source, some of these internal features may be considered gemmologically diagnostic of peridot in general. Following are descriptions of all those internal features noted in the present investigation.

'Lily pads': The one type of inclusion that is most characteristic for peridot from most localities is often referred to by gemmologists as a 'lily pad' inclusion. All five specimens in the test sample displayed these highly diagnostic inclusions (Figure 3).

'Lily pad' inclusions are actually cleavages that result from the rupturing of minute fluid-filled negative crystals, the filling usually being carbon dioxide and natural glass. They form as circular to ovoid planar discs, known as decrepitation halos, surrounding tiny whitish to transparent negative crystals that may appear dark brown to black under certain methods of illumination. These 'lily pads' form along the directions of imperfect cleavage in peridot and quite often behave as thin films, appearing brightly iridescent if illuminated from above (Koivula, 1981).

The majority of 'lily pad' inclusions observed in the Vietnamese peridots exhibited sufficiently high relief to be detected relatively easily using darkfield illumination. However, some had such low relief that they could go virtually unnoticed

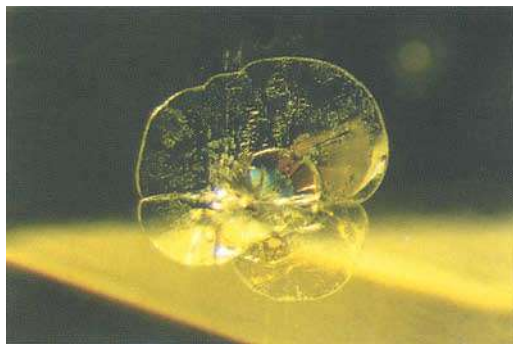


Fig. 3. This 1.1-mm 'lily pad' inclusion is typical of those found in Vietnamese peridots. Photomicrograph by John I. Koivula, GIA.



Fig. 4. These 'lily pad' inclusions are so thin as to be almost unnoticeable in darkfield illumination. Field of view approximately 3mm. Photomicrograph by John I. Koivula, GIA.

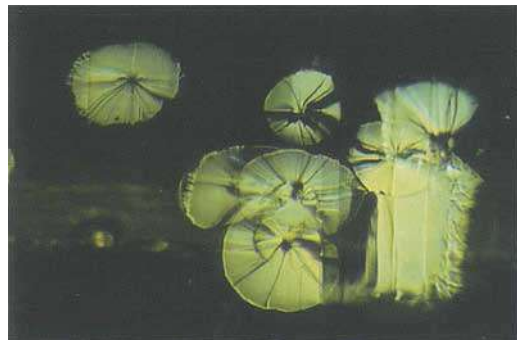


Fig. 5. In reflected fibre-optic light the 'lily pad' inclusions shown in Figure 4 behave as thin films, becoming very easy to see. Field of view approximately 3mm. Photomicrograph by John I. Koivula, GIA.



Fig. 6. White, smoke-like veiling is one of the internal characteristics noted in Vietnamese peridot. Field of view approximately 2.5mm. Photomicrograph by John I. Koivula, GIA.

(Figure 4) unless incident fibre-optic illumination was employed to take advantage of their thin-film reflectivity (Figure 5).

Smoke-like veiling: An internal feature perhaps best described as smoke-like veiling and already noted in peridots from San Carlos, Arizona (Koivula, 1981), Hebei Province, China (Koivula and Fryer, 1986), and Kilbourne Hole, New Mexico (Fuhrbach, 1992) was found in four of the test stones (see Figure 6). This feature is believed to result from incomplete solid solution-unmixing which occurs as the peridot is brought to the earth's surface and cools in the host (basalt?) – and visible strain caused by decorated dislocations

(Kohlstedt *et al.*, 1976). These inclusions are easily recognized, always appearing as ghostly white flowing streamers when viewed with a combination of darkfield and pinpoint fibre-optic illumination.

One of the test samples, a 2.77ct pear-shaped stone of distinctly brownish-green colour (again, see Figure 2) contains sub-parallel dark brown bands (Figure 7). These are similar in appearance to some of the white veil structures described above, differing only in their colour. Their distinctly brown coloration may result from iron concentrated along dislocation zones, or from chemical alteration of the peridot.

Chromian spinel: Chromian spinel is a rel-

atively common type of solid mineral inclusion in peridot (Dunn, 1974). It crystallizes in the isometric crystal system and when seen as an inclusion generally appears as opaque, black octahedra or anhedral, rounded masses exhibiting reddish-brown coloration at thin edges. Distorted octahedra, some flattened to an almost tabular habit, are also encountered. These crystalline inclusions are typically surrounded by tension fractures that result from the expansion of the spinel against the host peridot. One such inclusion was noted in our test sample, exhibiting a slightly rounded but still recognizable isometric habit (Figure 8).

Biotite: The mineral biotite has been documented previously as an inclusion in peridots from other localities, for example, Myanmar (Burma) (Gübelin, 1974), San Carlos, Arizona (Koivula, 1981) and Hebei Province, China (Koivula and Fryer, 1986). In our test sample of Vietnamese peridots, two very small, translucent brown, euhedral, micaceous-appearing inclusions tentatively identified as biotite were observed.

Optically active intergrowth: In the 2.77ct sample, an elongated, sharp-edged intergrowth zone was detected which was virtually undetectable in darkfield illumination, but was clearly visible in polarized light, displaying vivid interference colours (Figure 9). The extremely low relief exhibited in darkfield lighting indicates that the zone has similar if not identical optical properties to those of the surrounding peridot. The image noted in polarized light, however, proves that the optical orientation of the intergrowth zone differs from that of the host. The specific nature of this intergrowth zone is unknown. It is possible that it resulted from solid solution unmixing or chemical alteration, dendritic intergrowth or perhaps a form of twinning. Similar optically active areas have been observed in peridot nodules from Arizona although the authors are not aware of this feature having been documented previ-



Fig. 7. Subparallel dark brown bands, similar to some of the white veil structures shown in Figure 6, were observed in one of the test samples. Field of view approximately 2mm. Photomicrograph by John I. Koivula, GIA.

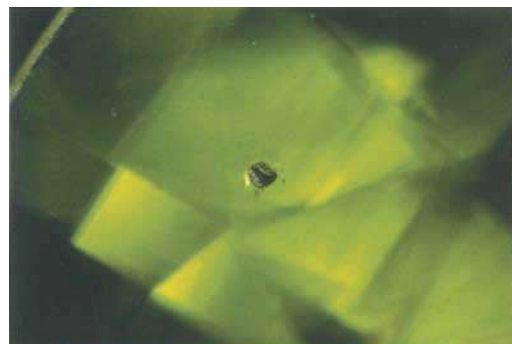


Fig. 8. Only one rounded octahedron (0.15mm) of what appears to be chromian spinel was noted in the Vietnamese peridots. Note the slightly reddish-brown colour at the edges of the inclusion. Photomicrograph by John I. Koivula, GIA.



Fig. 9. An optically active intergrowth zone, displaying vivid interference colours in polarized light, was observed in one of the test stones. Field of view approximately 4mm. Photomicrograph by John I. Koivula, GIA.

Table I: Gemmological properties of Vietnamese peridot¹

Diaphaneity:	Transparent
Colour:	Medium light to medium dark, yellowish-green to brownish-green of low to moderate saturation
RI:	$\alpha = 1.650$ $\beta = 1.665-1.667$ $\gamma = 1.687-1.688$
Birefringence:	0.037 - 0.038
Pleochroism:	Weak, very slightly brownish-green and yellowish-green
Chelsea filter:	Yellowish green (negative reaction)
Absorption spectrum:	Diffuse bands at 453, 473 and 493nm
SG:	3.34 ± 0.01
Magnification:	'Lily pad' inclusions surrounding negative crystals; smoke-like veiling; chromian spinel(?); biotite mica(?); optically active intergrowth.

¹Based upon examination of five faceted stones from Lam Dong Province, ranging from 1.60 to 5.56ct.

ously in photographs.

The gemmological properties are summarized in Table I.

Chemical analysis

Quantitative chemical analysis by energy-dispersive X-ray fluorescence (EDXRF) was performed on one specimen. This indicated the presence of magnesium, iron and silicon – essential components of peridot ($\text{Mg,Fe}_2\text{SiO}_4$) – as well as nickel, chromium, manganese and calcium. This chemistry is consistent with that of peridot from other localities (see, for example, Fuhrbach, 1992).

Based on the refractive indices and the direct correlation of RI and chemical composition in this material (Mg- and Fe-contents) (see Deer *et al.*, 1992), the Vietnamese peridots consist of approximately 10 per cent fayalite (Fe_2SiO_4) and 90 per cent forsterite (Mg_2SiO_4).

Discussion

Vietnam has been widely recognized as a commercial source of gemstones only in

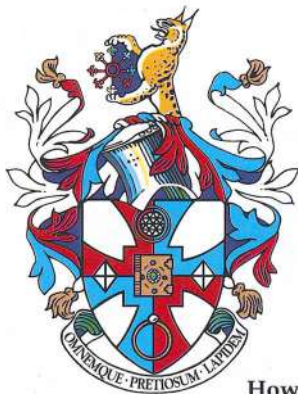
the past few years, first entering this arena with its rubies and pink to purple sapphires (Kane *et al.*, 1991) and holding potential as an economically viable source of other gems including sapphires (Koivula *et al.*, 1992b; 1993c) and now peridot.

The peridot from Lam Dong Province in southern Vietnam exhibits gemmological properties that are similar to those of peridot from other localities around the world and their internal features are typical of peridots from basaltic volcanic environments. We have not as yet discovered any features or properties which are unique to the peridots from Lam Dong Province.

References

- Deer, W.A., Howie, R.A., and Zussman, J., 1992. *An Introduction to the rock-forming minerals*. 2nd edn. Longman Group Limited, Harlow, p.11
- Dunn, P.J., 1974. Chromian spinel inclusions in American peridots. *Zeitschrift der Deutschen Gemmologische Gesellschaft*, **23**, 4, 304-7
- Fuhrbach, J.R., 1992. Kilbourne Hole peridot. *Gems & Gemology*, **28**, 1, 16-27
- Gübelin, E., 1974. *Internal World of Gemstones*. ABC Edition, Zurich, Switzerland.
- Gübelin, E., 1981. Zabargad: the ancient peridot island in the

- Red Sea. *Gems & Gemology*, 17, 1, 2-8
- Gunawardene, M., 1985. Peridot from Ratnapura District, Sri Lanka. *Journal of Gemmology*, 19, 8, 692-702
- Kammerling, R.C., Scarratt, K., Bosshart, G., Jobbins, E.A., Kane, R.E., Gübelin, E.J., and Levinson, A.A., 1994. Myanmar and its gems - an update. *Journal of Gemmology*, 24, 1, 3-40
- Kane, R.E., McClure, S.F., Kammerling, R.C., Khoa, N.D., Mora, C., Repetto, S., Khai, N.D., and Koivula, J.I., 1991. Rubies and fancy sapphires from Vietnam. *Gems & Gemology*, 27, 3, 136-55
- Kohlstedt, D.L., Goetze, C., Durham, W.B., and Vander Sande, J., 1976. New techniques for decorating dislocations in olivine. *Science*, 191, 1045-6
- Koivula, J.I., 1981. San Carlos peridot. *Gems & Gemology*, 17, 4, 205-14
- Koivula, J.I., and Fryer, C.W., 1986. The gemological characteristics of Chinese peridot. *Gems & Gemology*, 22, 1, 38-40
- Koivula, J.I., Kammerling, R.C., and Fritsch, E., 1992a. Gem news: update on peridot. *Gems & Gemology*, 28, 1, 60
- Koivula, J.I., Kammerling, R.C., and Fritsch, E., 1992b. Gem news: update on Vietnamese gems. *Gems & Gemology*, 28, 4, 274-5
- Koivula, J.I., Kammerling, R.C., and Fritsch, E., 1993a. Gem news: peridot from Zabargad. *Gems & Gemology*, 29, 2, 134-5
- Koivula, J.I., Kammerling, R.C., and Fritsch, E., 1993b. Gem news: peridot from Ethiopia. *Gems & Gemology*, 29, 1, 59
- Koivula, J.I., Kammerling, R.C., and Fritsch, E., 1993c. Gem news: spinel from Vietnam. *Gems & Gemology*, 29, 3, 213-14
- Sinkankas, J., Koivula, J.I., and Becker, G., 1992. Peridot as an interplanetary gemstone. *Gems & Gemology*, 28, 1, 43-51
- Stockton, C.M., and Manson, D.V., 1983. Peridot from Tanzania. *Gems & Gemology*, 19, 2, 103-7
- Webster, R., 1983. *Gems, their sources, descriptions and identification*. Fourth Edition by B.W. Anderson, Butterworths, London, UK, Chapter 7



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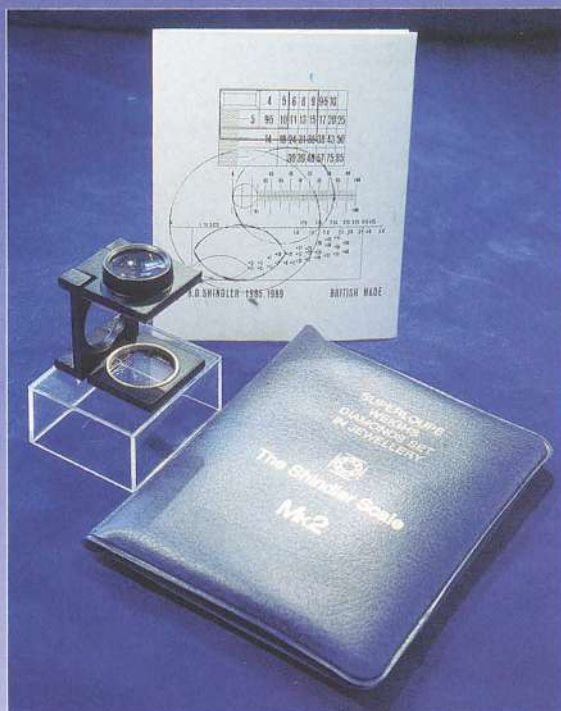
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Some observations on a gem-quality synthetic yellow diamond produced in the region of Vladimir (Russia)

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Abstract

The gemmological properties of a synthetic yellow diamond reported to come from Vladimir, east of Moscow, Russia, are described. The infrared spectrum of the synthetic resembles that of a natural yellow diamond but growth patterns revealed by fluorescence in ultraviolet radiation are distinctive.

Introduction

In December 1993 the Istituto Gemmologico Italiano (IGI) was presented with a faceted synthetic yellow diamond weighing 0.15ct by Fabio Pignataro, a gemstone dealer. The diamond was stated to come from the region of Vladimir east of Moscow in Russia. This is a possible new source of synthetic diamonds and a brief summary of our gemmological investigation is given below.

Colour and colour-zoning

The colour of the stone is an intense brownish-yellow when observed in both reflected and transmitted daylight and in strong fibre optic light (Figure 1). When exposed to a mercury lamp, the diamond displayed a strong green overtone, evenly distributed on the pavilion facets (Figure 2). Probably such a colour arises in response to the intense green emission component of the mercury lighting.

This phenomenon has also been observed in many natural yellow (fancy)

diamonds and is not a distinctive property of synthetics.

Using a gemmological microscope, an angular grain line separating a narrow colourless zone from another yellowish-brown area may be seen (Figure 3). The intensity of colour in the brown zone varies when the diamond is rotated around an imaginary axis perpendicular to the table of the stone (Figure 4). The simple pattern of two intersecting graining lines, corresponding with the distribution of the colour zoning, is different from the graining seen in Russian diamonds from Novosibirsk by Shigley *et al.* (1993). However this simple pattern has been observed in natural yellow diamonds in our laboratory.

Inclusions

The Russian synthetic diamond contains a cloud of tiny, grey, poorly-reflecting 'pinpoint' inclusions (Figure 5), not obviously oriented. Some of these small inclusions intersecting the table facet of the diamond were analyzed using a SEM-EDS system with quite surprising results (Figure 6). In addition to iron and nickel, a small quantity of caesium was detected. (The chlorine recorded in the EDS spectrum is probably the result of contamination.) Both iron and nickel have been previously reported (Shigley *et al.*, 1987, 1993; Moses *et al.*, 1993) and derive from flux material used in the crystal synthesis. The origin of the caesium is not clear. It may have been a component of the metal alloy, or it may be a contaminant from a previous experiment



Fig. 1. The 0.15 ct diamond of intense brownish-yellow colour from Vladimir, east of Moscow. Magnification 5x.



Fig. 4. As the stone is slightly rotated (compared to the position of Fig. 3) the longer grain line appears to be masked by a dark brown rectangular area. Diffuse and oblique illumination, magnification 6x.



Fig. 2. When illuminated with the mercury light, the diamond exhibits a green overtone over the pavilion facets. Oblique illumination, magnification 5x.

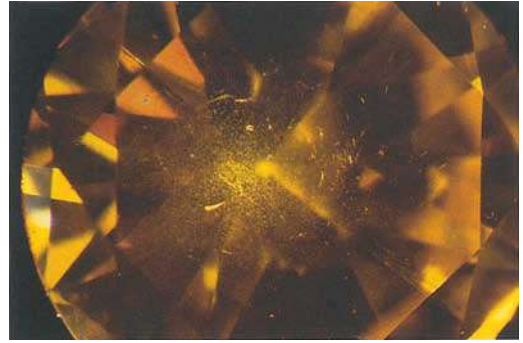


Fig. 5. Inside the diamond, a cloud of tiny greyish pinpoint inclusions is visible. Dark-field illumination, magnification 10x.

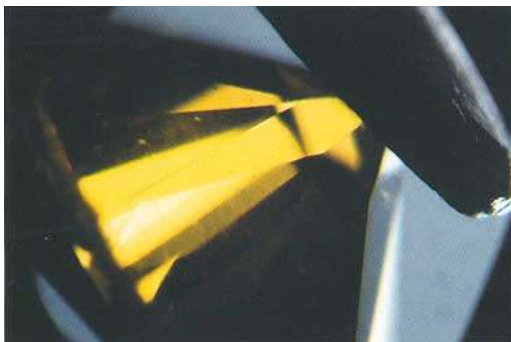


Fig. 3. Near colourless zone limited by two intersecting grain lines is visible through the pavilion facets. Diffused-transmitted light, magnification 8x.

in the high pressure cell. Or again, since the small metal inclusions intersecting the diamond table are softer, their surfaces lie slightly below the table, and as small 'pits' they may have trapped some possible coating material. It does not seem likely that a rare element like caesium was a component of the solutions used to release the diamond from the flux-alloy or during its cutting and polishing.

In spite of the presence of a cloud of metallic inclusions the diamond was not attracted by a simple magnet, suggesting that the magnetic attraction, previously reported in the General Electric (Koivula *et al.*, 1984), Sumitomo (Shigley *et al.*, 1986)

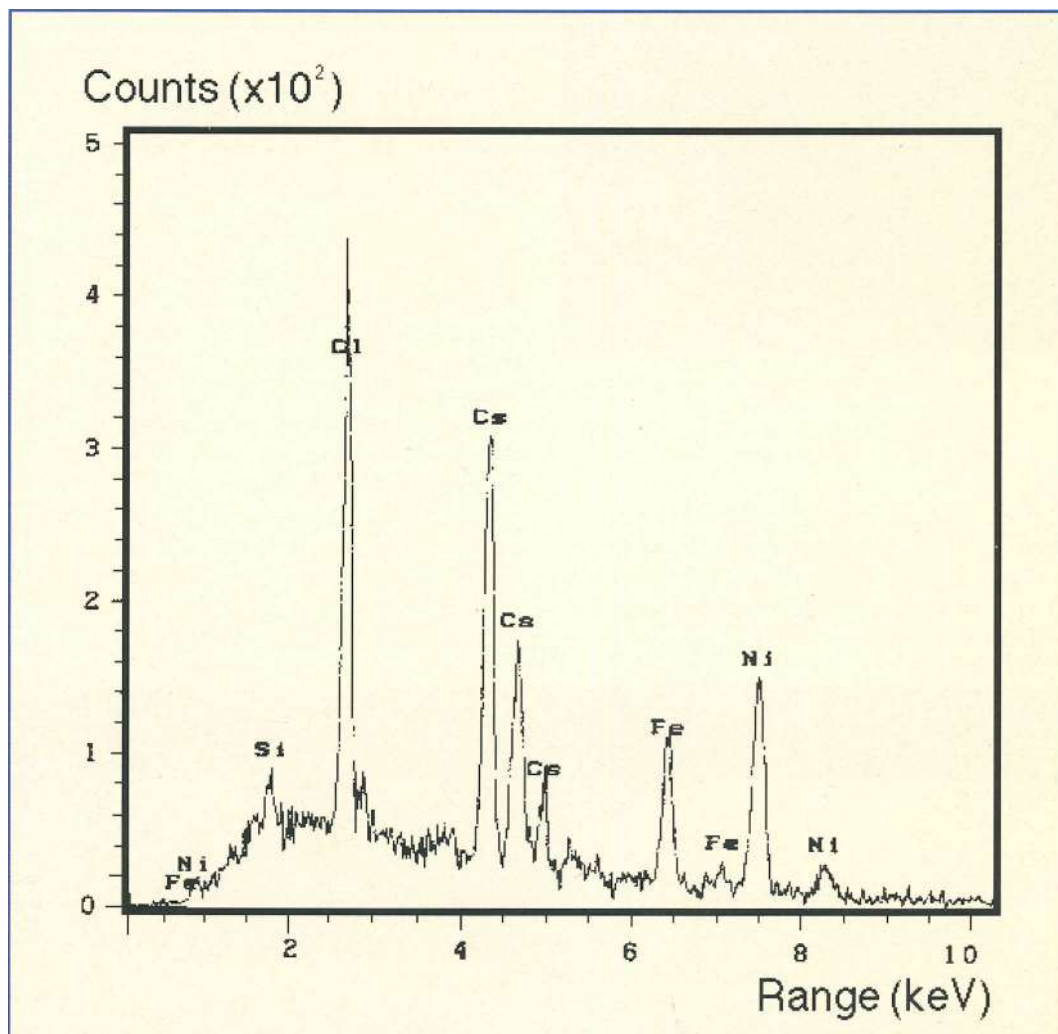


Fig. 6. SEM energy-dispersion graph showing the peaks of iron, nickel and caesium present in the metallic inclusions. (The peak on the left – chlorine – is due to contamination.)

and De Beers (Shigley *et al.*, 1987) synthetic diamonds, does not depend solely on the presence of metallic inclusions.

Luminescence phenomena

One of the most prominent characteristics of this Russian synthetic yellow diamond, which is useful in distinguishing it from natural diamonds, is the arrangement of distinct growth sectors which strongly luminesce when exposed to ultraviolet rays or to an electron beam (see

Ponahlo, 1992). Through the table of the diamond it is possible to see a cross-shaped area which fluoresces greenish-yellow to both long- and short-wave UV radiations (Figure 7), the response to long wave UV being slightly stronger. Outside the central cross-shaped area the stone is inert and no other growth sectors are visible.

The cathodoluminescence pattern (Figure 8), matches the UV fluorescence in the central zone of the stone but also reveals lines in a square pattern arranged



Fig. 7. The square sectors and the four arms arranged to form a cross pattern are clearly visible due to their intense fluorescence in UV radiation. Magnification 5x, ten minutes exposure.

at forty-five degrees with respect to the main arms of the central cross. It was not possible to determine which of the visible lines or arms represented cubic or octahedral growth zones.

In conclusion, cathodoluminescence analysis indicates the presence and shapes of different growth sectors (Shigley *et al.*, 1993) and helps to indicate the crystal as synthetic. Also the UV luminescence pattern of this diamond leads to the same conclusion.

Spectroscopy

The diamond was cooled to 273K and then to the spray refrigerant temperature (240K), but no absorption bands or lines were visible with a hand-held spectroscope.

Measurement of the infrared spectra in a Fourier Transform infrared (FT-IR) spectrophotometer (see Figures 9 and 10) revealed that the diamond is a mixture of Types Ib and IaA, with the following absorption features in the 'nitrogen region': 1132cm^{-1} , 1344cm^{-1} , (related to Ib nitrogen impurities) and 1282cm^{-1} (related to IaA

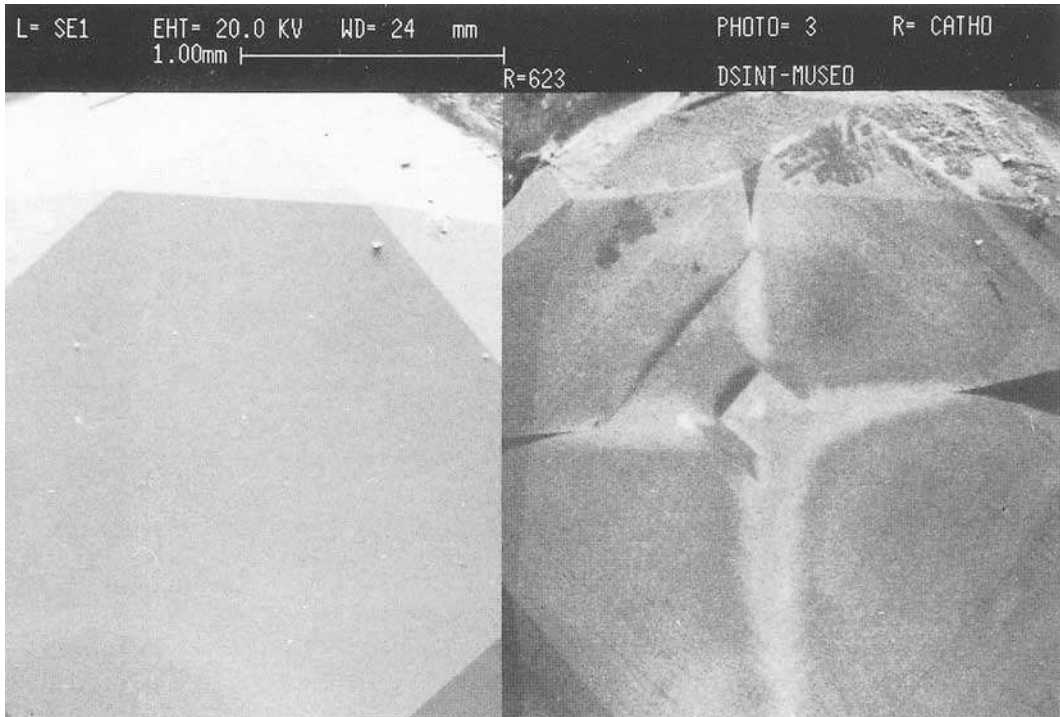


Fig. 8. Two SEM images of the synthetic diamond: (left) secondary electron image of the diamond table; (right) cathodoluminescence topograph: symmetric arrangement of square growth-sectors. The brightest central 'cross-shaped' area closely matches the UV luminescence pattern.

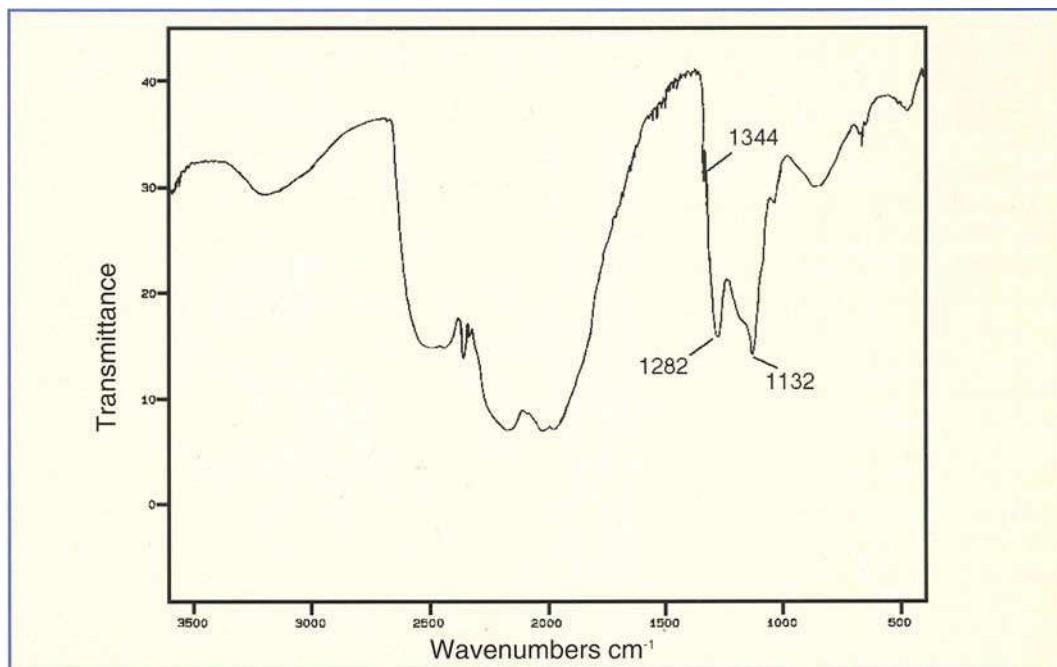


Fig. 9. Mid-infrared absorption of the yellow synthetic diamond showing the Ib and IaA N-related features.

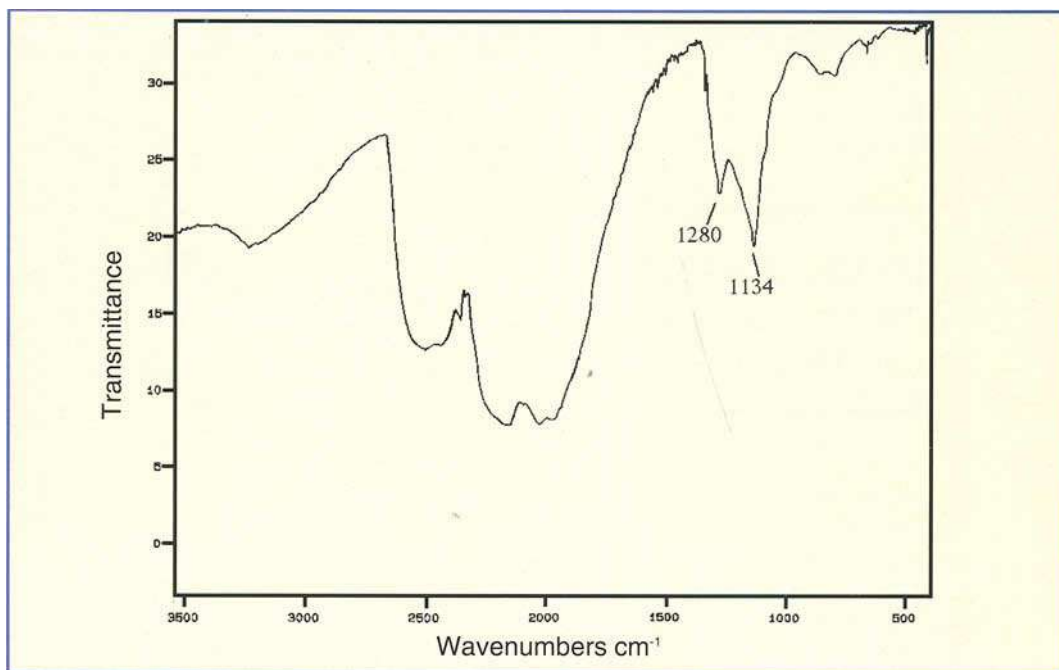


Fig. 10. Mid-infrared absorption of a natural yellow diamond. Note the strong similarity with the spectrum of the studied diamond.

nitrogen impurities). This pattern is very similar to those reported by Shigley *et al.* (1993) and Moses *et al.* (1993), for synthetic diamonds grown in Novosibirsk.

Conclusions

Although the Russian gem-quality synthetic diamonds coming essentially from Novosibirsk (Southern Siberia) have been known since 1991 (Koivula and Kammerling, 1991), this is the first gemmological examination of a synthetic diamond produced in the Region of Vladimir, east of Moscow.

Documentation of the properties of this synthetic diamond - e.g. pinpoint metal inclusions, colour zoning, UV fluorescence and infrared absorption spectrum - indicates that the diamond was manufactured by a process very similar to that used in Novosibirsk.

Perhaps the most important and diagnostic gemmological property of this diamond is the strongly zoned UV fluorescence related to the different growth sectors which does not resemble anything seen in natural stones.

Acknowledgements

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References

- Collins, A.T., 1980. Spectroscopic investigation of a canary yellow diamond. *Journal of Gemmology* XVII, 4, 213-222.
- Koivula, J.I., and Fryer C.W., 1984. Identifying gem-quality synthetic diamonds: an update. *Gems & Gemology*, 20, 3, 146-158.
- Koivula, J.I., and Kammerling, R.C., 1991. Gem news: gem-quality synthetic diamonds from the USSR. *Gems & Gemology*, 27, 1, p.46.
- Moses, T.M., Reinitz, I., Fritsch, E., and Shigley, J.E., 1993. Two treated-colour synthetic red diamonds seen in the trade. *Gems & Gemology*, 29, 3, 182-190.
- Ponahlo, J., 1992. Cathodoluminescence (CL) and CL spectra of De Beers experimental synthetic diamonds. *Journal of Gemmology*, 23, 1, 3-17.
- Shigley, J.E., Fritsch, E., Stockton, C.M., Koivula, J.I., Fryer, C.W., and Kane, R.E., 1986. The gemmological properties of the Sumitomo gem-quality synthetic yellow diamonds. *Gems & Gemology*, 29, 1, 38-45.
- Shigley, J.E., Fritsch, E., Stockton, C.M., Koivula, J.I., Fryer, C.W., Kane, R.E., Hargett, D.R., and Welch, C.W., 1987. The gemmological properties of the De Beers gem-quality synthetic diamonds. *Gems & Gemology*, 23, 4, 187-206.
- Shigley, J.E., Fritsch, E., Koivula, J.I., Sobolev, N.V., Malinovsky, I.Y., and Pal'yanov, Y.N., 1993. The gemmological properties of Russian gem-quality synthetic yellow diamonds. *Gems & Gemology*, 29, 4, 228-248.

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Letters

From N.P.G. Sturman

Dear Sir

Treated amber

With reference to the Letter from Richard Hughes (*J. Gemm.*, 24(3), 185-6) regarding the article 'A note from the Bahrain Laboratory - 3' (*J. Gemm.*, 24(1), 42-4), I quite agree with his observation that 'the colour of amber may darken over time' as I have seen some examples of amber with a darker surface colour and lighter interior colour that I most probably would not call surface-treated amber. All these examples have been what I would consider as old, possibly even antique, pieces (by this I mean the period that has passed since the pieces were fashioned, as all amber is antique in age!) and, as such, I believe the exposed (surface) colour has indeed altered without intentional interference. In other words, the colour was not altered on purpose to improve the appearance.

However, the visual gemmological features of the amber we discussed in the article were so different from untreated amber examined in both this laboratory and the Gem Testing Laboratory of Great Britain and of a type that was evidently fashioned recently that, in our opinion, we had no alternative but to call it surface colour enhanced (treated) amber. I certainly would not have purchased it as natural *untreated* amber, if it was offered to me as a potential customer. Therefore, it is our opinion that in this case and in some other examples we have seen (see *J. Gemm.*, 23(7), 398-9), the surface colour has in some way been artificially altered on purpose.

We would appreciate receiving any information about this subject from individuals or companies involved in modern enhancement methods and would be inter-

ested in purchasing samples of treated material, modern synthetics, etc., for our reference collection.

Yours etc.

Nick Sturman
Advisor, Bahrain Laboratory
1 October 1994

From W.W. Hanneman

Dear Sir

On the glass filling of diamonds

In his interesting two-part article on diamond-filling glasses (*J. Gemm.*: Part I, 1993, 23(8), 461-72; Part 2, 1994, 24(2), 94-103), Dr Nelson spoke of the difficulty of measuring the optical properties of exploration batches of these materials. These problems also hold true for high RI gem materials. I would like to offer a simple solution.

Take a small piece of the specimen, polish two facets meeting at an angle of 25 or 30 degrees and, using a Hanneman-Hodgkinson refractometer, determine the index of refraction for any wavelength of visible light that one might wish. It will also allow one to measure dispersion and the magnitude of birefringence in doubly refracting materials. Details are available from the address below.

Yours etc.

W.W. Hanneman
Hanneman Gemological Instruments,
Castro Valley, CA 94546, USA
13 September 1994

Abstracts

Diamonds

Gems and Minerals

Instruments and Techniques

Synthetics and Simulants

Diamonds

Characterisation study of diamond and diamond-like carbon.

D.P. DOWLING *et al.* *Surface & Coatings Technology*, **53** (2), 1992, pp 177-83 (Sep 15), 11 figs, 1 table, 19 refs.

A comparative characterization study of diamond and diamond-like carbon films deposited using plasma-enhanced CVD is presented. The films were examined using scanning electron microscopy (SEM), X-ray diffraction, X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy and Raman spectroscopy. As a result of these studies structural and chemical information was obtained on the carbon films. The SEM examination indicated the presence of high levels of stress in the diamond films. The ability of XPS and Raman spectroscopy to distinguish between diamond-type carbon (sp^3 hybridised) and graphitic carbon (sp^2 hybridised) is demonstrated. (Author's abstract) D.P.D.

Potassium in clinopyroxene inclusions from diamonds.

G.E. HARLOW AND D.R. VEBLER. *Science*, **251** (8), 1991, pp 652-5.

Analytical TEM, EPMA and single-crystal XRD data support the conclusion that high K contents, ≤ 1.5 wt.% K_2O , of some diopside and omphacite inclusions from diamonds represent valid

clinopyroxene compositions with K in solid solution. This conclusion contradicts the traditional view which holds that K is too large to be incorporated in the pyroxene structure. These diopside and omphacite inclusions have a high degree of crystal perfection and anomalously large unit-cell volumes, and a defect-free structure is observed by TEM on K-bearing regions. These results imply that clinopyroxene can be a significant host for K in the mantle and that some clinopyroxene inclusions and their diamond hosts may have grown in a highly K-enriched environment. R.A.H.

Gem News.

J.I. KOIVULA, R.C. KAMMERLING AND E. FRITSCH. *Gems & Gemology*, **30** (1), 1994, pp 47-57, illus. in colour.

The International Colored Stone Association reported two attempts to pass cubic zirconia as diamonds; in one case the imitation was in a parcel of rough diamonds and was in the form of an octahedron and even had etched 'trigons'; the other case involved CZ baguettes and round brilliants salted in a parcel of similarly sized and cut diamonds.

Enhancements

Care is required with filled diamonds as heat from repairs can damage the filling as can also prolonged ultra-sonic cleaning. Long exposure to short-wave ultraviolet radiation caused discoloration. R.J.P.

ABSTRACTORS

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K.A.R.
R.E.S.
E.S.
L.T.T.

For further information on many of the topics referred to consult *Mineralogical Abstracts* or *Industrial Diamond Review*.

Diamonds and their sources in the Venezuelan portion of the Guyana Shield.

H.O.A. MEYER AND M.E. MCCALLUM. *Economic Geology*, **88** (5), 1993, pp 989-98, 5 maps.

Two sources are suggested for the diamonds. The secondary source is the 2000m thick Roraima group of Proterozoic age. The main sources probably are unknown Proterozoic kimberlites or lamproites in the Guyana Shield of the Amazonian craton. No evidence exists to support an African source. K.A.R.

Three generations of diamonds from old continental mantle.

S.H. RICHARDSON, C.D. CANHAM AND S.R. PUGH. *Nature*, **366** (6452), 1993, pp 256-8.

Major elements, Rb, Sr and Rb-Sr, Sm-Nd isotopic data are presented of peridotitic garnet, clinopyroxene inclusions in diamonds and macrocrysts from the Proterozoic Premier kimberlite. The peridotitic inclusion minerals have compositions reflecting an origin in harzburgite (clinopyroxene-bearing) assemblages. The harzburgitic garnet inclusions and kimberlite have Nd and Sr isotopic features consistent with an Archaean age (> 3000 m.y.) and a metasomatized mantle source. Lherzolitic garnet and clinopyroxene inclusions gave a preferred Sm-Nd isochron age of 1930 m.y. (~100 m.y. less than that of the nearby Bushveld complex) suggesting a link analogous to that between harzburgitic diamond formation and komatiitic magmatism in the Archaean. The last generation of diamonds (with eclogitic inclusions) was formed ~1150 m.y. ago prior to the kimberlite emplacement. R.K.H.

Solid carbon dioxide in a natural diamond.

M. SCHRAUDER AND O. NAVON. *Nature*, **365** (6441), 1993, pp 42-4.

The discovery of solid CO₂ in the IR spectrum of brown-yellow diamond of unknown location is reported. The CO₂ is presently at 5 GPa and must have been trapped at even greater *P* in the mantle corresponding with depths of ~220-270km. At these *P* free CO₂ should react with olivine and pyroxene. The survival of free CO₂ at depth indicates the presence of an environment of different mineralogy such as a fully carbonated metasomatic vein or a block of subducted sediment. R.K.H.

A new find of microscopic diamonds in metamorphic rocks: evidence that the high-pressure metamorphism in the Kokchetav massif was regional in scope.

V.S. SHATSKIY, N.V. SOBOLEV, A.A. ZAYACHKOVSKIY, Y.M. ZORIN AND M.A. VAVILOV. *Doklady*, Russian Academy of Sciences, Earth Sciences Section. **322** (1), 1992, pp 128-32.

The literature is reviewed and the geology is discussed. Chemical data are tabulated for garnets, pyroxenes and amphiboles. Two microphotos are shown, and the Raman spectrum of the diamond is given. The authors conclude that probably the Kokchetav massif was submerged in the mantle in a manner similar to the Dora Maira coesite-bearing rocks of the Alps. K.A.R.

Diamond inclusions in the rock-forming minerals of metamorphic rocks.

T.Y. YEKIMOVA, L.D. LAVROVA AND M.A. PETROVA. *Doklady*, Russian Academy of Sciences, Earth Sciences Section. **323** (2), 1992, pp 101-3.

The previous work is reviewed. The diamonds commonly occur in garnet, quartz, biotite, pyroxene, etc. The petrography and mineralogy are discussed. Four microphotos are shown. The work suggests that diamonds can be formed in the crust as well as the mantle. K.A.R.

Gems and Minerals

[On the mineralogical characteristics of ruby and sapphire of Xinjiang, China.] (Chinese with English abstract)

P. ABDUKADER AND L. WANG. *Journal of Mineralogy & Petrology (Kuangwu Yanshi)*, **13** (4), 1993, pp 68-74, 1 map.

Detailed mineralogical examination of rubies and sapphires from Xinjiang is reported. They have *D* 3.96-3.99 g/cm³; hardness parallel to *c* 2034-2570 kg/mm² (Mohs 8.8-9.24), perpendicular to *c* 1947-2392 kg/mm² (Mohs 8.5-9.0); ϵ 1.761-1.762, ω 1.768-1.771; and unit cell parameters *a* 0.4756, *c* 1.2960 nm. Electron microprobe analyses gave SiO₂ 0.06, 0.11; Al₂O₃ 99.28, 98.71; Cr₂O₃ 0.16, 0.70; TiO₂ 0.02, 0.03; FeO 0.40, 0.37; MnO 0.06, 0.02; MgO 0.01, 0.05; CaO 0.00, 0.00; Na₂O 0.01, 0.00; K₂O 0.02, 0.01; Co 0.02, 0.01; Ni 0.01, 0.01; Totals 100.05, 100.02. Analyses are also reported for inclusions of rutile. Comparisons are made with ruby and sapphire from other localities. R.A.H.

Specific surface area and ultramicroporosity in polymorphs of silica.

M.A. BUSTILLO, R. FORT AND M. BUSTILLO. *European Journal of Mineralogy*, 5 (6), 1993, pp 1195-1204.

A detailed study of the specific surface area (SSA) and the volume of pores between 10 and 400 Å (ultramicroporosity or UMP) in different types of silica phases from different localities and geological settings is reported. It was found that small proportions of other minerals in the siliceous rocks can alter the SSA and UMP substantially. Opal-A (diatomite) has SSA 23.87 m²/g and UMP 9.90%; opal-CT has 7.76-14.05 m²/g and 6.68-8.50%; α -cristobalite has 1.93-2.43 m²/g and 1.27-1.52%; α -tridymite has 1.93-2.56 m²/g and 1.05-1.62%. There is a loss of SSA and UMP in the diagenetic transformation opal A \rightarrow opal-CT \rightarrow opal-C (α -cristobalite). The host rock in which the silica phase is formed may play an important role in the SSA: e.g. opal-CT formed in a sepiolite rock has a greater SSA than opal-CT formed in a limestone. The UMP is characteristic of the silica phase, though in opal-CT this may vary in relation to the texture. R.A.H.

Jade in Switzerland.

H. GIESS. *Bull. Friends of Jade*, 8, 1994, pp 1-46, 3 photos, 10 figs, 3 maps.

Nephrite sites in Switzerland are described with notes on early settlements and the artefacts they produced. No jadeite has been found *in situ*.

M.O'D.

A gem collection never before published. The Dactyliotheca of H.H. Pope Leo XII.

G. GRAZIANI, M. MARTINI AND P. EVANGELISTA. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, pp 49-72, 2 tables, 2 illus. in black-and-white, 3 in colour, bibl.

The collection containing 388 gems, ornamental stones and rings was given by H.H. Pope Leo XII to the Mineralogical Laboratory of the 'Archiginnasio' of the ancient Rome University 'La Sapienza' in 1824. Details have not been published before. The items have been divided on basis of cut and shape, later identified in contemporary catalogues. Precise description has shown some differences between the antique and modern identification. Some theories concerning interpretation of some marks in a ring and two collets are discussed, as are country of origin of the rings and of the collection as a whole. E.S.

Achat als Nebenprodukt der Tonmineralbildung.

H. HARDER. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, pp 19-37, 2 tables, 7 illus. in colour, bibl.

Worldwide agate occurrences have been extensively discussed in the literature, and their origin by high or low temperature processes compared. Recent isotope investigations suggest agate formation at lower temperatures. The author explains agate formation as a by-product of clay mineral formation at low temperatures.

Experiments at low temperatures with solutions containing up to 1000x more silicon than aluminium and iron can lead to a water-rich precipitate with gel-like texture, chemically similar to agates. Agates are mostly found in strongly decomposed volcanic rocks. During the weathering process Fe-rich clay minerals are formed. The remaining solution contains ions not incorporated into the clay mineral structure; these have a relatively high Si content and a low Fe and Al content. Contents of sodium and potassium were probably high. Acid surface water will neutralise the basic solution in the cavities and thus precipitate the SiO₂. Numerous rotations of different fillings and precipitation of hydroxide silicate led to the banded and layered agate structure during geological times.

Larger quartz crystals contain less iron and aluminium than the surrounding agates. These crystals are grown from purer solution which existed during formation of the agate gels from which diagenetically the chalcedony fibres grow.

E.S.

Zur Entstehung von verkieselten Hölzern.

H. HARDER. *Aufschluss*, 44 (1), 1993, pp 23-31.

Silicified wood ('woodstone') predominantly consists of fine-grained or fibrous quartz with some larger idiomorphic quartz crystals; opal is rare. The quartz must have grown from only slightly supersaturated solutions. Silicified wood contains up to 0.9% Fe₂O₃ and \leq 0.4% Al₂O₃ concentrated in the fine-grained parts. This indicates that weakly basic weathering solutions were neutralized by acid solutions formed by wood decay, precipitating e.g. Al hydroxides, which then absorbed colloidal silica which slowly silicified the wood. In the pore space of the hydroxide-silica precipitates, diagenetic quartz crystallization took place, with the larger quartz grains growing from genuine solutions. The results of experiments of colloidal silica enrichment are reported. K.v.G.

Jadeitites, albitites and related rocks from the Motagua Fault Zone, Guatemala.

G.E. HARLOW. *Journal of Metamorphic Geology*, 12 (1), 1994, pp 49-68, 1 map.

Jadeitites are found as weathered blocks in tectonized serpentinite in a 15-km zone N of the Motagua fault zone; they occur with albitites, albite-mica rocks, omphacite/taramitic amphibole-bearing metabasites, chlorite-actinolite schists, talc-carbonate rocks and antigorite schists. In addition to jadeite, the jadeitites also contain micas, omphacite, albite, titanite \pm zircon, apatite and graphite. Conditions of jadeite formation are 100-400°C and 5-11 kbar. Fluid inclusions, coarse textures, vein structures and rhythmic zoning of pyroxene indicate that an aqueous fluid was involved. Jadeitites are either: (1) metasomatic modifications of former felsic-to-pelitic inclusions that underwent silica depletion plus Na exchange and enrichment, or (2) solution precipitations derived from such a source. They may have formed in a relatively high-*P/T* setting with substantial flow of sodic fluid in a tectonized zone. Most Guatemalan jadeitites are extensively altered to analcite, albite, taramitic amphibole, (clino)zoisite \pm nepheline and preiswerkite; this alteration reflects depressurization + heating to below the jadeite \pm fluid = analcite reaction at high a_{Na} . With progressive alteration, analcite and nepheline are replaced by albite. R.A.H.

Gemmologische Kurzinformation.

U. HENN, H. BANK AND C.C. MILISENDA. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, pp 1-4, 6 illus. in colour, bibl.

In the south-east of Finland, about 130km north of Helsinki, some yellow, yellowish-green, green and pale blue beryls of gem quality were found by a Finnish mineral collector. In the region of Eskishehir in Turkey, a district known for the occurrences of meerschaum and beryls, some cuttable emeralds were found. The crystals were up to 2cm long in a matrix of quartz, feldspar and black mica. Details of constants are given. Amethysts from the Auvergne, France, are mentioned. The crystals are relatively small and full of inclusions, but have a very good colour. Also from France, near St. Leger the rare stolzite (lead tungstate) hardness 3, SG 8.37, the cut sample weighs 2.15ct. Under the name of 'Nicholas created alexandrite' the firm J.O.

Crystal markets faceted synthetic alexandrites with definite colour change blue-green to violet-red. Also by the firm J.O. Crystal, synthetic emeralds under the name of 'Empress culture emeralds'. Lastly a synthetic blue sodalite from China weighing 32.98 ct, SG 2.42. E.S.

Transparenter, schleifwuerdiger, grueener Barium-Orthoklas aus Minas Gerais, Brasilien.

J. KARFUNKEL AND M.L.S.C. CHAVES. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, pp 5-13, 1 map, 1 table, 3 graphs, 1 illus. in black-and-white, bibl.

The green, transparent, cuttable mineral was found south of Felicio dos Santos, Minas Gerais, Brazil, and was identified as barium-orthoclase, a feldspar variety previously unknown in this colour; it is found in small veins in quartz-mica schist. It is to be hoped that mining will prove economically viable. The light green colour with perfect transparency could lead to a future demand as an ornamental stone or collector's item. E.S.

A photo essay dedicated to Bill Hicks.

J.I. KOIVULA. *Australian Gemmologist*, 18 (10), 1994, pp 323-6, 12 illus. in colour.

This set of photomicrographs taken with Nomarski Differential Interference Contrast shows the beauty of surface patterns on 'rough' crystals. Some faces may show superficial growth features while others may reveal dissolution or etching of previously formed faces. These features reflect a crystal's internal symmetry. Thus identical crystal faces display similar forms. From these superficial 'imperfections' the author poses a question on the nature of perfection itself. R.J.P.

Gem News.

J.I. KOIVULA, R.C. KAMMERLING AND E. FRITSCH. *Gems & Gemology*, 30 (1), 1994, pp 47-57, illus. in colour.

A jade cutting factory on the Myanmar-Thai border was described. At the time of the visit nephrite from British Columbia was being carved.

Tucson '94

Gem materials from Arizona were well represented and included turquoise and a bright greenish-blue chrysocolla chalcedony; emeralds from Brazil were offered by several dealers. A pleasing aroma emanating from rough emerald

from the Carnaíba area in Bahia state was due to the natural oil from the peroba tree. Carved amber both from the Dominican Republic and the Baltic states was often in the form of dinosaurs (presumably due to the success of the film *Jurassic Park*). Materials from Madagascar included emeralds from Tulear, aquamarine, morganite, colourless phenakite, apatite and a wide range of garnets. Rubies from the new mining area of Mong Hsu in Myanmar were notable for their bright consistent colour.

There was greater availability of Mexican obsidian with striking iridescent colours. An intertwined 'rope' from a single piece of obsidian was an unusual carving shown. Cat's-eye opal from Brazil was plentiful with fine fibres and readily absorbed water which improved the transparency as well as causing the body colour to become browner. These effects were reversible as the water evaporated. Opal from Ethiopia was of two types: pale yellow, orange and brown with either weak or no play-of-colour visually similar to Mexican fire opal; a dark brown to reddish-brown body colour with strong play-of-colour in a mosaic pattern of rectangular to rounded patches. Russian goods were offered by many dealers including drusy uvarovite garnet on a chromite matrix and hessonite and demantoid garnets.

From the state of Orissa in India were shown bright brownish-orange hessonite garnets together with rhodolite garnets of a very purple hue.

R.J.P.

Leuchtend orangefarbige Spessartine aus einem neuen Vorkommen in Namibia.

T.H. LIND, U. HENN, H. BANK. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, 39-47, 3 tables, 3 graphs, 1 illus. in black-and-white, 1 illus. in colour, bibl.

The new occurrence was found in 1992 in the north of Namibia near the confluence of the river Maria with the river Kunene, very close to the Angolan border. It was first called Kunene spessartine, then Dutch spessartine (because of its orange colour); it has also been marketed as mandarin spessartine. The occurrence is of primary nature, the crystals often rhombododecahedra. The orange colour is evenly distributed. The largest stone found weighted 55.4 ct, but normally stones up to 15 ct were found. SG 4.09-4.15; RI 1.790-1.797. It was found to be a pyrope spessartine, the spessartine content being 80-90 per cent, with visible absorption spectra near to pure

spessartine. NIR absorption spectra revealed a small quantity of hydrospessartine. E.S.

Nature and cause of colour in Indian beryls.

J. PANJIKAR. *National Academy Science Letters*, 16 (1), 1993, pp 13-15.

The blue in Kashmir beryls is due to Fe^{2+} occupying the channel portions in the lattice with absorption spectra of 32 000 to 11 500 cm^{-1} . Beryls from Rajasthan have absorption bands due to Fe^{2+} and Fe^{3+} in the octahedral and tetrahedral sites, respectively. It is assumed that some replacement of Fe^{2+} for Al^{3+} also occurs at the octahedral site. Orissa beryls also have absorption peaks \parallel or \perp the *c*-axis, both of which are related to Fe^{2+} in tetrahedral and octahedral sites. In the case of beryl from Andhra Pradesh, Fe sorption has been observed in the IR region. Gujarat beryl shows absorption with the polarization \parallel *c*-axis due to Fe^{2+}/Fe^{3+} charge transfer. It shows an absorption band due to the presence of Fe^{3+} in the octahedral site.

R.E.S.

Campolungo, Schweiz: Neufund der grössten Korund-Kristalle der Alpen.

A. ROVETTI, R. ROVETTI AND M. PACCIORINI. *Lapis*, 19 (9), 1994, pp 35-6, 11 photos (7 in colour), 4 figs., 2 maps.

A rose-violet corundum crystal measuring 5 cm in length and found in a dolomite matrix with similar but smaller crystals at Campolungo, Ticino, Switzerland, is believed to be the largest crystal of corundum so far to be found in the Alps.

M.O'D.

Emeralds from the Mananjary Region, Madagascar: internal features.

D. SCHWARZ. *Gems & Gemology*, 30 (2), 1994, pp 88-101, 19 illus. in colour.

This excellent review is the first of its kind about emeralds from the Mananjary region in eastern Madagascar. Inclusions are reported and compared with those in emeralds from other localities especially from Africa. Although most of the internal features are similar to other emeralds from schist-type deposits, Mananjary emeralds can be separated by association of certain mineral inclusions with specific liquid inclusions. These minerals include talc, carbonates, amphiboles (mostly of the actinolite/tremolite series) and quartz. However, the latter is a common constituent of emeralds from most African localities so is of little diagnostic significance. The presence of talc - especially when it appears in a fibrous or sheaf-

like form - is a good diagnostic feature for Mananjary emeralds. R.J.P.

What's new in minerals?

J.A. SCOVIL. *Mineralogical record*, 25 (5), 1994, pp 377-82, 15 photos (12 in colour).

Among gem-quality minerals noted are emerald from Hiddenite, North Carolina, green dravite from the Mikhaylovskoye mine, Chita Oblast, Russia, peridot (as a crystal 3.2cm high) from Pyaung Guang, Myanmar, elbaite from the Bennett mine, Buckfield, Maine, and red beryl from the Violet claims, Wah Wah Mountains, Utah. M.O'D.

The incorporation of alkalis in beryl: multi-nuclear MAS NMR and crystal-structure study.

B.L. SHERRIFF, H.D. GRUNDY, J.S. HARTMAN, F.C. HAWTHORNE AND P. CERNY. *Canadian Mineralogist*, 29 (2), 1991, pp 271-85.

The stereochemical details of the incorporation of alkali ions into the beryl structure were examined by multi-nuclear MAS NMR spectroscopy and single-crystal structure refinement. The ^{29}Si signal is narrow in alkali-poor beryl, and broadens with increasing alkali content, a result of the different short-range next-nearest-neighbour configurations produced by the incorporation of alkalis into the structure; the value of this substitutional broadening is calculated from the proposed local configurations and the method of Sherriff & Grundy (1988). Substitutional broadening is observed in the ^{27}Al spectra that also show only [6]-coordinate Al to be present, in agreement with the current and earlier X-ray results. Two ^7Li signals are observed, indicating that Li occurs both as a framework constituent and as a channel species. The crystal structures of the four samples were refined, to R indices of 2-3 per cent using $\text{Mo}[\text{K}\alpha]$ radiation. The $\langle\text{Be-O}\rangle$ distance expands linearly with increasing Li = Be substitution at this site, but the O-Be-O bond angles remain unchanged. This substitution produces a bond-valence deficiency at the O(2) anion. This is compensated by lengthening of Si-O(1) and Si-O(1)a, and contraction of Si-O(2) with increasing Li = Be substitution. All samples of alkali-bearing beryl examined show residual electron density in the channels due to occupancy by alkali ions; all show more density at the 2a site than at the 2b site. Comparison of these residual densities with known alkali contents confirms previous work that assigned Cs to the 2a position. The electron density observed at the 2b position correlates well with the Na contents and is insufficient to account for the H_2O ; thus

Na is assigned to 2b and H_2O to 2a. Local stereochemistry and analytical results suggest that Na is bonded to two H_2O groups in the channel. L.T.T.

Jades of North America.

J. SINKANKAS. *Bull. Friends of Jade*, 8, 1994, pp 67-104.

This is a major revision of the jade section of volume 2 of *Gemstones of North America*. Additional material is given for the states of the USA and for other north and central American countries. Each country or state description has its own list of references. M.O'D.

Fluorite from Seiles, Andenne, Belgium: Coloration, fluorescence, and a remarkable crystal geometric discoloration phenomenon.

R.F. VOCHTEN, M.D. VAN DOORSELAER AND H. DILLEN. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, pp 73-84, 2 tables, 3 graphs, 5 diagrams, 6 illus. in colour, bibl.

A study of experimental and literature data reveals that the violet and blue coloration of fluorite from Seiles, Belgium, cannot be caused by the mere presence of rare earth elements but should be attributed mainly to high energy radiation. The fluorescence which typifies some of the coloured fluorite samples could be caused by specific colour centres which are not present in non-fluorescing samples. A particular discoloration phenomenon with a trigonal pattern is described and tentatively related to enhanced oxygen diffusion along disturbed boundaries of penetration twin crystals. E.S.

Instruments and Techniques

Miniature fibre optics.

T. LINTON. *Australian Gemmologist*, 18 (10), 1994, pp 329-31, 2 illus. in black-and-white.

This informative article will be welcomed by practising gemmologists who have to examine set stones. The miniature fibres are usually hand held and ensure quick, effective and simple illumination. They can be used with the microscope and many other instruments. R.J.P.

Computer assisted gem identification.

P. READ. *Australian Gemmologist*, 18 (10), 1994, pp 332-3, 4 illus. in black-and-white.

The history and development of this topic were amply covered and showed how the increased

capacity of the personal computer allowed a much wider scope for gemstone identification as well as enabling the textual data to be expanded. The GEMDATA programme is now in its fifth update enabling the most recent advances in gemmology to be incorporated. R.J.P.

Synthetics and Simulants

Crystallization of diamond from a silicate melt of kimberlite composition in high-pressure and high-temperature experiments.

M. ARIMA, K. NAKAYAMA, M. AKAISHI, S. YAMAOKA AND H. KANDA. *Geology*, 21 (11), 1993, pp 968-70.

A series of experiments was carried out at high *P* (7.0 and 7.7 GPa) and high *T* (1800- 2000°C) using a modified belt-type high-*P* apparatus with a 32mm bore diameter. Diamond crystallized and grew in a volatile-rich kimberlite melt of an aphanitic group 1 kimberlite from Wesselton mine, South Africa. The diamond has well-developed {111} faces and its morphological characteristics resemble those of natural diamond but differ from those of synthetic diamond grown from metallic solvent-catalysts. The kimberlite melt has a strong solvent-catalytic effect on diamond formation, supporting the view that some natural diamond crystallized from volatile-rich melt in the upper mantle.

L.C.H.

Synthetic rubies by Douros: a new challenge for gemologists.

H.A. HÄNNI, K. SCHMETZER AND H. BERNHARDT. *Gems & Gemology*, 30 (2), 1994, pp 72-86, 3 tables, 23 illus. in colour.

Introduced in 1993, these synthetic rubies are produced by controlled spontaneous nucleation and slow cooling techniques by unseeded flux growth. Although conventional methods may show the synthetic nature of these stones, sophisticated methods such as energy-dispersive X-ray fluorescence (EDXRF) and UV visible spectrophotometry may have to be employed. EDXRF spectra showed chromium, titanium and iron in varying amounts together with lead. The Douros product most closely resembles the Ramaura synthetic ruby and the presence of yellow flux particles often associated with rounded bubbles are easily recognized. Without these, chemical analysis and immersion

microscopy (to reveal characteristic crystal-growth patterns and colour zoning) should provide the necessary distinguishing evidence. The crystallography of the new synthetic is thoroughly discussed including the marked colour zoning seen in crystal specimens. R.J.P.

Synthetische Rubine aus Griechenland.

U. HENN AND C.C. MILISENDA. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 43 (1/2), 1994, pp 15-17, 2 illus. in black-and-white, 2 in colour, bibl.

A new type of synthetic ruby from Greece has come on to the market. It is manufactured by the firm Douros in Piraeus and is known under the name of Douros. Physical properties are those of corundum and under the microscope flux residues can be seen, typical for a flux growth environment. E.S.

Gem News.

J.I. KOIVULA, R.C. KAMMERLING AND E. FRITSCH. *Gems and Gemology*, 30 (1), 1994, pp 47-57, illus. in colour.

Synthetic sapphires had been diffusion-treated with a cobalt compound. The Chelsea colour filter, spectroscopic and UV examinations readily confirmed the cobalt whilst microscopic examination revealed gas bubbles and/or curved colour banding of the synthetic.

Beryl triplets were offered as emerald simulants. Chatham introduced a new pink synthetic sapphire with less than 0.2 per cent w/w chromium trioxide. Apart from having an orangey-red fluorescence to short wave UV of equal intensity to the red fluorescence under long-wave UV, it showed all the gemmological characteristics of a Chatham flux-grown synthetic ruby. Synthetic material from Russia included hydrothermal emeralds, synthetic rubies by a number of techniques, flux-grown red and blue spinels, numerous quartzes including a new pink quartz, and synthetic malachite and turquoise. Cubic zirconia was available in many colours together with a yellow-green which would make an effective simulant for peridot.

R.J.P.

Book Reviews

Jades from China.

A. FORSYTH AND B. MCELNEY, 1994. *Museum of East Asian Art*, Bath. pp 422, illus. in black-and-white and in colour, hardcover. Price £105.00. ISBN 1 897734 03 4.

The Museum of East Asian Art in Bath opened in April 1993 and the present catalogue describes and illustrates jade objects at present in the Museum's custody. About 50 per cent of the artefacts come from the collection of the second author, presented to the Museum by him as founder. The remainder of the objects come from two collections on long-term loan to the Museum, the Peony and Rannerdale collections.

The book opens with a note by the authors particularly concerning the difficulty of dating jade objects. This topic is constantly under discussion. A chronological table, short glossary with illustrations and maps follow, the text and labelling in English and Chinese. Introductory essays cover jade as a raw material, jade supplies to China and working with jade. Then come jade culture and dynastic essays before the catalogue itself begins. The introductory essays are in English and Chinese.

The chief feature and one seldom seen today is that each object is illustrated in colour. As there are 354 objects and some have more than one photograph more than 400 colour photographs are included. Each description of an artefact includes descriptive name, place of origin and period, description and note of publication where applicable. If similar pieces exist in the collection these are referred to. This main section is arranged chronologically and each division has a short essay in English and Chinese. The book ends with a bibliography of 100 entries which could perhaps have been extended to match the importance of the text.

In a book of this kind reviewed in a journal dealing with the scientific background of the production of worked specimens, we first need to ensure that the coverage of the mineralogical and gemmological area is correct and balanced. The essay on jade as a raw material tells us surprisingly little about the mineralogy of the jades though what there is seems adequate enough. The account of how various characters have been

used to denote jade (or 'precious stone') is interesting but there is little new information.

These are small points or would be if this was a smaller catalogue. Clearly the promise of further work on the background of so excellent a collection remains and it would be unfair to expect everything to go in one volume, especially one in which the illustration is the main aim - and in this the book succeeds admirably. The price is not unreasonable for today and serious students will welcome so prodigal a display of illustrations. M.O'D.

Red coral, jewel of the sea.

B. LIVERINO, translated [from the Italian] by J.H. Johnson, 1989. *Analisi-Trend*, Bologna. pp 208, illus. in black-and-white and in colour (Industrial history series) Price £31.50.

Books on coral are rare and though several books in Italian have been published since the early 1970s the major texts have not been translated. For this reason the present work is to be welcomed, with its profusion of good-quality colour photographs which, given the warm colour of most coral artefacts, make a pleasing effect. The aim of the book is to present not only the artistic but also the historical, social and economic importance of coral recovery and fashioning to the people of the area round Torre del Greco: in this town the author has established a Museum of Coral and Cameos.

Early chapters describe the origin, zoology and formation of coral and early methods of fishing, both in the Mediterranean and elsewhere, particularly in the Pacific. The history of coral working is examined from archaeological sources and then by centuries. Other uses of coral - in pharmacology and as ornament - are outlined before an account of the present state of the industry. The final chapter concentrates on the centre of Torre del Greco and its importance in the history of coral. Despite the absence of a bibliography which would have been especially welcome the book can be recommended for students and for everyone with an interest in this particular material. M.O'D.

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

OBITUARIES

Malcolm (Mac) James Hanslip (D. 1950) died on 16 July 1994 aged 68.

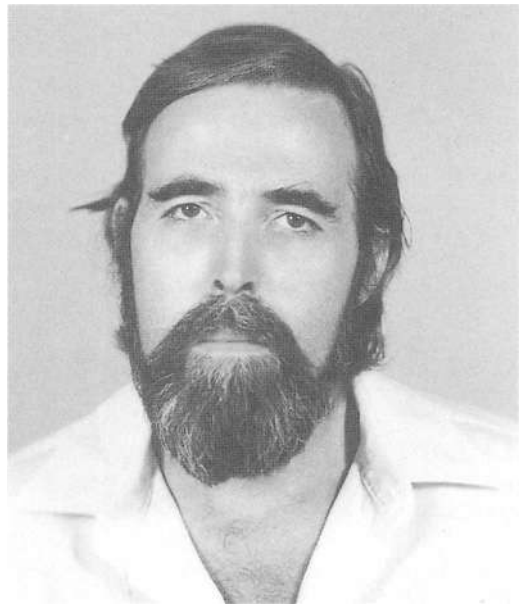
When Mac left school, he trained as an engine fitter in Devonport dockyard, completing his apprenticeship in 1946. Mac then left the dockyard and joined his father's watchmaking business, qualifying as a fellow of the Gemmological Association in 1950. One year later he joined the firm of Conroy Couch Jewellers in Torquay, part of the R.W. Yeo group of companies, as the Senior Sales Assistant.

Promotion within the company took Mac back to Plymouth as manager of Samuel Edgecombe Ltd., where he remained until the mid 1960s when he transferred to the Technical Centre in Exeter, the head office for Ron Yeo's group of companies. As well as a training centre where students could learn all aspects of the jewellery trade, Exeter was the head office from which Mac travelled to all the company's shops, his expertise and enthusiasm taking him to the position of Chairman of R.W. Yeo (Associated Companies) Ltd.

Mac enjoyed being involved with the staff of his shops. Always passionate about gemstones and jewellery, he loved being behind the counter meeting people, and relished the opportunity of working on the sales floor of the company's various shops when covering for holidays or helping out at Christmas.

Mac is survived by his wife, two daughters and two grandchildren. A man who loved 'people', Mac will be missed by all those who knew him. D. Garrod

Keith Richard Willmott MA (Oxon) (D. 1990 with Distinction) died on 29 October 1994.



Richard Willmott

Richard Willmott started his career after graduating with a first class honours degree in mathematics from Oxford University followed by two years' research at Cambridge. From there he embarked on various teaching and journalism assignments around the world. However, his interest in gemmology started in his twenties when he collected books on famous gems. He often joked about his early disastrous attempts at buying rough gems from the mines in Sri Lanka.

At the age of 45 he realized his long term interest in gemmology and obtained his FGA with distinction in 1990. He also found time to travel across the Australian Nullabor Plain by train, stopping at all the gem mines along the way, and started his Gem Technical Services business in the free trade zone in Sri Lanka. Among other things, he employed local gem cutters to produce replicas of crown jewels and celebrity jewellery (such as the Taylor Burton necklace) made from cubic zirconia. His article 'Diamond replicas - possible but just' (*J. Gemm.*, 1993, 23 (8), 486) dealt with the history of making replicas and the practical problems he encountered in obtaining accurate information on famous originals. During the last few years he started 'The Diamond Extravaganza' to produce and promote his CZ replicas to the jewellery trade and to various museums*. His clients included famous names such as Christies, Garrards and De Beers. Replicas made by Richard have been the subject of recent articles in various trade publications including *The Retail Jeweller* and were featured on a BBC television programme *The Diamond Empire* earlier in 1994.

Sadly, Richard became ill during this time and was not able to reap fully the benefits of his unique enterprise or to realize his long-term ambition of starting a London Diamond Museum and he died aged 50 years. He is sadly missed by his numerous friends and colleagues around the world.

Lynda Thorn

GIFTS TO THE ASSOCIATION

The Association is most grateful to Thor Johne of the Geologisk Museum, Oslo, Norway, for the gifts of ruby crystals in matrix and feldspar variety sunstone, both of which are from Norway.

* The CZ replicas and museum artefacts are now being sold. For information, please fax 0171 258 1810 or write to Diamond Extravaganza, c/o PO Box 1041, London W2 3ZW.

NEWS OF FELLOWS

On 24 October 1994 **Michael O'Donoghue** gave an address to Gemmologia Europa V in Milan. His subject was *Ruby and sapphire: treatment, synthetics and imitations*, and special emphasis was given to the heat-treated sapphires from Montana, USA, specimens of which were demonstrated. A display of rare books on ruby synthesis and mineral colour alteration was also provided and slides shown by courtesy of Eric Emms of the GAGTL.

Alan Jobbins and **Ken Scarratt** also contributed lectures in this series concerning the natural origins and resources of ruby and sapphire.

MEMBERS' MEETINGS

London

The 1994 Annual Conference was held on 23 October at the Great Western Royal Hotel, Paddington. A full report of the Conference was published in the December 1994 issue of *Gem and Jewellery News*.

The following meetings were held at 27 Greville Street, London EC1N 8SU:

On 28 September Alan Clark gave a talk entitled *Diamonds in the retail trade*.

On 22 November Cally Hall gave a talk entitled *Gemstones on display at the Natural History Museum: past, present and future*.

On 5 December Stephen Kennedy spoke on *Sapphires in the Laboratory*.

Midlands Branch

On 28 October at Dr Johnson House, Bull Street, Birmingham, a Bring-and-Buy Sale was held.

On 6 November the Autumn Seminar was held at the Cobden Hotel, Hadley Road, Birmingham.

On 25 November at Dr Johnson House Grenville Millington gave a talk entitled *How to buy gemstones*.

The Branch's Annual Dinner was held on 3 December.

North West Branch

A visit to the Liverpool Museum of Geology was organized on 19 October.

On 16 November at Church House, Hanover Street, Liverpool 1, the Annual General Meeting was held at which Irene Knight and Joe Azzopardi were re-elected Chairman and Secretary respectively.

PRESENTATION OF AWARDS

The Presentation of Awards gained in the 1994 examinations was held at Goldsmiths' Hall, London, on 25 October.

The President, Mr Eric Bruton, presided and welcomed those present. He announced that a total of 1059 students had taken the gemmology and gem diamond examinations in 1994, 599 of whom had been successful. The 197 students who had passed the Diploma examination came from a total of 26 countries representing all five continents. Award winners from 14 countries attended the Presentation, from as far away as Brazil, the People's Republic of China, the Republic of China and the USA.

The awards were presented by Vice-President Alec Farn and his address is set

out below.

The vote of thanks was given by Vivian Watson and in conclusion Eric Bruton thanked the Goldsmiths' Company for once again allowing the GAGTL to hold the ceremony at the Hall.

Address by Alec Farn

'Ladies, Gentlemen and Fellow Gemmologists, it gives me considerable pleasure to be here this evening to talk to you and present the awards. I hope that you will enjoy your visit.

'We are extremely fortunate in having this great hall for our annual awards ceremony. It is to the Worshipful Company of Goldsmiths that we address our thanks.

'Although I am a retired director of the original pearl testing station founded in Hatton Garden in 1925, I am not going to talk about pearls. It is fatal to ask someone of my age to talk at a Presentation of Awards Ceremony. The opportunity to reminisce is too great an offer to miss. I must remember that some of you are not only younger than myself but come from countries hundreds – if not thousands – of miles away. That in itself is a compliment



Prize Winners at Goldsmiths' Hall: from left Alicia Arnold (Preliminary Trade Prize), Neil Rose (Tully Medal) and Deborah Wilson (Anderson Medal).

to the London scene.

'I like to think of myself essentially as a trades person. My father was the manager of a pawnbroker and retail jewellers shop in south east London. The well known sign of a pawnbroking establishment together with a public clock hung outside my bedroom window. I was employed in four other pawnbroking shops in various parts of London and lived-in at two of them, the last of which was the most important. At that time I knew very little about gemstones and gemmology was a new word in my vocabulary.

'My own introduction to the Goldsmiths' Hall was of a non-gemmological nature in the mid-thirties. I was working and living-in as a member of staff in an old established jewellers in London's Oxford Street. We held a fine stock of both antique and modern silver as well as important jewellery. Occasionally our silver buyer would obtain tickets to lectures at the Goldsmiths' Hall on silversmiths, their work and like matters of historical interest. These lectures were very popular. A colleague and myself always attended - there was a free buffet and claret. This *may* have been a reason for the popularity of the lectures, especially to young men in their twenties earning quite modest salaries!

'I specifically mention my colleague whose name was George E. Ratcliffe, FGA. He obtained his diploma in that very impressive and important year (1934) when R. Keith Mitchell beat Robert Webster for the Tully Medal - you had to be extremely good to do that. It may have been the claret at one of the lectures or just genuine friendship which inspired George Ratcliffe to say to me: "You know, you are really ignorant about gems and gemmology. You ought to go to evening classes at Chelsea Polytechnic." I did in fact go to Chelsea Poly. The instructor was a tall, fair haired young man over six feet tall. His name was Basil Anderson. You may have heard of him.



Vice President Alec Farn

'I passed the first year exam and received a certificate from Chelsea Polytechnic. Then the war intervened. Some six years later in 1946 I was demobbed but my pre-war job no longer existed. I was ex-service and unemployed. I wrote to Basil Anderson, hoping that he might know of a vacancy in the retail jewellery trade. He replied promptly and asked me to go to see him. He offered me a job in the laboratory. I was considerably taken aback - all I had was a first year certificate nearly seven years old and a brand new demob suit. I thought he must have mistaken me for someone else. A week or two later I joined the Laboratory of the Diamond Pearl and Precious Stone Trade Section of the London Chamber of Commerce. This evening I am wearing their tie in their honour and as a compliment to all of you successful FGAs.

'My first year at the laboratory was trade gem testing with a vengeance. We had monocular microscopes which were back-

aching to use standing up and awkward to use sitting down. Monobromonaphthalene was the main immersion liquid. Each stone and pearl was tested individually. In that year we tested 104 849 rubies and sapphires, 62 616 natural pearls and 7553 cultured pearls. We worked together as a team for 25 years before successive retirements began to take their toll. With B.W. Anderson's retirement I changed from junior to senior in all-too-swift escalation and found myself with young faces around me. It was quite a contrast when you consider the birth years of that first foursome – Robert Webster 1899, Basil Anderson 1901, C.J. Payne 1905 and myself, the youngest, 1916.

I would like to dwell a little upon the history of this magnificent building, its Livery hall and the Goldsmiths' Company. As early as 1339 the Company acquired a site and building in the goldsmiths' quarter of the City of London. King Edward I in 1300 required that all silver articles were to be of the same sterling standard as the coins of the realm and that they were to be assayed by the wardens of the Goldsmiths' Guild. Before they left the workers they had to be marked with a leopard's head which signified London. The Sterling Standard was 11 ounces 2 pennyweights in the pound Troy, or as it is recognized today, 925 parts per thousand pure.

The Goldsmiths' Company has a link with gemmology from the year 1666, the date of the Great Fire of London when the Goldsmiths' Hall was burned to the ground. In that same year Isaac Newton proved that white light has a composite nature. Sir Isaac Newton, as he later became, was appointed Warden of the Mint in 1696. Lord Montague, the Chancellor of the Exchequer at the time, had authorized a new coinage because the old coins had been badly clipped around the edges by the populace who used the clippings as a source of income as scrap silver, etc. He was obviously very efficient

as he became Master of the Mint three years later.

The Trial of the Pyx was an annual event at the Goldsmiths' Hall when silver coins were tested by a jury composed of members of the Goldsmiths' Guild. There was a strong link between the Goldsmiths' Company and the Royal Mint in the Tower of London.

This present Hall was completed in 1835 following a commission by the Goldsmiths' Company to their surveyor, Stephen Hardwicke. It followed a reconstruction of the previous hall which was built after the Great Fire in 1666. This in time had become dilapidated and needed propping up. It was eventually demolished in 1829.

On the opening day of the present Hall in 1835 words described it as "marked by an air of palatial grandeur not exceeded by any other piece of interior architecture in the metropolis". The Duke of Wellington, victor of the Battle of Waterloo (1815), was the Goldsmiths' Company's principal guest at the celebratory dinner since the King, William IV, was indisposed.

The recent refurbishment of this hall is interestingly described in the Goldsmiths' Review of 1989/90. Many unexpected problems arose requiring long consultations with technicians with a wide range of skills. The day fixed for the official opening by HM Queen Elizabeth and the Duke of Edinburgh was fast approaching. In an article describing the tension experienced in the run up to this, the Clerk of the Goldsmiths' Company had the comments by the Duke of Wellington on the result of the Battle of Waterloo in mind when he quoted: "It was a damned nice thing - the nearest run thing you ever saw in your life."

It is interesting to note how the word "hallmark" has entered our vocabulary. After 700 years of assaying we can truly say that the Goldsmiths' Company has left its mark upon the trade.

GAGTL GEM TUTORIAL CENTRE

Recognizing Treatments and Synthetics

14-15 February

An opportunity for you to handle treated and synthetic gem materials currently encountered in the trade, plus materials which have recently appeared.

Improve your technique for detection work on these materials.

Price £223.25 (including sandwich lunch)

Identification of Beads and Necklaces

22 February

Baffled by beads? Artificial, artistic, mineral, organic - a survey and discussion led by the Bead Society, with an opportunity to bring your own enigmas, gather tips on identification, detection, relative values and on cataloguing your collection. Learn from experts in gemmology and archaeology, people who appreciate beads of all kinds.

Price £35.25 (including sandwich lunch)

Enquire Within : Emerald

1 March

A valuable and concentrated look at all aspects of emerald: natural rough and cut stones, treated, synthetic and imitation stones.

Price £111.63 (not including lunch)

Weekend Diamond Grading Course

4-5 March

This successful course concentrates on the practical aspects of polished diamonds, using 10x lens, microscope and colour comparison stones. Mounted stones, simulants and clarity enhanced stones will be seen. Of great value to all involved in diamond trading and appraisal, the course is taught by Laboratory staff.

Price £246.75 (not including lunch)

Preliminary Workshop

15 March

A day of practical tuition for Preliminary students and anyone who needs a start with instruments, stones and crystals. You can learn to use the 10x lens at maximum efficiency, to observe the effects and results from the main gem testing instruments and to understand important aspects of crystals in gemmology.

Price £47.00; GAGTL students £33.49 (including sandwich lunch)

Enquire Within : Ruby and Sapphire

4 April

A concentrated look at all aspects of these gems: natural rough and cut stones; treated, synthetic and imitation stones.

Price £111.63 (including sandwich lunch)

NOTE ALL PRICES INCLUDE VAT AT 17.5%

Just phone, fax or write for details to Doug Garrod at the GAGTL Education Office -
27 Greville Street, London EC1N 8SU. Tel: 0171-404 3334 Fax: 0171-404 8843

'When the mathematician Archimedes was called upon to prove the quality of gold in a crown he was literally "out of his depth". The gold could have been alloyed during manufacture. Still pondering the problem he stepped into his rather full bath. As he sat down water poured over the sides. Observing this he realized that a body must displace its own volume or bulk when immersed. Excited by this revelation and its portent he shouted Eureka meaning "I have it", and dashed naked to verify the experiment. It is doubtful whether many gemmologists today will be carried away with such enthusiasm, but who knows whether from among our present successful students we may yet read of similar excitements.

The excitement, though, this evening is the presentation to you of your well-earned diplomas. These are your hallmarks as qualified gemmologists.

'During my thirteen years in retirement the gemmological world has moved on apace. I look back now with pleasurable nostalgia to that small intimate laboratory where we used to speak of Angstroms and the familiar names were Burma, Ceylon, Siam, the Persian Gulf and the Gulf of Mannar.

'On that retrospective note I will conclude and say "thank you" to you all for listening so patiently to my reminiscences.'

MEETING OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held on 7 September 1994 at 27 Greville Street, London EC1N 8SU, the business of the meeting included the election of the following:

Gold Laboratory Membership

Clive Ranger Ltd, Cardiff

Ordinary Laboratory Membership

Chard (1964) Ltd, Blackpool
Cranbrook (Jewellers) Ltd, Basildon
Dianoor Jewels Ltd, London W1

MEETING OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held on 26 October 1994 at 27 Greville Street, London EC1N 8SU, the business transacted included the election of the following:

Transfers from Ordinary Membership to Fellowship

Jargiello, Barbara, London. 1994
Hamza, Mohamed Hassan, Kandy, Sri Lanka. 1994

Diamond Membership

Zhang, Shuyun, Shanghai, China. 1994
Stossel, Hilary, London. 1994

Fellowship

Alexander, Maria K., Buenos Aires, Argentina. 1994
Armstrong, Michael J., Whitley Bay. 1994
Au Yang So Wah, Natasha, Kowloon, Hong Kong. 1994
Bao, Deqing, Hubei, Hong Kong. 1994
Barcados, Alexander J., Toronto, Ont., Canada. 1994
Bossenbroek, Anna E.H., Doorn, The Netherlands. 1994
Chan Kin-Chung, John, Chai Wan, Hong Kong. 1994
Chan, Kwok Keung, Kowloon, Hong Kong. 1994
Chan Wai Ching, Joanne, Kowloon, Hong Kong. 1994
Chan, Yuk Victoria, Burnaby, BC., Canada. 1994
Chua, Virna Ngo, New Territories, Hong Kong. 1994
Chung, Yam Ming, Kowloon, Hong Kong. 1994
Cooke, Joanne T., Petchburi, Thailand. 1994
Cookson, Ian P., Sheffield. 1994
Dragland, Frode R., Sortland, Norway. 1994
Gamst, Terje, Lannavaara, Sweden. 1994
Goldschmidt-Husein, Asli, St. Ingbert, Germany. 1994

- Gunell, Carola M., Kirjala, Finland. 1994
 Hasler, Christian, Toronto, Ont., Canada. 1994
 Hindley, Stuart W., Worksop. 1994
 Hui, Sze Wai, Kowloon, Hong Kong. 1994
 Kam Siu Tong, John, Tsuen Wan, Hong Kong. 1994
 Kon, Kiang Fung, North Point, Hong Kong. 1994
 Kwan, Wai Shun, Kowloon, Hong Kong. 1994
 Louie, Miu Man, Kowloon, Hong Kong. 1994
 Mann, William M., Gloucester. 1994
 Ng, Lok Chung Angela, North Point, Hong Kong. 1994
 Or, Chi Ching, New Territories, Hong Kong. 1994
 Paredes Quevedo, Juan C., Madrid, Spain. 1994
 Smyth, Lesley J., London. 1994
 Syren, Riitta A., Pirkkala, Finland. 1994
 Tang Man Wah, Connie, Kwai Chung, Hong Kong. 1994
 Tang, Wai Chun, Kowloon, Hong Kong. 1994
 To, An You, Kowloon, Hong Kong. 1994
 Varey, Irena M., Leicester. 1994
 Welton, Andrew V., Hayes. 1994
 Ying, Kai Yiu, Kowloon, Hong Kong. 1994
 Young, Patrick Pak-chee, Taipei, Taiwan. 1994
 Zhao, Xinmin, Wuhan, China. 1991
- Duann, Teresa, Taichung, Taiwan.
 Glaser, Sonja, Zurich, Switzerland.
 Greenbank, Patricia, Kendal.
 Hill, Rebecca Mary, Edinburgh.
 Ho, Mary Malai, London.
 Hopkinson, Barrie, Nottingham.
 Horniblow, Kathy, Henfield.
 Hsu, Ming-Hung, Taipei, Taiwan.
 Hui, Mu-Cheng, Taipei, Taiwan.
 Iwata, Kaoru, Kingston-upon-Thames.
 Jensen, Brenda, Nesbru, Norway.
 Jiranek, Jaroslav, Ostrava-Svinov, Czech Repub.
 Kathoon, June S., Holte, Denmark.
 Koneru, Suresh, London.
 Kou, Wai Hung, Taipei, Taiwan.
 Lee, Chiu-Hsia, Taipei, Taiwan.
 Lin, Kuei-Yu, Fiona, Taipei, Taiwan.
 Loughran, Anna, London.
 Lundsrud, Berit, Sandvika, Norway.
 Makri, Hariklia, Thessaloniki, Greece.
 McInnes, John, Edinburgh.
 Merrigan, Noel J.P., Cambridge.
 Messent, Judith A., Colchester.
 Mittel, Rita, Lusaka, Zambia.
 Moreland, Lena, London.
 Mourtzanos, Stefanos, Kensington.
 Nakamura, Shukubin, London.
 Obles, Maria Angeles, Madrid, Spain.
 Quintin-Baxendale, Brian W., Rickmansworth.
 Shu, Xingying, Wuhan, China.
 Smith, T.J., Dartmouth.
 Sugg, Duncan, High Wycombe.
 Sugiyama, Shigeru, Cambridge.
 Susan-Roet, Violet E., HD Naarden, The Netherlands.
 Tsai, Pei-Lun, Taipei, Taiwan.
 Turner, Caroline, Southwold.
 Tzou, Jyh-Jeng, Taipei, Taiwan.
 Webster, Paul Timothy, Greenford.
 Wu, Ching-Lin, Taipei, Taiwan.

Ordinary Membership

- Abbott, Deborah, Harrogate.
 Abrmian, Levon, London.
 Ankh, Catrin, Arsta, Sweden.
 Au, Ming Cheung, Wanchai, Hong Kong.
 Bailey, Alison, Hong Kong.
 Bailey, Henry, London.
 Barker, Cyrine, London.
 Cadby, Sarah L., London.
 Chan, Hsiu-Yin, London.
 Churchill, David, Halifax, Nova-Scotia, Canada.
 Crowley, Mark, Dunkineely, Co. Donegal, Ireland.

BACK ISSUES OF THE JOURNAL

The family of one of our late members on the Belgian/Dutch border has some bound copies of *The Journal of Gemmology* for sale at £2.00 per issue. From 1965-75 they are bound in red and from 1975-85 they are

bound in grey; subsequent issues are loose.

A member in Wales has a set of *The Journal of Gemmology* (January 1972 to date) for sale at £2.00 per issue, as well as back numbers of *Boletin del Instituto Gemologico Espanol*, *Revue de Gemmologie* and the *Indian Gemmologist*.

Please contact Mary Burland at the GAGTL who will forward enquiries.

CORRIGENDA

On p. 285 above, first column, letter from Professor Hurlbut, second paragraph, first line, for 'it low surface tension' read 'its low surface tension'

On p. 270 above, under *Sampling and sample preparation*, first paragraph, last line, for 'Knamti' read 'Khamti'

On p. 276 above, second column under *References*, for 'Noeting, F.' read 'Noetling, F.'

FORTHCOMING MEETINGS

London

Meetings are held in the GAGTL Gem Tutorial Centre, 2nd Floor, 27 Greville Street, London EC1N 8SU (entrance in Saffron Hill).

The charge for a member is £3.50. Entry will be by ticket only, obtainable from the GAGTL.

20 March	Jewellery at Sotheby's	Alexandra Rhodes
12 June	Annual General Meeting	
16 October	Recent developments in the diamond industry	Howard Vaughan

Midlands Branch

19 February	Gem Club - Composite gems	
24 February	Inclusions in silica gems	Clive Burch
19 March	Gem Club	
31 March	Jewellery through the ages	Nigel Dunn

Meetings will be held at Dr Johnson House, Bull Street, Birmingham. Further details from Mandy MacKinnon on 0121-444 7337.

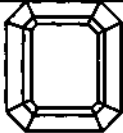
North West Branch

15 March	A taste of Scottish gemmology*	Alan Hodgkinson
17 May	Diamonds in the Laboratory	Eric Emms

* Please note that this meeting will start at 7.00 p.m.

Meetings will be held at Church House, Hanover Street, Liverpool 1. Further details from Joe Azzopardi on 01270 628251.

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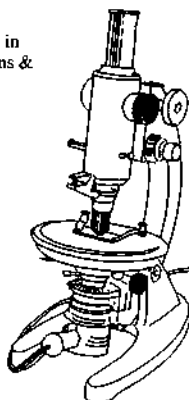
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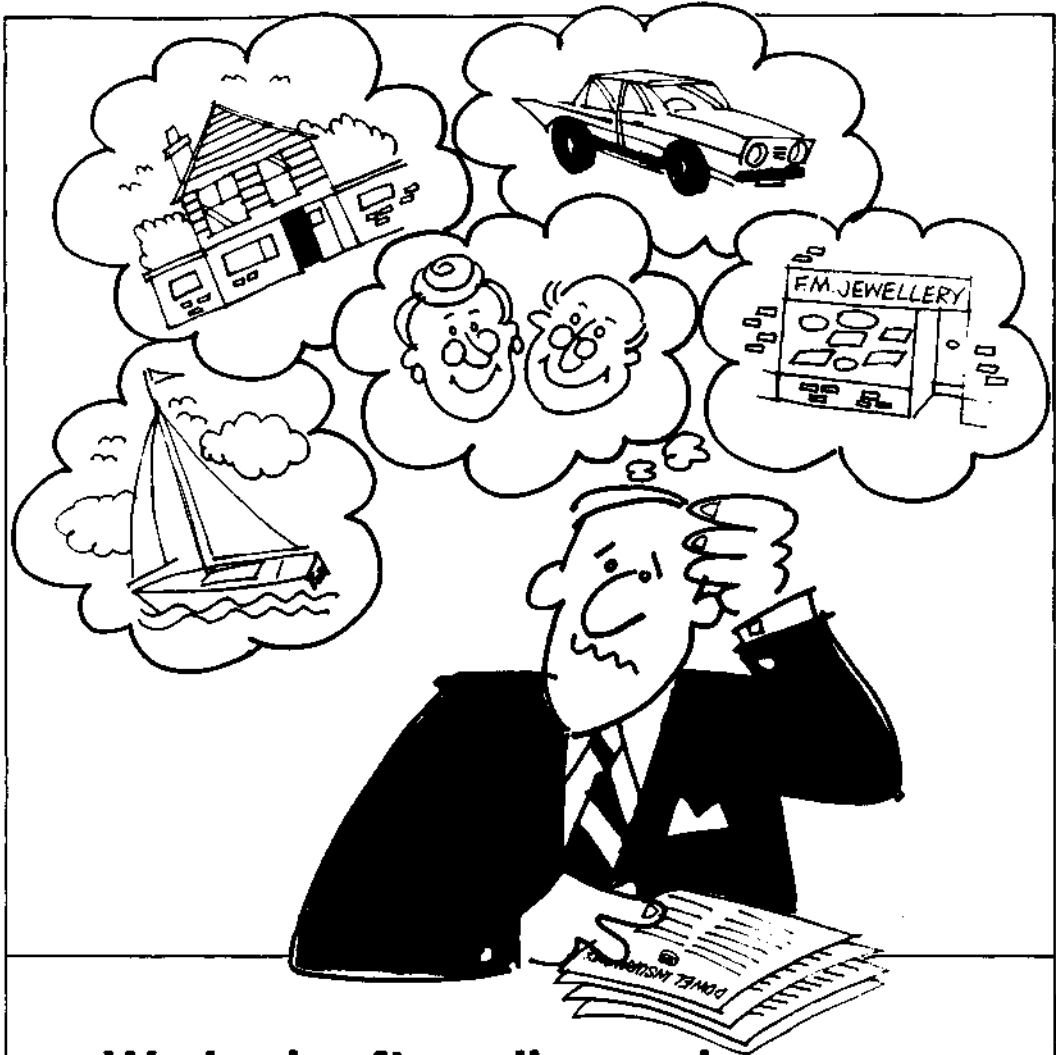
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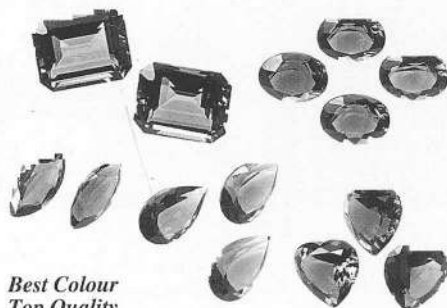
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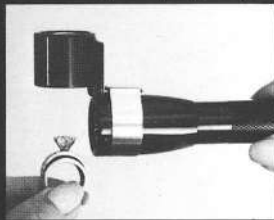
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The **Journal of
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